



# **From cash flows to water flows: An assessment of financial risks to rural water supply sustainability in sub-Saharan Africa**



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degree of Doctor of Philosophy in Geography and the Environment

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## Abstract

This research examines the collective action and financial dimensions of rural waterpoint sustainability in sub-Saharan Africa. Four interlinking papers empirically evaluate the nature and drivers of financial risks, and how they in turn impact the operational performance of community water supplies. The research is grounded in conceptual and theoretical frameworks pertaining to collective action and common-pool resource management, in particular Ostrom's social-ecological systems framework (Ostrom, 2007), Musgrave & Musgrave's economic good framework (Musgrave & Musgrave, 1973), and Marwell & Oliver's critical mass theory (Marwell & Oliver, 1993).

The first paper analyses data extracted from national waterpoint inventories in Liberia, Sierra Leone, and Uganda. The remaining three papers draw on primary data from rural Kenya comprising 229 years' worth of water committee financial records, a census of 571 waterpoints, and a survey of 3,361 households. These data were collected during extensive field work campaigns in Kwale, Kenya. Quantitative analyses were carried out by way of advanced statistical techniques, including logistic regression, linear mixed (repeated measure) models, and generalised estimating equations.

Results suggest collection of user fees is a significant determinant of waterpoint sustainability, alongside other institutional, technical, geographical and environmental variables. However, monthly payment arrangements are beset by non-payment and late payment, particularly if rainfall levels are high, group size is large, households are far away, and water is aggressive and unpalatable. Although monthly contribution levels remain relatively stable above a collective payment rate of 60%, there is little evidence of self-sustaining growth beyond this point, and revenue collection is prone to collapse below this collective payment threshold. In comparison, pay-as-you-fetch fees are associated with increased revenue and improved operational performance, but result in a higher proportion of households opting for an unimproved water source.

If the Sustainable Development Goal of universal access to safe water supplies is to be achieved in rural sub-Saharan Africa, strategies are needed to strengthen revenue collection systems and bolster payment incentives. External support and professionalised service delivery models present potential pathways to advance these goals. Policymakers may also need to introduce carefully designed subsidies, or promote self-supply approaches that realign lifecycle costs with users' willingness-to-pay.

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# Chapter 1 – Introduction

## 1.1 Framing the research

Community-managed handpumps have been the predominant approach to rural water supplies in sub-Saharan Africa for over thirty years (Arlosoroff et al., 1987; Harvey & Reed, 2004). A low-cost technology managed by local users has held great appeal for governments, donors and non-government organisations (NGOs) (Harvey & Reed, 2004, 2007). Under this model, communities are expected to take responsibility for operation and maintenance (O&M) activities, including tariff setting, revenue collection and coordination of maintenance and repairs (Schouten & Moriarty, 2003; Harvey & Reed, 2004). However, with an estimated one in three handpumps non-functional at any one time (RWSN, 2009), flaws in this techno-institutional coupling have become apparent.

Perhaps the most consistently cited challenge of keeping rural waterpoints functional is the financing of O&M activities. Revenue collection from water users has long been considered a keystone of community management (Arlosoroff et al., 1987; Briscoe & de Ferranti, 1988) and a critical ingredient for sustainability (Carter et al., 1996, 1999; Harvey, 2007). While full cost recovery – including capital costs – is viewed as unrealistic in rural sub-Saharan Africa (Harvey, 2007), community management proceeds upon the assumption that self-financing of recurrent O&M costs is attainable. As such, the principle of self-financing O&M is now formalised in policies and assumed in financing plans across the continent (African Development Bank, 2010; Banerjee & Morella, 2011; GLAAS, 2014). Despite this consensus, waterpoint mapping datasets and household surveys suggest community-based revenue collection remains the exception rather than the norm in rural areas (Hirn, 2011, 2012; Afrobarometer, 2014).

While it is conventional wisdom that waterpoint financial and operational performance are integrally linked, few attempts have been made to empirically and rigorously interrogate this nexus. Likewise, the underlying determinants of financial performance have thus far avoided empirical scrutiny.

Although it is suspected a sizable proportion of waterpoint users fail to meet their payment obligations (Carter et al., 2010), little effort has been made to quantify the extent of the free-riding problem or examine the primary causes. To be sure, there is an established body of literature assessing determinants of willingness to pay for hypothetical water services in rural sub-Saharan Africa (World Bank Water Demand Research Team, 1993; Arouna & Dabbert, 2012; Bogale & Urgessa, 2012; Naiga & Penker, 2014), but few studies have sought to evaluate the conditions affecting actual payment behaviours. This is of critical importance given evidence of a divergence between factors which influence a household's stated willingness to pay and those which determine their actual behaviours (Griffin et al., 1995). Hence, critical knowledge gaps remain around the prevalence, predictors, patterns and operational implications of financial contributions from rural water users.

Theory pertaining to collective action and common-pool resource (CPR) management is highly relevant to rural water sustainability dilemmas. Both of these fields offer reasoning and analytical approaches that have the potential to shed light on why some communities are able to self-finance waterpoint O&M, while others fail. Several theoretical and conceptual frameworks have been developed to help explain CPR management and collective action processes and outcomes, such as Ostrom's social-ecological systems framework (Ostrom, 2007), Musgrave & Musgrave's economic good framework (Musgrave & Musgrave, 1973), and Marwell & Oliver's critical mass theory (Marwell & Oliver, 1993). Yet, despite their potential to yield fresh insights into the possibilities and pitfalls of community-managed waterpoints and their financing, these theories and frameworks have remained largely unexploited (Hanatani & Fuse, 2012; Naiga & Penker, 2014).

In order to address the aforementioned knowledge gaps, this doctoral research applies collective action and CPR theoretical frameworks to assess financial risks to rural waterpoint sustainability in sub-Saharan Africa. Adopting a 'DPhil by Publication' approach, the thesis is framed around four interlinking papers that assess the prevalence, predictors, patterns and operational implications of community-based financing for handpump water supplies.

## **1.2 Structure and overview of the thesis**

The structure of the thesis is as follows. Chapter 2 presents a survey of the literature relevant to rural water supply sustainability, collective action and CPR management. Chapter 3 describes the aims of the research, the frameworks upon which the research is based, and the methods utilised to carry out the studies. Chapter 4 (Paper 1) analyses national waterpoint datasets from Liberia, Sierra Leone and Uganda to assess the predictors of rural waterpoint functionality, including variables pertaining to revenue collection. Chapter 5 (Paper 2) applies a social-ecological systems (SES) framework to waterpoint financial records from rural Kenya to quantify the prevalence and determinants of collective payment rates. Chapter 6 (Paper 3) applies an economic goods framework and CPR theory to waterpoint revenue collection strategies in rural Kenya, and quantifies their association with operational performance and water source choices. Chapter 7 (Paper 4) applies critical mass theory to monthly waterpoint payments to assess how interdependence of decision-making and self-reinforcing dynamics influence financial outcomes. The concluding section, Chapter 8, summarises the findings and original contributions arising from the four papers, discusses the implications for policy and practice, and outlines directions for future research.

Chapter 2 summarises the body of literature pertaining to rural water supply sustainability, and traces the recent evolution of collective action and CPR theories. The literature survey characterises the rural water sustainability challenge in sub-Saharan Africa – particularly for community-managed handpumps – and synthesises the emerging policy trends within the sector. The section also highlights key knowledge gaps: namely, the paucity of evidence on the relationship between financial and operational performance, and the extent, determinants, dynamics and implications of non-payment. The focus then turns to the birth and maturation of key economic and sociological frameworks upon which collective action and CPR theories are founded. The chapter concludes by contending that these academic fields offer salient perspectives from which to examine rural waterpoint sustainability issues.

Chapter 3 explains the research aims, frameworks and methodologies. The overarching objectives of the doctoral research are put forward, as well as the specific goals for each of the four papers, all of which respond to the research gaps identified in Chapter 2. The theoretical and conceptual frameworks to which the research is anchored are also outlined. The various methods adopted throughout the course of the research are then described. This includes a detailed account (and justification) of the study site, data collection activities and analytical approaches utilised. Further to this, section 3.4 elucidates the nature of collaborations and division of responsibilities vis-à-vis other members of the wider research team at Oxford University.

Chapter 4 (Paper 1) sets out to identify operational, technical, institutional, financial, and environmental predictors of functionality for community-managed handpumps. The study applies logistic regression analyses to a dataset of 25,000 handpumps drawn from national waterpoint inventories in Liberia, Sierra Leone and Uganda. Along with system age and distance from district/county capital, absence of user fee collection is found to be a significant risk factor across all three countries. Other variables exhibiting significant associations with functionality status in at least one country included well type, handpump type, funding organization, implementing organization, spare parts proximity, availability of a handpump mechanic, regular servicing, regular water committee meetings, women in key water committee positions, rainfall season, and perceived water quality. While the findings suggest revenue collection – along with a multifaceted range of other conditions – is critical for the sustainability of community-managed handpumps, the study also indicates this key requirement remains absent from a high proportion of cases.

Chapter 5 (Paper 2) applies Ostrom's SES framework to community waterpoints in rural Kenya, to empirically assess the prevalence and determinants of financial contributions among handpump users. The analysis draws on multi-decadal data integrating 229 years' worth of water committee financial records, a census of 518 community waterpoints, and a survey of 3,233 water users. Results reveal that non-payment and late payment are prevalent, and payment behaviours are predicted by

groundwater quality, waterpoint location, group size, and rainfall season. In doing so, the results validate the SES framework as a diagnostic tool for rural waterpoint sustainability assessments. The findings also shine a spotlight on the challenge of securing the financial sustainability of waterpoints across heterogeneous environmental and social settings. A range of strategies to improve contribution rates are proffered, from practical measures relating to spare parts and waterpoint siting, through to more fundamental policy changes, such as provision of ongoing external support.

Chapter 6 (Paper 3) applies collective action and CPR theory to waterpoint revenue collection approaches, and empirically assesses the implications for waterpoint sustainability outcomes and safe water access in Kwale, Kenya. Results suggest communities adopting pay-as-you-fetch fees collect more revenue than communities with regular fixed fees, and experience downtime 16.5 days shorter than all other waterpoints. These outcomes are tempered by evidence that households are more likely to opt for an unimproved drinking water source when a pay-as-you-fetch system is in place. The findings point to possible a tension between financial sustainability and universal access.

Chapter 7 (Paper 4) applies critical mass theory to community waterpoint financial contributions in rural sub-Saharan Africa. Critical mass dynamics have been widely used to explain the initiation and spread of collective behaviours, from protests and political representation, through to vaccinations and adoption of new technologies. The presence of self-reinforcing dynamics and critical mass points is empirically evaluated through assessment of waterpoint financial records from rural Kenya, comprising 43,020 household contributions over a 26 year period. An examination of collective payment rates of change and financial record continuity suggests user contributions remain relatively stable between 61-100%, although become unstable and prone to collapse below this level. Despite evidence of a critical mass point at a collective payment rate of 60%, there is little indication of self-reinforcing growth dynamics. Results highlight the fragility of community-based financing, and its vulnerability to small perturbations.

Chapter 8 concludes the thesis by discussing the contributions of the research to our understanding of rural water sustainability issues, and to collective action and CPR management theory more generally. Section 8.1 explains how, in totality, the four papers present a complementary sequence of findings, and draws out the common threads connecting the individual studies. The theoretical frameworks utilised throughout are also reflected upon, along with further explication as to how the research advances the broader fields of collective action and CPR management. Implications and recommendations for policymakers and practitioners are then detailed in section 8.2. It is argued that if the Sustainable Development Goal of universal access to safe water is to be achieved, strategies aimed at boosting the resilience of revenue collection arrangements and strengthening payment incentives are needed. Finally, section 8.3 flags opportunities and directions for future investigations that can build on this research and tackle remaining knowledge gaps.

## Chapter 2 – Survey of Literature

### 1.1 Community handpumps and financial sustainability

Community-managed handpumps have been the mainstay techno-institutional approach to rural water supplies in sub-Saharan Africa for over three decades (Arlosoroff et al., 1987; Parry-Jones et al., 2001; Harvey & Reed, 2004, 2007). Combining a low-cost technology for lifting groundwater with an institutional model premised on the assumption that local users are willing and able to self-organise, the approach has long been embraced by governments, donors and non-government organisations (NGOs) (Harvey & Reed, 2004, 2007). Almost a million handpumps have been installed on wells and boreholes across the continent (Macarthur, 2014), with an additional 60,000 deployed every year (Sansom & Koestler, 2009). Under this model, community-based water committees are expected to assume responsibility for handpump operation and maintenance (O&M), including tariff setting, revenue collection and management of maintenance and repairs (Schouten & Moriarty, 2003; Harvey & Reed, 2004, 2007). Originally borne of a pragmatic shift of O&M responsibilities from under-resourced governments to local community members (Parry-Jones et al., 2001; Arlosoroff et al., 1987), community management has also provided donors and NGOs with a convenient justification for adopting a ‘project approach’ to water supply interventions (Harvey & Reed, 2007).

However, with an estimated one in three handpumps non-functional at any one time (RWSN, 2009), flaws in this techno-institutional coupling have become apparent. Although low levels of rural water supply sustainability were observed as early as the 1980s (McNeill, 1985; Arlosoroff et al., 1987; Churchill et al., 1987; Briscoe & de Ferranti, 1988; Therkildsen, 1988), the problems were largely attributed to a supply-driven approach that rarely sought the involvement and input of local communities. To address these issues, a demand-responsive philosophy and greater emphasis on user participation were widely adopted (Sara & Katz, 1998; Narayan, 1995). While in some instances these changes led to improved outcomes (Sara & Katz, 1998; Narayan, 1995; Whittington et al. 2009),

communities still struggle to perform management responsibilities effectively, and low levels of sustainability endure. The resultant service disruptions likely force millions of households to revert to unsafe or distant water sources at any point in time. The financial ramifications are also considerable. Baumann (2009) estimates that inoperable handpumps represent US\$1.2-1.5 billion in wasted investment.

In response, a chorus of voices advocate for a paradigm shift away from project implementation toward long-term service delivery (Harvey & Reed, 2007; Lockwood & Smits, 2011). Along the same lines, there is an emerging consensus that rural communities cannot be expected to manage their own water supplies effectively without some degree of ongoing external support that spans financial, technical and administrative domains (Harvey & Reed, 2004; Schouten & Moriarty, 2003; Baumann, 2006; Whittington, et al., 2009; RWSN, 2010; IRC, 2012; Schweitzer & Mihelcic, 2012; Hutchings et al., 2015). Some have also questioned whether the community management paradigm ought to be rethought altogether, with household self-supply and private sector management models proposed as possible alternatives (Harvey & Reed, 2007; Sutton, 2009; Hope et al., 2012).

A growing body of literature has begun to examine the complex combination of factors that influence the sustainability of rural water supplies (Parry-Jones et al., 2001; Arlosoroff et al., 1987; Harvey & Reed, 2007; Carter et al., 1999; Montgomery et al., 2009; Hutchings et al. 2015; Bonsor et al., 2015; Walters & Javernick-Will, 2015), with hypothesised determinants being operational, technical, social, institutional, environmental and financial in nature (Table 1). While a raft of purported preconditions are oft quoted, a lack of empirical evidence has made it difficult to evaluate their relative importance. Though there has been a steady stream of qualitative and case study appraisals, there have been few attempts to rigorously quantify associations between risk factors and rural water supply performance. Of the small number of quantitative studies conducted, most have focused on characteristics relating to user participation in planning and implementation (Isham et al., 1995; Sara & Katz, 1998; Narayan, 1995; Gross et al., 2001; Marks et al., 2014), or have bundled together various water supply

technologies (Hutchings et al., 2015; Narayan, 1995). A study of waterpoints in 175 Ghanaian villages carried out by Whittington et al. (2009) stands alone as a rare example of an investigation quantifying the relationship between sustainability determinants and outcomes specifically for handpumps in sub-Saharan Africa.

Table 1 – Hypothesised factors influencing rural water supply sustainability in sub-Saharan Africa<sup>a</sup>

| Domain                               | Influencing factors                                                                                                                                                 |
|--------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Operational &amp; technical</b>   | Design and construction quality; preventive maintenance; handpump technology; access to spare parts, tools and equipment                                            |
| <b>Social &amp; community</b>        | Willingness to pay; number of users; participation of women; training and capacity building; social cohesion; active water committee; dynamic or charismatic leader |
| <b>Institutional &amp; policy</b>    | Post-construction support; regulation; technology standardization; sector coordination; enabling environment                                                        |
| <b>Environmental</b>                 | Water quality; availability of alternative sources; groundwater reliability                                                                                         |
| <b>Financing &amp; cost recovery</b> | Revenue collection to cover recurrent costs and capital replacement costs; mechanisms for saving and storing funds                                                  |

<sup>a</sup> Adapted from Harvey & Reed (2004); Parry-Jones et al. (2001); Lockwood et al. (2003)

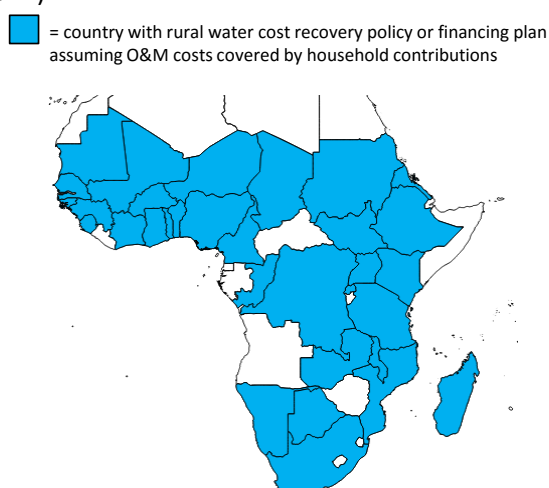
Perhaps the most consistently cited challenge of keeping rural waterpoints functional is the financing of O&M activities. Revenue collection from water users has long been considered a cornerstone of community management (Arlosoroff et al., 1987; Briscoe & de Ferranti, 1988), and widely regarded as critical to sustainability (Carter et al., 1996, 1999; Harvey, 2007). While full cost recovery<sup>1</sup> – including capital costs – is viewed as unrealistic in rural sub-Saharan Africa (Harvey, 2007), community management proceeds upon the assumption that self-financing of recurrent O&M costs is attainable. The rationales are manifold. Governments and donors have traditionally been considered ill-equipped to reliably finance recurrent water service costs in the long-term (Briscoe & de Ferranti, 1988; Churchill et al., 1987). Additionally, as with community management more generally, the expectation of self-financing fits neatly with the predilection of donors and NGOs to approach water supply interventions

<sup>1</sup> According to Cardone & Fonseca (2003), ‘cost recovery’ means “to recover all the costs associated with a water system, programme or service to ensure long-term sustainability.” This includes all lifecycle cost components associated with delivering a rural water service, including (a) operational expenditure, (b) capital maintenance expenditure, (c) cost of capital, (d) expenditure on direct support, (e) expenditure on indirect support, (f) capital expenditure hardware, and (g) capital expenditure software (see Fonseca et al., 2011).

as one-off projects, and is arguably reinforced by a Western “cultural idealization” that rural communities will harmoniously cooperate and act collectively (Harvey & Reed, 2007). Briscoe & de Ferranti (1988) also advance justifications based on principles of equity and efficiency, as user contributions raise money in a non-distortionary way, minimise waste, and liberate donor and government funds to expand improved water supply access to the poorest and hardest to reach.

Although taxes and transfers play a role in subsidising major handpump repairs, technician salaries and equipment, and spare part supply chains (MWE, 2011a; MLGH, 2007; Hystra, 2011; Jones, 2013), the bulk of financing for handpump O&M is expected to derive from tariffs paid by water users. The principle of self-financing of O&M is now formalised in policies and assumed in financing plans across the continent (African Development Bank, 2010; Banerjee & Morella, 2011; GLAAS, 2014) (Figure 1). The sums of money are not inconsiderable: applying WASHCost (2012) benchmarks to handpump coverage estimates, the recurrent handpump expenditure requirements across sub-Saharan Africa may lie between US\$386 million and US\$579 million a year, with an annual increase of US\$28 million to US\$42 million.<sup>2</sup>

Figure 1 – Countries with a rural water cost recovery policy or financing plan assuming some or all O&M costs covered by household contributions (compiled from data presented in Banerjee & Morella, 2011; GLAAS, 2014).



<sup>2</sup> Based on an annual O&M cost requirement of US \$2-3 per person (WASHCost 2011), adjusted to 2014 values. Current handpump coverage estimates taken from Macarthur (2015), and annual growth estimates taken from Sansom & Koestler (2009).

Despite this consensus, waterpoint datasets from East and West Africa are suggestive of a considerable mismatch between policy and reality (Table 2). Less than half of all handpumps have a revenue collection system in place, and only 1 in 5 water user groups chooses to regularly collect and save funds in advance of a breakdown. Moreover, nationally representative surveys across 19 sub-Saharan African countries in 2008-9 found only 30% of rural households pay for water (Figure 2), at a time when improved water coverage in rural areas of those countries collectively stood at 54%.<sup>3</sup> At the same time, ‘back-of-the-envelope’ calculations suggest waterpoint non-functionality rates could be twice as high when a revenue collection system is lacking (Foster, 2015). This agrees with the logic that user fees are essential to sustain a virtuous cycle of strong operational and financial performance (Rouse, 2007). The widespread nature of the revenue collection problem therefore has profound implications for the Sustainable Development Goal (SDG) of universal access to safe water, and the realisation of the human right to water (UNGA, 2010).

Table 2 – Prevalence of revenue collection for waterpoints fitted with handpumps in five sub-Saharan African countries

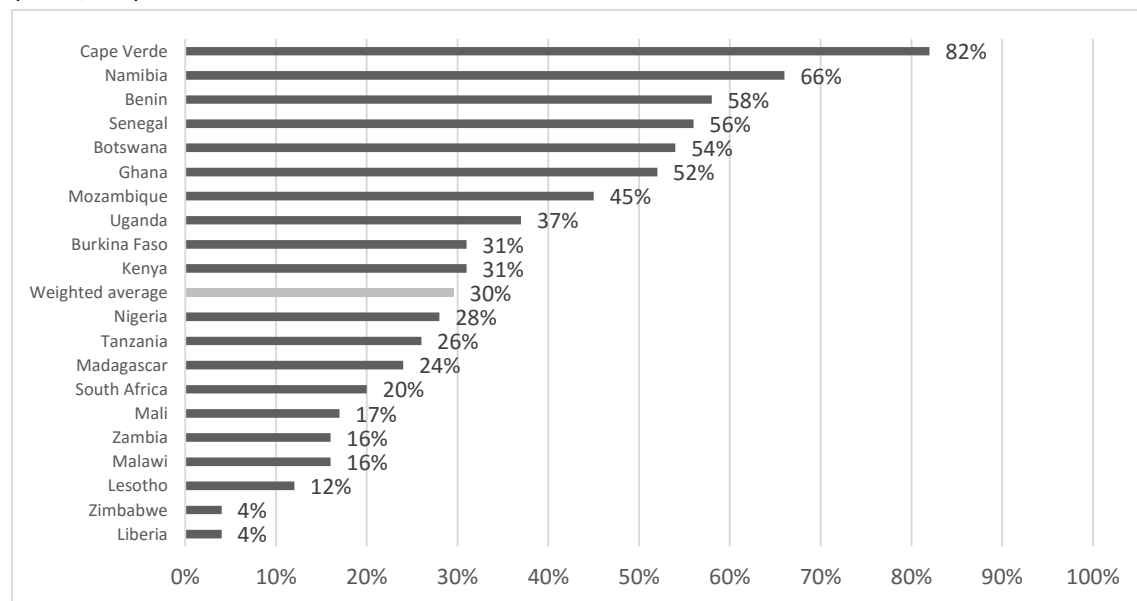
| Country      | Scope                   | No. handpumps | Handpumps with revenue collection (%) | Primary revenue collection approach (%) |                                   |
|--------------|-------------------------|---------------|---------------------------------------|-----------------------------------------|-----------------------------------|
|              |                         |               |                                       | Upon breakdown                          | Regularly in advance of breakdown |
| Kenya        | 8 counties <sup>a</sup> | 2,119         | 52.2 <sup>b</sup>                     | 8.1                                     | 44.0                              |
| Liberia      | National                | 9,388         | 46.8 <sup>c</sup>                     | 30.2                                    | 16.6                              |
| Sierra Leone | National                | 12,003        | 20.0 <sup>d</sup>                     | 15.5                                    | 4.5                               |
| Tanzania     | National                | 21,884        | 42.1 <sup>e</sup>                     | 13.2                                    | 28.9                              |
| Uganda       | National                | 47,200        | 42.8                                  | -                                       | -                                 |
| <b>Total</b> |                         | <b>92,594</b> | <b>40.4 (37.6<sup>f</sup>)</b>        | <b>17.4<sup>f</sup></b>                 | <b>20.2<sup>f</sup></b>           |

Author’s analysis based on publicly available waterpoint datasets (Virtual Kenya, 2015; NWSHPC, 2014; Sierra Leone STATWASH Portal 2014; Government of Tanzania, 2014; Government of Uganda, 2012)

<sup>a</sup> Busia, Embu, Isiolo, Kajiado, Kiambu, Kisumu, Kwale, Turkana. <sup>b</sup> Excludes 229 handpumps with unknown revenue collection regime. <sup>c</sup> Excludes 51 handpumps with unknown revenue collection regime. <sup>d</sup> Excludes 682 handpumps which were under construction, and 12 handpumps with unknown revenue collection regime. <sup>e</sup> Excludes 2,899 handpumps with unknown revenue collection regime. <sup>f</sup> Excludes data from Uganda, which do not distinguish between revenue collection approaches.

<sup>3</sup> Improved water coverage rate was calculated using data from UNICEF/WHO (2015).

Figure 2 – Proportion of households that pay for water in rural sub-Saharan Africa in 2008/9 (n=17,156)<sup>a</sup>



<sup>a</sup> Author's analysis of data from Afrobarometer (2015) household surveys

While the view that waterpoint financial and operational performance go hand in hand is widely held (Hope & Rouse, 2013), no attempts have been made to empirically and rigorously interrogate this nexus. The mere fact a community has a revenue collection system in place is no guarantee the water service will be reliable. For example, the Ghanaian study by Whittington et al. (2009) found that even where communities collected user fees, only 65% maintained sufficient finances to cover minor repairs, and only 30% stored enough to cover major repairs. Such shortfalls may arise for several reasons. First, fees are rarely determined in accordance with the expected lifecycle cost of a handpump (Parry-Jones et al., 2001; Harvey, 2007; Carter et al., 2010). Thus in many cases, the amount collected is an arbitrary sum that will be insufficient to cover the real long-term maintenance costs. Second, handpump repair costs are variable and unpredictable in magnitude and frequency, and may exceed a tariff even if it is based on an 'average' lifecycle cost (Hope et al., 2012). Third, it has been noted that a sizable proportion of waterpoint users fail to meet their payment obligations and choose instead to free-ride (Carter et al., 2010; van der Werff & Visscher, 1995).

Until now, little effort has been made to quantify the extent of the free-riding problem and examine the underlying causes. Although there is an established body of literature examining determinants of willingness to pay for hypothetical water services in rural sub-Saharan Africa (World Bank Water Demand Research Team, 1993; Arouna & Dabbert, 2012; Bogale & Urgessa, 2012; Naiga & Penker, 2014), there have been few studies seeking to evaluate the conditions affecting actual payment behaviours. This is of critical importance given evidence of a divergence between factors which influence a household's stated willingness to pay and those which determine their actual behaviours (Griffin et al., 1995). A notable exception is a study of rural water users in Senegal which examines predictors of self-reported payment compliance (Hanatani & Fuse, 2012). In conclusion, although rural water sustainability issues are attracting more scholarly interest than ever, critical knowledge gaps remain around the prevalence, predictors, patterns and operational implications of financial contributions from water users.

## **1.2 Handpumps, collective action & common-pool resource theory**

Theoretical frameworks pertaining to collective action and common-pool resource (CPR) management are highly relevant to rural water sustainability dilemmas. They offer both insights and analytical approaches that have the potential to shed light on why some communities are able to self-finance waterpoint O&M, while others fail. To varying degrees, community waterpoints in rural sub-Saharan Africa possess the hallmarks of a CPR on the premise that use is subtractable<sup>4</sup> and non-excludable. Excludability refers to the degree to which consumption of a good or service can be denied (Ostrom, 2003). Subtractability – also known as rivalry – describes the extent to which one's person consumption reduces the availability of the good or service for others (Ostrom, 2003). As with all CPR

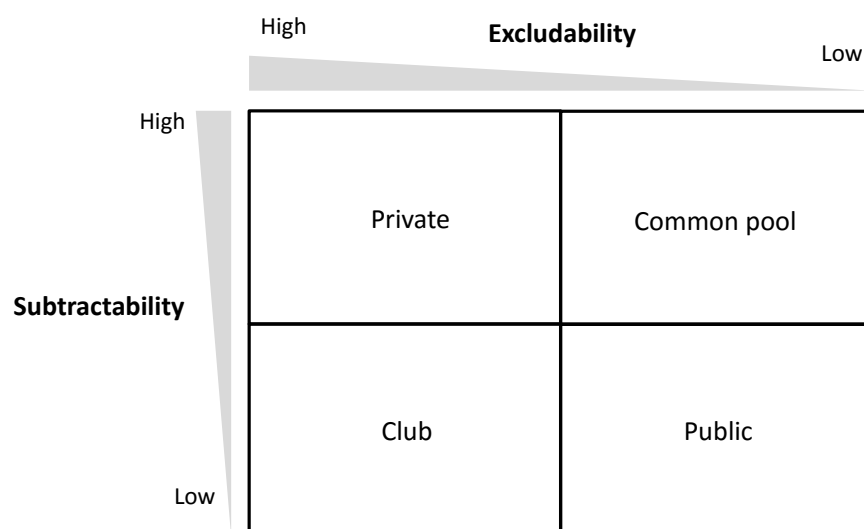
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<sup>4</sup> Subtractability reflects the reality that use of the handpump incurs a marginal cost greater than zero. This marginal cost can be realised in several forms. First and foremost, handpump use incurs a unit operation and maintenance cost (i.e. 'wear and tear'). Even though systems are hand-operated, each unit of use reduces the amount of usage before the next failure occurs. Second, queues and congestion at waterpoints can occur, particularly at peak times of the day and during periods of low rainfall. At such times every unit of use increases that congestion. Third, where yield or water tables are low enough, each unit of use may temporarily reduce the availability of the resource for others.

collective action problems, it is the non-excludable nature of handpump supplies that heightens the risk of free-riding. However, this characteristic is both mutable and a question of degree (Baumol, 1986). In other words, non-excludability need not be an inherent property of waterpoints if communities are able to apply institutional and physical measures to restrict access (Koehler et al., 2015).

CPRs are but one sub-class within a broader universe of economic goods classified according to the two-fold criteria of subtractability and excludability (Figure 3). The criterion of subtractability originally shot to prominence on the back of a seminal paper by Samuelson (1954), who introduced the concept as a way of distinguishing between private and public goods. In the ensuing years, the importance of excludability received greater attention by way of the landmark analyses of collective action (Olson, 1965), commons (Hardin, 1968) and club goods (Buchanan, 1965). Soon after, Musgrave & Musgrave (1973) combined the attributes of excludability and subtractability into a single framework for the first time, with Ostrom & Ostrom (1977) subsequently populating their two-by-two matrix with four types of goods: (i) private goods, (ii) public goods, (iii) club (toll) goods, and (iv) common-pool resources.

Figure 3 – Classification of goods and services according to excludability and subtractability (based on Musgrave & Musgrave, 1973; Ostrom & Ostrom 1977)



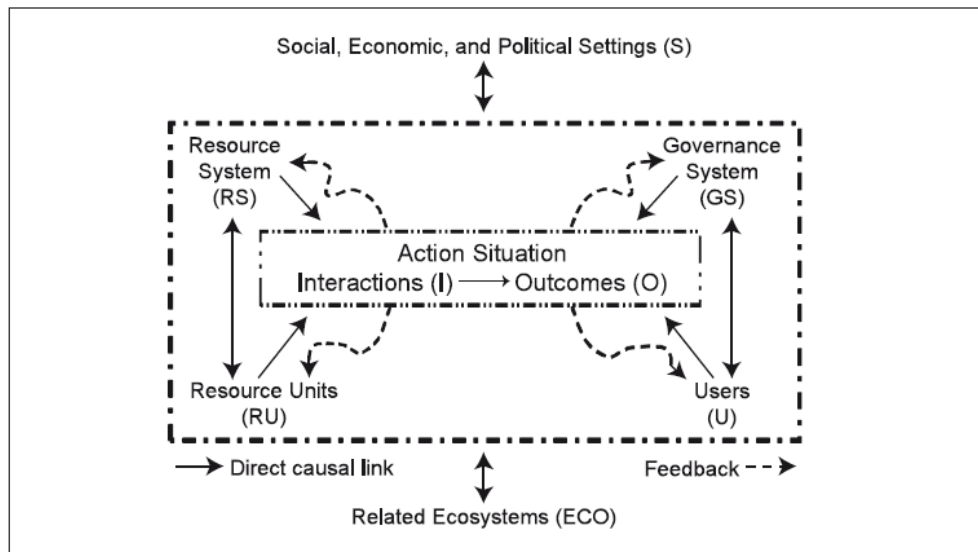
Scholarly interest in collective action and CPR dilemmas emerged more than four decades ago, when Hardin (1968) theorised that commons used collectively would inevitably result in overexploitation, degradation and collapse of the resource. The critical attribute upon which Hardin's forecast turned was 'non-excludability', such that the benefits of consumption could not be withheld from non-contributors. Olson (1965) postulated similarly dire consequences for large groups entrusted with solving collective action problems. While these seminal works initiated a wave of theoretical and empirical research, their predictions were overly pessimistic. This is not to deny that collective management of CPRs can in some instances lead to overuse and destruction, particularly when users are anonymous, do not communicate, and receive no feedback (Basurto & Ostrom, 2009). However, examples of users successfully collaborating and managing CPRs in a sustainable fashion have been noted across a range of resource types, including fisheries, forests, grazing pastures and water resources (Wade, 1987; McCay & Acheson, 1987; Berkes, 1989; Baland & Platteau, 1996; van Laerhoven & Ostrom, 2007; Basurto & Ostrom, 2009).

While Olson (1965) predicted rational actors would be motivated by narrow self-interest and free-ride if a collective good could not be withheld from non-participants, his logic contained a critical flaw – the assumption that decisions made by actors were independent. In a marked departure, Granovetter (1978) proposed a threshold model to explain collective behaviours in recognition that people's propensity to participate in collective efforts is influenced by the number of people already participating. That is, one's decision to join a collective endeavour is dependent on the involvement of others. Interdependence has since commonly formed the basis of theoretical and empirical analysis of collective behaviours (Granovetter & Soong, 1983; Oliver et al., 1985; Macy 1990). The interdependence assumption also spawned the theory of critical mass, an argument that has played an important role in explaining collective action in a way that harmonises rational choice theory with sociological perspectives (Oliver et al., 1985). Recently defined as "the level of activity above which a behaviour becomes self-sustaining" (Centola, 2013), critical mass concepts have been applied to a range of collective behaviours, from the spread of protests, migration and political representation,

through to diffusion of new technologies, uptake of vaccinations, and adoption of birth control devices (Yin, 1998; Childs & Krook, 2008; Macdonald & Macdonald, 1964; Markus, 1987; Hershey et al., 1994; Rogers & Kincaid, 1981).

Recognising that both successful and failed examples of collective CPR management abound, scholars have also turned their attention to the conditions under which groups are able to self-organise and sustainably manage resources (Ostrom, 1990; Wade, 1994; Baland & Platteau, 1996; Agrawal, 2003). Identification of factors that facilitate or hinder CPR management continues to provoke debate, and disagreement as to the size and direction of associations endures (Araral, 2009). Given the complexity of collective action and CPR processes, a single and comprehensive explanatory theory has proved elusive. In response, Ostrom (2007; 2009) crafted a multilevel social-ecological system (SES) framework as a common diagnostic tool for analysing factors that influence outcomes for complex environmental and human systems. The SES framework is intended to aid cumulative learning by laying out a classificatory system and vocabulary that helps organise analysis and communicate findings (Ostrom & Cox, 2010). Shaped by decades of theoretical and empirical work, the framework is premised upon the logic that SES outcomes can be explained by factors contained within four core sub-systems – resource systems, resource units, governance systems, and users – as well as related ecosystems, and broader political and economic settings (Figure 4). The framework has since been applied to a range of CPR challenges, from fisheries and transboundary river basins, through to Hardin’s allegorical overgrazed pasture (Cinner et al., 2013; Basurto et al., 2013; Garrick et al. 2013; Cole et al., 2014)

Figure 4 – Social-Ecological Systems Framework (Ostrom, 2007)



Applying collective action and CPR theories and frameworks to the literature gaps relating to waterpoint financial sustainability presents an important opportunity to advance new knowledge that informs both policy and practice. For example, the SES framework provides an ideal tool with which to analyse and identify the complex set of social and ecological factors influencing rural water supply sustainability. Likewise, community handpumps – and the associated revenue collection systems – possess traits that make them amenable to a critical mass analysis: they are a collective good and the assumption that each actor is aware of others’ payment decisions is realistic. Finally, different waterpoint revenue collection approaches inherently embed various degrees of excludability, begging the question: how do these arrangements impact financial and operational performance? Yet, despite their potential to yield fresh insights into the possibilities and pitfalls of community-managed waterpoints and their financing, theories and frameworks pertaining to collective action and CPR management have remained largely unexploited (Hanatani & Fuse, 2012; Naiga & Penker, 2014). Instead, the vast majority of collective action and CPR analyses of water-related challenges have focussed on irrigation systems that supply water for productive rather than domestic purposes (Araral, 2003; Ostrom, 1992; Meinzen-Dick, 2007).

## **Chapter 3 – Aims and Methods**

### **3.1 Research aims**

In response to the aforementioned knowledge gaps, the overarching aim of this research is to empirically evaluate the dynamics and drivers of financial risks, and how they in turn impact the operational performance of community waterpoints. The specific objectives of the four papers are to answer the following questions:

- Paper 1: What are the operational, technical, financial, institutional and environmental factors that predict waterpoint functionality in Liberia, Sierra Leone and Uganda?
- Paper 2: What is the prevalence and social-ecological determinants of collective payment rates for community waterpoints in rural Kenya?
- Paper 3: How does the choice of revenue collection strategy impact the financial and operational performance of community waterpoints and household drinking water choices in rural Kenya?
- Paper 4: How do critical mass dynamics influence revenue collection outcomes for community waterpoints in rural Kenya?

### **3.2 Theoretical and conceptual frameworks**

Collective action and CPR theory guides the research, and provides the grounding for the conceptual frameworks employed in the papers. Specifically, the four papers draw on Ostrom's SES framework, Musgrave & Musgrave's economic good classification, and Oliver and Marwell's critical mass theory.

Ostrom's (2007) SES framework provides the basis for the analysis of waterpoint functionality and collective payment rates in Papers 1 and 2, whereby resource system, resource unit, user group and governance system variables are included as explanatory variables in regression models. Community waterpoints provide fertile ground for applying the SES framework as they lie at the interface between

social groups and hydrogeological systems, thus a holistic analysis must traverse both social and natural science disciplines.

Paper 3 considers revenue collection approaches through the lens of Musgrave & Musgrave's economic good classification (Musgrave & Musgrave, 1973), specifically the attribute of 'excludability' and how it can shift a waterpoint from a CPR to a private good, thereby diminishing the complexity and burdens of collective action.

Paper 4 applies threshold and critical mass theory (Marwell & Oliver, 1993) to monthly waterpoint payments to establish the interdependence of payment behaviours, and identify the existence of critical mass points and self-reinforcing dynamics.

### **3.3 Methodology**

#### **Study site**

Kwale County in Kenya is the study site for most of the research (Figure 5).<sup>5</sup> Kwale has a population of around 730,000 people, 82% of whom live in rural areas (Commission on Revenue Allocation, 2013). Based on a poverty gap index measure, the region is one of the most impoverished in Kenya, ranked 41st out of 47 counties (Commission on Revenue Allocation, 2013). Waterpoints drawing on groundwater are the dominant mode of supply (Figure 6). In particular, boreholes fitted with Afridev handpumps are a ubiquitous feature of the rural water supply landscape, owing to successive donor-funded programmes which installed around 580 of these waterpoints between 1983 and 1995 (Figures 7). Community-based committees and revenue collection systems were established alongside the infrastructure investments, and the early results were hailed as a successful example of community-based water supply management (Narayan-Parker, 1988; Rondinelli, 1991). Given the majority of waterpoints are now 20-30 years old, the site provides a unique opportunity to assess the long-term financial performance and operational sustainability of community-managed handpumps.

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<sup>5</sup> The exception is Paper 1, which utilises data from Liberia, Sierra Leone and Uganda.

Figure 5 –Locations of waterpoints fitted with Afridev handpumps in Kwale County, Kenya

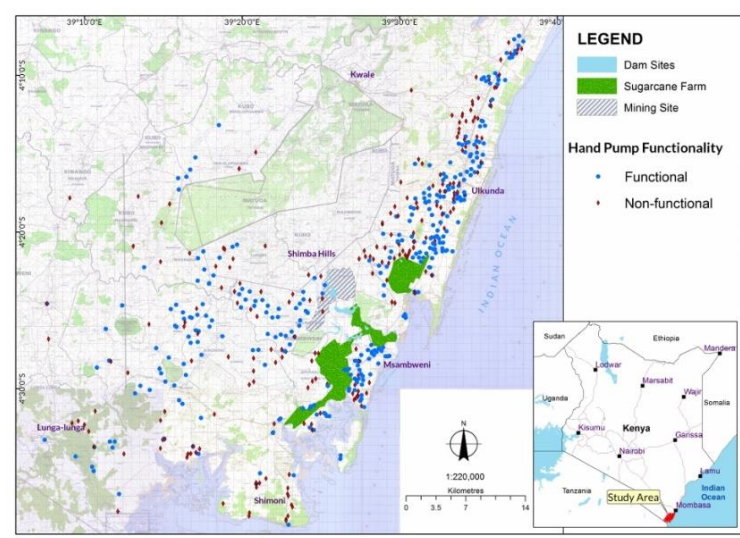
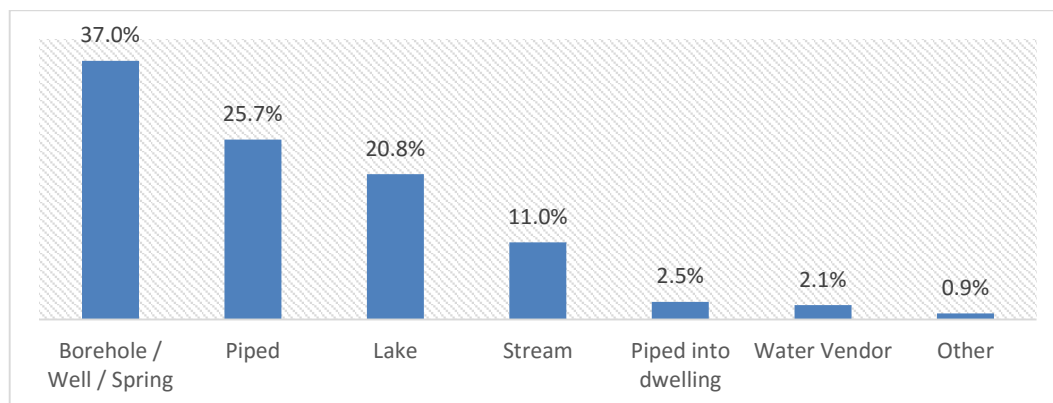
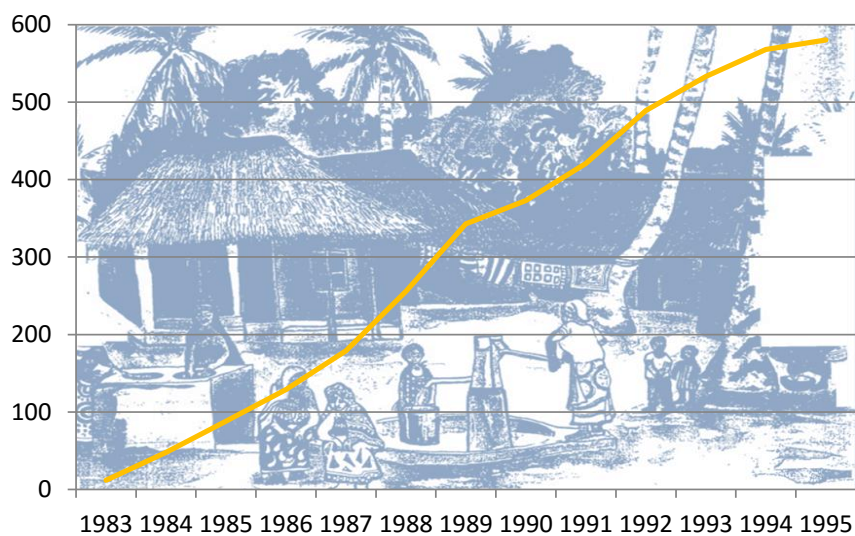


Figure 6 – Main source of drinking water in Kwale County (2009)<sup>a</sup>



<sup>a</sup> Data sourced from Kenyan Census (Government of Kenya, 2009)

Figure 7 – Cumulative Afridev handpump installations in Kwale, 1983-1995<sup>a</sup>



<sup>a</sup> Data drawn from Kwale County waterpoint installation records

The selection of the study site for the doctoral research was inextricably linked to the choice of study site for a wider research project led by Oxford University entitled “New Mobile Citizens and Waterpoint Sustainability in Rural Africa’ (NMCWSRA, ESRC Project No. R23715)”. The doctoral research was funded through the NMCWSRA project, and formed an important pillar of the overall research agenda. The geographical focuses therefore coincided. The original plan was to carry out the study in Zambia, where there was strong support from key stakeholders within the relevant government ministry. However, a change of national government took place shortly after the funding proposal was submitted, which resulted in the turnover of departmental staff – and with that, the institutional commitment to partner in the research. Kenya was chosen as an alternative country in which to carry out the research, due to the research team’s pre-existing relationships and rapport with government stakeholders and its track record of effective partnership with a local water engineering consultancy (Rural Focus Ltd) who would form a suitable implementing partner.

The NMCWSRA project involved the deployment of 300 remote monitoring devices specifically designed to be installed within the handles of Afridev handpumps. The study therefore needed to take place in a region where Afridev handpumps were prevalent. With its well documented history of Afridev installations (Arlosoroff et al., 1987; Narayan-Parker, 1988) and recent evidence of a high density of Afridev handpumps (Coast Water Services Board, 2013), Kwale emerged as an ideal candidate. Moreover, the implementing partner (Rural Focus Ltd) had previously established a satellite office in Kwale County, which would allow for the provision of the necessary administrative and logistical backing. Finally, local support to host the NMCWSRA project in Kwale materialised in February 2013 when the research team met with key stakeholders from the County Government, Coast Water Services Board, and District Water Office.

### **Data collection**

The research utilises mixed methods chiefly drawing on primary data from household surveys (n = 3,361 households), a waterpoint census (n = 571 waterpoints), and water committee financial audits

(n = 100 communities) (Table 3). Both the waterpoint census and household surveys were undertaken by trained enumerators and delivered in local languages, predominantly Swahili and Digo. I carried out the field work to collect financial record data with the support of a local research assistant. Planning and implementation of field work involved close engagement and collaboration with government stakeholders, including the National Ministry of Environment, Water and Natural Resources; the National Water Services Regulatory Board; the Coast Water Services Board; and local County government officials.

Table 3 – Kwale data collection activities

| <b>Data collection</b> | <b>Scope</b>            | <b>Dates</b>        |
|------------------------|-------------------------|---------------------|
| Waterpoint census      | 571 Afridev waterpoints | Aug 2013            |
| Household survey       | 3,361 households        | Sep 2013 – Jan 2014 |
| Financial records      | 100 communities         | Jan 2014            |

All data were collected as part of the DFID-ESRC funded projects ‘New Mobile Citizens and Waterpoint Sustainability in Rural Africa’ (ESRC Project No. R23715) and ‘Insuring Against Rural Water Risks’ (ESRC Project No. R28701). Prior to data collection, the wider Oxford University research group (of which I was a member) obtained a research permit from the Government of Kenya’s National Council of Science and Technology to conduct research on ‘rural water sustainability’ in Kwale (2013-16). Ethics approval was also granted by the Central University Research Ethics Committee (CUREC) at the University of Oxford.

### **Waterpoint census**

A census of 571 Afridev handpump sites across Kwale was carried out by four trained enumerators in August 2013. Waterpoints were located in consultation with original installation records, a partial dataset created by Coast Water Services Board, and by way of local knowledge. Key technical, social, institutional, operational, financial and geographical information pertaining to the waterpoint and its management were captured through structured interviews with a community member (water committee member where possible) (see Appendix I). Water quality parameters (EC, pH, temperature)

were measured with Hannah meters where feasible, and training was provided to the enumerators to ensure appropriate procedures were followed. All data collection was paper-based, and information was subsequently entered into a spreadsheet on a daily basis. Logistical and administrative support was provided throughout the data collection by Rural Focus Ltd, a Kenyan water engineering consultancy with a local office in Kwale.

### **Household survey**

A sampling frame for the household survey was informed by the waterpoint census, based on waterpoints deemed communal in use ( $n=531$ ).<sup>6</sup> Between October 2013 and January 2014, the survey was administered to a random sample of 3,361 households within the service area of the 531 community waterpoints. Prior to the commencement of the data collection, 18 enumerators were trained over a five day period to ensure a high level of comprehension of the questionnaire and sampling approach. The survey instrument was then piloted over a three day period, and during this time modifications were made to questions where necessary. The enumerators were grouped into three teams, each covering specific geographies with which they were familiar. As with the waterpoint census, Rural Focus Ltd provided logistical and administrative support throughout the survey.

A mean of 6.3 (SD 2.0) households were surveyed per waterpoint. Enumerators were instructed to administer the survey to between 4 and 8 households per waterpoint, with the final number depending on several factors, including logistical considerations, the size of enumerator teams, availability of respondents, and the length of time a waterpoint had been non-functional. In order to randomly select participating households, a sketch map of all dwellings within the estimated waterpoint service area was first drawn by an enumerator in consultation with a local community member. Each household was given a number, and the households were then chosen using a random number generator application installed on a tablet device.

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<sup>6</sup> “Communal in use” was defined as two or more households using the waterpoint.

An in-depth questionnaire was developed to capture a range of demographic, socio-economic, water use, water payment and health indicators for each household and its members (see Appendix II). Towards the end of the questionnaire, one of two choice experiments was randomly assigned for the enumerator to conduct.<sup>7</sup> Depending on household composition, respondents were asked approximately 200 to 250 questions (or more for households with many occupants), with the questionnaire generally taking between 45 to 60 minutes to complete. At the end of the questionnaire enumerators documented whether or not they had concerns over the accuracy of the responses, or believed the respondent had a poor understanding of the questions asked. All data were collected using tablet devices, specifically using a subscription-based software application called doForms.<sup>8</sup> Digital photographs and GPS coordinates were captured for each dwelling to allow for follow-up surveys to be conducted with the same households at a later date. At the end of each day, all data were uploaded to the doForms server, which were then accessible and downloadable via a password-protected website.

Figure 8 – Enumerators conducting household surveys in Kwale



#### **Financial records.**

Water user payment and expenditure data were obtained from written financial records kept by water committees. The participating committees were identified throughout the waterpoint census, during which respondents were asked whether documentation was kept of revenue collected and/or

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<sup>7</sup> For operational reasons, the choice experiments were not conducted for households surveyed in January 2014.

<sup>8</sup> See <http://www.doforms.com/>

expenses incurred. For those communities who stated they kept written records (n=213), a follow-up visit was undertaken in January 2014.<sup>9</sup> At 100 communities, financial records were located, reviewed and photographed for data entry and analysis. A structured interview with the person presenting the financial records (most commonly a water committee member) was also carried out and additional questions were asked to clarify any uncertainties and ambiguities that were evident in the records.

Figure 9 – Reviewing financial records in Kwale



### Data analysis

A variety of datasets and analytical techniques were carried out across the four studies. Specific data sources and analytical methods employed are as follows:

Paper 1 applied multivariable logistic regression to identify significant predictors of functionality status for community handpumps in three African countries. The analysis draws on publicly available national waterpoint data sets from Liberia, Sierra Leone, and Uganda. These waterpoint inventories were created by government ministries with the support of development partners and made available to the public via online databases. Further details on these data collection exercises and aggregated results can be found in reports produced by, or on behalf of, national water ministries (Hirn, 2011, 2012; MWE, 2011b).

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<sup>9</sup> Due to security concerns, 18 handpumps north of Tiwi which reportedly had financial records could not be visited.

Paper 2 draws on a dataset integrating 229 years' worth of water committee financial records, a census of 518 community waterpoints, and a survey of 3,233 waterpoint users in Kwale, Kenya. In order to examine the association between social-ecological characteristics and the level of monthly financial contributions by water users, a mixed effect repeated measure modelling technique (linear mixed model) was employed. This analytical method accounts for the correlation between recurring monthly observations for a given waterpoint, which would otherwise violate the independence assumption underpinning simple regression.

Paper 3 also draws on financial, waterpoint and household data from Kwale, Kenya. To ascertain whether there was a significant difference in the revenue amounts raised under different revenue collection approaches, independent samples t-tests and Mann-Whitney U tests were performed. Generalised Estimating Equations (GEEs) were run to assess whether revenue collection approach exhibited an association with waterpoint downtime, while controlling for potential confounders. The GEE was the chosen technique as it adjusts for the autocorrelation between breakdown events which pertain to the same waterpoint. To evaluate the influence of outcome variable outliers, GEEs with a log-transformed outcome variable were also run, and results were compared. A series of logistic regression GEEs were then conducted on outcome variables dichotomized at different downtime thresholds, so as to obtain a more nuanced understanding of the link between tariff structure and revenue collection. In order to appraise the access implications of each revenue collection approach, the odds of a household opting for an unimproved drinking water source were determined across revenue collection approaches for both wet and dry season, and disaggregated by wealth tertile. This regression analysis again employed GEEs to adjust for clustering of households around waterpoints, and controlled for user perceptions of taste and distance between the household and the waterpoint.

Paper 4 draws on a dataset containing 43,020 monthly household financial contributions from 57 communities in Kwale. Four types of analyses were undertaken to identify collective payment critical mass points and zones of self-reinforcing dynamics. First, collective payment rates of change were

calculated (mean, median, quartiles) for each collective payment interval of ten. Second, probabilities for rate of change direction (negative, no change, positive) were calculated for each collective payment rate interval of ten. Third, the recorded revenue 'survival' was plotted for the 12 months after a collective payment rate was documented, again with disaggregation of analysis by collective payment rate intervals of ten. Fourth, collective payment rates of 'high performing' communities with five or more consecutive years of financial records were plotted and key parameters were assessed.

### 3.4 Statement on research collaboration and joint publications

As the doctorate was linked to a wider programme of research work in Kwale, the data collection and preparation of papers involved collaboration with other colleagues at Oxford University. Table 4 outlines the specific roles and responsibilities I assumed in the relevant activities.

Table 4 – Roles and responsibilities I assumed for each aspect of the research<sup>a</sup>

| Activity                      | Roles & responsibilities I assumed                                                                                                                                                                                                                                                                                                                                                                                                                                  |
|-------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Data collection</b>        |                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |
| Waterpoint mapping            | <ul style="list-style-type: none"> <li>• Co-designed questionnaire with RH and PT</li> <li>• Ensured quality control throughout data collection</li> <li>• Cleaned data</li> </ul>                                                                                                                                                                                                                                                                                  |
| Household survey              | <ul style="list-style-type: none"> <li>• Co-designed questionnaire with RH, PT and JK</li> <li>• Set up data collection system including software and tablet devices</li> <li>• Trained enumerators with RH &amp; JK</li> <li>• Coordinated and led the implementation of the survey over two month period (logistical and administrative support provided by RFL)</li> <li>• Ensured quality control throughout data collection</li> <li>• Cleaned data</li> </ul> |
| Financial records             | <ul style="list-style-type: none"> <li>• Carried out all field work to collect data</li> <li>• Cleaned and collated data</li> </ul>                                                                                                                                                                                                                                                                                                                                 |
| <b>Manuscript preparation</b> |                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |
| Paper 1                       | <ul style="list-style-type: none"> <li>• Conducted all analyses</li> <li>• Wrote the paper (reviewed by RH)</li> </ul>                                                                                                                                                                                                                                                                                                                                              |
| Paper 2                       | <ul style="list-style-type: none"> <li>• Conducted all analyses (RH constructed welfare index)</li> <li>• Wrote the paper (with support from RH)</li> </ul>                                                                                                                                                                                                                                                                                                         |
| Paper 3                       | <ul style="list-style-type: none"> <li>• Conducted all analyses (RH constructed welfare index)</li> <li>• Wrote the paper (with support from RH)</li> </ul>                                                                                                                                                                                                                                                                                                         |
| Paper 4                       | <ul style="list-style-type: none"> <li>• Conducted all analyses</li> <li>• Wrote the paper</li> </ul>                                                                                                                                                                                                                                                                                                                                                               |

<sup>a</sup> Involvement of colleagues noted with following initials: RH = Rob Hope (supervisor); PT = Patrick Thomson (research colleague); JK = Johanna Koehler (research colleague); RFL = Rural Focus Ltd (implementation partner)

## **Chapter 4 – Paper 1**

### **Published in *Environmental Science & Technology***

Foster, T. (2013). Predictors of Sustainability for Community-managed Handpumps in Sub-Saharan Africa: Evidence from Liberia, Sierra Leone and Uganda. *Env Sci Tech*, 47 (21) 12037-12046.

# Predictors of Sustainability for Community-Managed Handpumps in Sub-Saharan Africa: Evidence from Liberia, Sierra Leone, and Uganda

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## S Supporting Information

**ABSTRACT:** Rural water supply sustainability has remained an enduring policy challenge in sub-Saharan Africa for decades. Drawing on the largest data set assembled on rural water points in sub-Saharan Africa to date, this paper employs logistic regression analyses to identify operational, technical, institutional, financial, and environmental predictors of functionality for over 25 000 community-managed handpumps in Liberia, Sierra Leone, and Uganda. Risk factors significantly associated with nonfunctionality across all three countries were (a) system age, (b) distance from district/county capital, and (c) absence of user fee collection. In at least one of the three countries, other variables found to have significant multivariable adjusted associations with functionality status included well type, handpump type, funding organization, implementing organization, spare parts proximity, availability of a handpump mechanic, regular servicing, regular water committee meetings, women in key water committee positions, rainfall season, and perceived water quality. While the findings reinforce views that a multifaceted range of conditions is critical for the sustainability of community-managed handpumps, they also demonstrate that these factors remain absent from a high proportion of cases. Governments and development partners must significantly strengthen postconstruction support for operation and maintenance systems, and greater efforts are needed to test and evaluate alternative models for managing handpump water supplies.



## INTRODUCTION

The poor operational performance of rural water supplies in sub-Saharan Africa has long been recognized.<sup>1–6</sup> Despite many billions of dollars' worth of investment over the past three decades, a stubbornly high proportion of water point systems across the continent are in a state of disrepair. Handpumps are the predominant mode of supplying water in rural sub-Saharan Africa, with more than 60 000 installed every year.<sup>7</sup> Yet, it is estimated that around one in three are nonfunctional at any one time.<sup>8</sup> In addition to the direct financial costs, this situation is likely to have considerable health and welfare ramifications as water users are forced to resort to unsafe and distant alternatives.

Low levels of handpump sustainability have undoubtedly hampered sub-Saharan African efforts to achieve the Millennium Development Goal (MDG) of halving the proportion of people without access to safe drinking water. While globally this MDG milestone has already been attained, current trends suggest it will not be met in rural sub-Saharan Africa until 2033. Disappointingly, the number of rural sub-Saharan Africans without safe drinking water has actually risen from 240 million in 1990 to 275 million in 2011.<sup>9</sup> Low levels of sustainability may also mean MDG coverage figures are overestimated, as many of the systems to which users are deemed to have "access" are in reality nonfunctional or delivering a poor quality service.

Persistently high nonfunctionality rates have led some to question whether the dominant community-based management (CBM) paradigm ought to be reconsidered.<sup>10</sup> For over 30 years, CBM has been embraced by governments, donors, and nongovernment organizations (NGOs) as the accepted model for managing water supplies in rural sub-Saharan Africa.<sup>4,6,10,11</sup> Under this approach, community-based water committees have assumed responsibility for the ongoing operation and maintenance (O&M) of water points, including tariff setting, revenue collection, and management of maintenance and repairs.<sup>10,11</sup> CBM was originally borne of a pragmatic shift of O&M responsibilities from under-resourced governments to local community members.<sup>2,4</sup> Roles and responsibilities have evolved over time, from Village Level Operation and Maintenance (VLOM) in the 1980s to the more professionalized O&M approaches emerging today. In an effort to boost outcomes, implementing organizations have also sought to buttress CBM with a demand-responsive philosophy and greater participation in planning and construction. While these arrangements have in some instances led to improved

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outcomes,<sup>12,13</sup> disappointingly low levels of sustainability endure.

In recognition of these problems, policy makers, implementers, and investors are now placing greater emphasis on the building blocks needed for the long-term sustainability of rural water points. In pursuit of an MDG defined by access to improved water source technologies, a focus on installing infrastructure has arguably been at the expense of putting in place the institutional, operational, and financial arrangements required to keep systems working indefinitely. In response, a chorus of voices advocate for a paradigm shift away from project implementation toward long-term service delivery.<sup>10,14</sup> Furthermore, there is an emerging consensus that rural communities are unable to manage their own water supplies without some degree of ongoing external support that encompasses monitoring, technical advice, administrative support, training, and encouragement.<sup>1,10,11,15,16</sup> Under certain conditions, others also advise consideration of alternatives to CBM, such as household self-supply or private sector management models.<sup>1,10,17–19</sup>

There is a growing body of literature that examines the complex combination of factors that influence the sustainability of rural water supplies (see Table S1 in Supporting Information).<sup>2,4,10,20–22</sup> However, while purported preconditions are oft quoted, a lack of empirical evidence makes it difficult to rate or prioritize their relative importance. Though there has been a steady stream of qualitative and case study appraisals, there have been surprisingly few attempts to rigorously quantify associations between determining factors and rural water point functionality. Of the handful of studies conducted, most have focused on characteristics relating to users' participation in planning and implementation and have bundled together projects involving a variety of water supply technologies across different continents.<sup>12,13,23</sup> Even scarcer are studies that have sought to quantify the relationships between sustainability determinants and outcomes specifically for handpumps, the principal water supply technology in rural sub-Saharan Africa. The study of handpumps in 175 Ghanaian villages carried out by Whittington et al.<sup>24</sup> is a notable exception.

This paper seeks to address this knowledge gap by empirically evaluating the relationships between a range of operational, technical, institutional, financial, and environmental characteristics and the functionality status of more than 25 000 community-managed handpumps in rural Liberia, Sierra Leone, and Uganda. By drawing on a sample size 2 orders of magnitude greater than any previous study, this analysis has important implications for policy makers and practitioners developing strategies geared toward effective handpump O&M systems and long-term service delivery. In particular, postconstruction support should yield greater dividends if it is designed to fortify the areas that most likely lead to water point failure. Furthermore, quantifying key risk factors can provide the evidence base that decision makers need to specify the conditions under which alternative management models or technologies might be considered.

## METHODS

This study aims to identify statistically significant operational, technical, institutional, financial, and environmental predictors of nonfunctional water points in Liberia, Sierra Leone, and Uganda. As the most common approach to rural water supplies in sub-Saharan Africa, the study focuses on community-

managed handpumps. In doing so, it draws on sub-Saharan Africa's three largest publicly available rural water point data sets. The study therefore allows for comparative analysis across contexts with varying hydrogeological settings, socio-economic conditions, rural water policies, and dominant handpump technologies (see Table S2 in the Supporting Information).

Data sets were extracted from national water supply databases from Liberia, Sierra Leone, and Uganda. These comprehensive water supply inventories were created by government ministries with the support of development partners for the purposes of service delivery performance monitoring and investment planning. All three inventories contain a range of technical, institutional, financial, and geographical information associated with rural water supply systems. Liberian data were collected during 2011 as part of a nationwide mapping exercise that covered 10 001 improved water points. Of these water points, 9388 were equipped with handpumps. In Sierra Leone, data on 28 845 water supply systems were collected during a similar mapping initiative in 2012, of which 12 003 were handpumps. Ugandan data were collected during the 2009/2010 financial year, and the census involved physical visits to all improved water supply technologies. Within the data set are 42 151 water points fitted with handpumps. Though enumerators were trained and data sets were cleaned, the presence of nonsampling errors such as those arising from misinterpretation of questions, inaccurate responses, or erroneous data entry cannot be ruled out. Further details on these data collection exercises and aggregated results can be found in reports produced by national water ministries and development partners.<sup>25–27</sup>

The data analyzed were subsamples confined to handpumps that (a) had a water committee established and (b) had been installed less than nine years prior to the time of data collection. This was to the exclusion of other handpumps managed institutionally (such as schools and health centers), privately, or by any other noncommunity based organization. Where possible, handpumps still undergoing installation were excluded from the samples. An eight year age constraint was applied in order to avoid handpumps that were installed during periods of civil war in Liberia and Sierra Leone. This exclusion was deemed important given the significant institutional and infrastructural degradation that took place during these conflicts.<sup>28,29</sup> Limiting the temporal parameters also strengthens the relevance of findings to more recent policies and approaches in the rural water subsector. Applying these criteria produced sample sizes of 4480 cases for Liberia, 5488 cases for Sierra Leone, and 15 133 cases for Uganda (see Figures S1–S3 in the Supporting Information).

By virtue of the cross-sectional nature of the data used, sustainability was defined as whether or not a handpump was functioning. In all three countries, the dichotomous outcome variable was handpump functionality status. Handpumps deemed nonfunctional included those broken down due to technical faults relating to the handpump and supporting infrastructure, and environmental failure modes such as changes in water level. For the purposes of the analyses, those water points described as partially working, or in working order but not in use, were considered to be functional. It is acknowledged that the outcome measure chosen is an imperfect proxy for sustainability—nonfunctionality represents only a point-in-time snapshot and says little about other aspects often incorporated into more holistic notions of sustainability such as accessibility, equity, and the realization of intended benefits. Nor does it

Table 1. Prevalence of Water Point Characteristics and Associated Nonfunctionality Rates

| variables                                                                 |                       | Liberia ( <i>n</i> = 4480) |                  | Sierra Leone ( <i>n</i> = 5448) |                  | Uganda ( <i>n</i> = 15 133) |                  |
|---------------------------------------------------------------------------|-----------------------|----------------------------|------------------|---------------------------------|------------------|-----------------------------|------------------|
|                                                                           |                       | cases (%)                  | NFR <sup>a</sup> | cases (%)                       | NFR <sup>a</sup> | cases (%)                   | NFR <sup>a</sup> |
| system age (years)                                                        | 1                     | 14.7                       | 11.4             | 20.1                            | 11.2             | 14.2                        | 11.3             |
|                                                                           | 2                     | 16.7                       | 13.4             | 18.6                            | 13.1             | 16.2                        | 14.4             |
|                                                                           | 3                     | 17.1                       | 17.6             | 12.8                            | 17.3             | 15.9                        | 15.5             |
|                                                                           | 4                     | 19.1                       | 21.7             | 11.2                            | 21.5             | 12.0                        | 20.3             |
|                                                                           | 5                     | 15.0                       | 22.1             | 9.5                             | 21.7             | 11.4                        | 22.2             |
|                                                                           | 6                     | 13.5                       | 20.6             | 9.1                             | 23.3             | 11.9                        | 24.5             |
|                                                                           | 7                     | 2.9                        | 23.5             | 8.9                             | 26.7             | 9.7                         | 26.8             |
|                                                                           | 8                     | 1.0                        | 36.2             | 9.7                             | 20.6             | 8.7                         | 25.0             |
| well type <sup>b</sup>                                                    | borehole              | 12.9                       | 16.8             | 14.2                            | 15.8             | 54.0                        | 13.9             |
|                                                                           | shallow/hand-dug well | 87.1                       | 18.5             | 85.8                            | 18.2             | 46.0                        | 25.1             |
| handpump type                                                             | Afridev               | 91.0                       | 18.2             | 4.3                             | 16.5             |                             |                  |
|                                                                           | India Mk II           | 5.4                        | 15.6             | 72.0                            | 18.6             |                             |                  |
|                                                                           | Kardia                | 0.6                        | 16.0             | 16.2                            | 13.5             |                             |                  |
|                                                                           | Inkar                 |                            |                  | 3.0                             | 17.8             |                             |                  |
|                                                                           | Other                 | 2.9                        | 25.8             | 4.5                             | 24.3             |                             |                  |
| funding organization                                                      | government            |                            |                  |                                 |                  | 62.1                        | 19.1             |
|                                                                           | local govt.           |                            |                  |                                 |                  | 39.0                        | 22.4             |
|                                                                           | national govt.        |                            |                  |                                 |                  | 23.1                        | 13.6             |
|                                                                           | NGO                   |                            |                  |                                 |                  | 31.5                        | 20.3             |
|                                                                           | other                 |                            |                  |                                 |                  | 5.5                         | 11.7             |
| implementing/installing organization <sup>c</sup>                         | private               |                            |                  |                                 |                  | 0.9                         | 14.7             |
|                                                                           | government            | 2.5                        | 14.2             | 14.4                            | 22.9             |                             |                  |
|                                                                           | NGO                   | 81.4                       | 18.4             | 69.1                            | 16.1             |                             |                  |
|                                                                           | private               | 3.0                        | 13.3             | 2.9                             | 18.1             |                             |                  |
|                                                                           | other                 | 13.1                       | 18.9             | 13.7                            | 21.6             |                             |                  |
| trained committee                                                         | yes                   |                            |                  |                                 |                  | 70.7                        | 17.8             |
|                                                                           | no                    |                            |                  |                                 |                  | 29.3                        | 22.0             |
| regular committee meetings                                                | yes                   |                            |                  |                                 |                  | 41.3                        | 10.6             |
|                                                                           | no                    |                            |                  |                                 |                  | 58.7                        | 25.0             |
| no. of committee members                                                  | 0                     |                            |                  |                                 |                  | 7.0                         | 33.4             |
|                                                                           | 1–3                   |                            |                  |                                 |                  | 1.7                         | 28.2             |
|                                                                           | 4–5                   |                            |                  |                                 |                  | 13.6                        | 24.2             |
|                                                                           | 6–7                   |                            |                  |                                 |                  | 37.5                        | 17.5             |
|                                                                           | 8+                    |                            |                  |                                 |                  | 40.3                        | 15.9             |
| women in key committee positions                                          | yes                   |                            |                  |                                 |                  | 73.3                        | 17.0             |
|                                                                           | no                    |                            |                  |                                 |                  | 26.7                        | 24.7             |
| revenue collection                                                        | yes                   | 78.1                       | 17.1             | 23.3                            | 11.8             | 55.6                        | 11.0             |
|                                                                           | reactive payment      | 49.0                       | 15.7             | 17.8                            | 11.9             |                             |                  |
|                                                                           | advance payment       | 29.1                       | 19.5             | 5.4                             | 11.5             |                             |                  |
|                                                                           | no                    | 21.9                       | 22.2             | 76.7                            | 19.7             | 44.4                        | 29.1             |
| regular servicing                                                         | yes                   |                            |                  |                                 |                  | 47.3                        | 11.1             |
|                                                                           | no                    |                            |                  |                                 |                  | 52.7                        | 26.2             |
| mechanic available                                                        | yes                   |                            |                  | 49.4                            | 13.1             |                             |                  |
|                                                                           | no                    |                            |                  | 50.6                            | 22.6             |                             |                  |
| distance to spare parts                                                   | in community          |                            |                  | 16.7                            | 11.6             |                             |                  |
|                                                                           | <20 miles             |                            |                  | 25.7                            | 16.3             |                             |                  |
|                                                                           | >20 miles             |                            |                  | 57.6                            | 20.4             |                             |                  |
| perceived water quality                                                   | good                  | 83.1                       | 14.7             | 85.9                            | 14.2             |                             |                  |
|                                                                           | poor                  | 16.0 <sup>d</sup>          | 32.6             | 10.5 <sup>e</sup>               | 32.1             |                             |                  |
| rainfall season                                                           | dry                   | 76.0                       | 19.9             |                                 |                  | 78.4                        | 18.0             |
|                                                                           | wet                   | 24.0                       | 12.9             |                                 |                  | 21.6                        | 22.7             |
| distance from administrative capital of county/district (km) <sup>f</sup> | 0–10                  | 18.3                       | 14.8             | 22.4                            | 12.9             | 20.7                        | 16.9             |
|                                                                           | 10–20                 | 18.5                       | 17.4             | 18.4                            | 17.2             | 32.1                        | 18.0             |
|                                                                           | 20–30                 | 22.8                       | 14.8             | 18.1                            | 20.8             | 23.5                        | 18.1             |
|                                                                           | 30–40                 | 12.5                       | 17.0             | 17.3                            | 20.3             | 11.1                        | 21.5             |
|                                                                           | 40+                   | 27.8                       | 24.5             | 23.8                            | 19.1             | 12.2                        | 25.2             |
| district/county handpump density                                          | 0–0.2                 | 66.0                       | 18.8             | 62.2                            | 17.8             | 19.0                        | 19.5             |
|                                                                           | 0.2–0.4               | 19.5                       | 19.7             | 33.7                            | 18.8             | 43.0                        | 19.0             |
|                                                                           | 0.4+                  | 14.5                       | 13.6             | 4.2                             | 12.3             | 38.0                        | 18.9             |

Table 1. continued

| variables | Liberia ( <i>n</i> = 4480) |                  | Sierra Leone ( <i>n</i> = 5448) |                  | Uganda ( <i>n</i> = 15 133) |                  |
|-----------|----------------------------|------------------|---------------------------------|------------------|-----------------------------|------------------|
|           | cases (%)                  | NFR <sup>a</sup> | cases (%)                       | NFR <sup>a</sup> | cases (%)                   | NFR <sup>a</sup> |
| total     | 100.0                      | 18.2             | 100.0                           | 17.9             | 100.0                       | 19.1             |

<sup>a</sup>NFR = nonfunctionality rate. <sup>b</sup>In Uganda, well types were differentiated by depth—shallow wells are less than 30 m deep, and boreholes are greater than 30 m deep. In Liberia and Sierra Leone, well types were differentiated by whether or not they were hand-dug. <sup>c</sup>Variable relates to implementing organization in Sierra Leone and installing organization in Liberia. <sup>d</sup>0.9% of water points had unknown quality. <sup>e</sup>3.6% of water points had unknown quality. <sup>f</sup>0.4% of water points in Uganda did not have reliable GPS coordinates.

Table 2. Unadjusted and Multivariable Logistic Regression Models for Nonfunctional Handpumps in Liberia

| explanatory variables                  | unadjusted               |                             | multivariable adjusted   |                             |
|----------------------------------------|--------------------------|-----------------------------|--------------------------|-----------------------------|
|                                        | OR (95% CI) <sup>a</sup> | <i>P</i> value <sup>a</sup> | OR (95% CI) <sup>a</sup> | <i>P</i> value <sup>a</sup> |
| age (years)                            | 1.17 (1.12–1.22)         | <i>p</i> < 0.001            | 1.17 (1.11–1.22)         | <i>p</i> < 0.001            |
| well type                              |                          |                             |                          |                             |
| hand-dug well                          | 1                        |                             | 1                        |                             |
| borehole                               | 0.89 (0.71–1.12)         | 0.332                       | 0.90 (0.71–1.15)         | 0.413                       |
| pump type                              |                          |                             |                          |                             |
| Afridev                                | 1                        |                             | 1                        |                             |
| India Mk II                            | 0.83 (0.58–1.19)         | 0.307                       | 0.98 (0.68–1.44)         | 0.937                       |
| Kardia                                 | 0.86 (0.29–2.51)         | 0.780                       | 1.01 (0.34–3.04)         | 0.979                       |
| other                                  | 1.56 (1.05–2.33)         | 0.028                       | 1.43 (0.94–2.19)         | 0.099                       |
| installing organization                |                          |                             |                          |                             |
| government                             | 1                        |                             | 1                        |                             |
| NGO                                    | 1.37 (0.80–2.34)         | 0.249                       | 1.54 (0.86–2.76)         | 0.148                       |
| private                                | 0.93 (0.45–1.93)         | 0.851                       | 1.10 (0.50–2.39)         | 0.820                       |
| other                                  | 1.42 (0.80–2.50)         | 0.229                       | 1.69 (0.91–3.14)         | 0.094                       |
| revenue collection                     |                          |                             |                          |                             |
| yes, reactive payment                  | 1                        |                             | 1                        |                             |
| yes, advance payment                   | 1.30 (1.09–1.56)         | 0.004                       | 1.16 (0.95–1.41)         | 0.141                       |
| no                                     | 1.53 (1.26–1.85)         | <i>p</i> < 0.001            | 1.48 (1.20–1.81)         | <i>p</i> < 0.001            |
| perceived water quality                |                          |                             |                          |                             |
| good                                   | 1                        |                             | 1                        |                             |
| poor                                   | 2.82 (2.35–3.38)         | <i>p</i> < 0.001            | 2.85 (2.36–3.44)         | <i>p</i> < 0.001            |
| rainfall season—settlement type        |                          |                             |                          |                             |
| dry—rural                              | 1                        |                             | 1                        |                             |
| wet—urban                              | 0.59 (0.49–0.72)         | <i>p</i> < 0.001            | 0.70 (0.55–0.88)         | 0.003                       |
| distance to county capital (10 km)     | 1.11 (1.08–1.14)         | <i>p</i> < 0.001            | 1.08 (1.05–1.12)         | <i>p</i> < 0.001            |
| handpump density (hp/km <sup>2</sup> ) | 0.74 (0.57–0.95)         | 0.017                       | 0.94 (0.69–1.28)         | 0.681                       |

<sup>a</sup>Bold text indicates statistically significant association (*p* < 0.05).

necessarily equate to a service level that local users or policy makers may deem satisfactory. However, it is an indicator that is relatively straightforward to verify and was captured by all three data collection efforts that underpin this study.

Descriptive and logistic regression analyses were performed to identify associations between a range of explanatory variables and handpump functionality. Descriptive analysis was first conducted to ascertain the relative prevalence of different characteristics, along with the associated nonfunctionality rates. Logistic regression analyses were then performed on the data using STATA version 11.1.<sup>30</sup> This statistical method was employed as it allows for the ascertainment of a relationship between a dichotomous outcome variable and a predictor variable (which could be either categorical or continuous), while controlling for all other independent variables included in the model. This affords the advantage of being able to calculate adjusted odds ratios which account for the effect of confounding covariates. For reasons outlined elsewhere,<sup>31,32</sup> a full model with all independent variables was preferred over a stepwise model selection. The analysis was designed to reveal

those explanatory variables that are significant and those that are not, rather than to find the “best” model for predictive purposes. Explanatory variables were tested for multicollinearity by calculating variance inflation factors.

Explanatory variables were selected based on their relevance to the sustainability factors hypothesized in the literature (see Table S3 in Supporting Information). Variables were both continuous and categorical and cut across operational, technical, institutional, financial, and environmental domains. Numerous variables were constructed, either by collapsing variables into broader categories (e.g., implementing organization, collection of user fees, perceived water quality) or calculating new variables (e.g., rainfall season, handpump density, distance to district/county capital) through linkage with precipitation, geolocation, and land mass data.

## RESULTS

**Descriptive Analysis.** Results of the descriptive analysis are presented in Table 1. Overall, handpumps which were

Table 3. Unadjusted and Multivariable Logistic Regression Models for Nonfunctional Handpumps in Sierra Leone

| explanatory variables                  | unadjusted               |                      | multivariable adjusted   |                      |
|----------------------------------------|--------------------------|----------------------|--------------------------|----------------------|
|                                        | OR (95% CI) <sup>a</sup> | P value <sup>a</sup> | OR (95% CI) <sup>a</sup> | P value <sup>a</sup> |
| system age (years)                     | 1.14 (1.11–1.17)         | <i>p</i> < 0.001     | 1.16 (1.12–1.20)         | <i>p</i> < 0.001     |
| well type                              |                          |                      |                          |                      |
| hand-dug well                          | 1                        |                      | 1                        |                      |
| borehole                               | 0.84 (0.68–1.03)         | 0.095                | 0.72 (0.57–0.92)         | 0.009                |
| pump type                              |                          |                      |                          |                      |
| India Mk II                            | 1                        |                      | 1                        |                      |
| Afridev                                | 0.87 (0.61–1.23)         | 0.429                | 1.08 (0.72–1.64)         | 0.701                |
| Kardia                                 | <b>0.68 (0.55–0.84)</b>  | <i>p</i> < 0.001     | <b>0.69 (0.54–0.88)</b>  | <b>0.002</b>         |
| Inkar                                  | 0.95 (0.63–1.43)         | 0.799                | 0.92 (0.59–1.45)         | 0.733                |
| other                                  | <b>1.40 (1.04–1.90)</b>  | <b>0.028</b>         | <b>1.53 (1.10–2.14)</b>  | <b>0.012</b>         |
| implementing organization              |                          |                      |                          |                      |
| government                             | 1                        |                      | 1                        |                      |
| NGO                                    | <b>0.65 (0.54–0.78)</b>  | <i>p</i> < 0.001     | <b>0.73 (0.59–0.90)</b>  | <b>0.003</b>         |
| private                                | 0.75 (0.48–1.15)         | 0.187                | 0.82 (0.50–1.34)         | 0.431                |
| other                                  | 0.93 (0.73–1.18)         | 0.557                | 1.03 (0.79–1.34)         | 0.846                |
| revenue collection                     |                          |                      |                          |                      |
| yes, reactive payment                  | 1                        |                      | 1                        |                      |
| yes, advance payment                   | 0.96 (0.64–1.44)         | 0.835                | 1.15 (0.76–1.75)         | 0.513                |
| none                                   | <b>1.81 (1.47–2.23)</b>  | <i>p</i> < 0.001     | <b>1.62 (1.30–2.02)</b>  | <i>p</i> < 0.001     |
| distance to spare parts                |                          |                      |                          |                      |
| in community                           | 1                        |                      | 1                        |                      |
| <20 miles                              | <b>1.48 (1.16–1.90)</b>  | <b>0.002</b>         | 1.26 (0.96–1.65)         | 0.100                |
| >20 miles                              | <b>1.95 (1.56–2.43)</b>  | <i>p</i> < 0.001     | <b>1.45 (1.13–1.86)</b>  | <b>0.004</b>         |
| availability of mechanic               |                          |                      |                          |                      |
| yes                                    | 1                        |                      | 1                        |                      |
| no                                     | <b>1.93 (1.67–2.23)</b>  | <i>p</i> < 0.001     | <b>1.55 (1.32–1.83)</b>  | <i>p</i> < 0.001     |
| perceived water quality                |                          |                      |                          |                      |
| good                                   | 1                        |                      | 1                        |                      |
| poor                                   | <b>2.86 (2.35–3.47)</b>  | <i>p</i> < 0.001     | <b>2.54 (2.08–3.11)</b>  | <i>p</i> < 0.001     |
| distance to district capital (10 km)   | <b>1.09 (1.05–1.13)</b>  | <i>p</i> < 0.001     | <b>1.11 (1.06–1.15)</b>  | <i>p</i> < 0.001     |
| handpump density (hp/km <sup>2</sup> ) | <b>0.53 (0.30–0.94)</b>  | <b>0.030</b>         | 1.21 (0.64–2.30)         | 0.561                |

<sup>a</sup>Bold text indicates statistically significant association (*p* < 0.05).

nonfunctional accounted for 18.2% of the subsample in Liberia, 17.9% in Sierra Leone, and 19.1% in Uganda.

For all three countries, nonfunctionality rates were higher for shallow wells than boreholes. India Mark II handpumps performed better than Afridev handpumps in Liberia, but the converse was true in Sierra Leone. Those handpump types that were small in number performed poorest. In all countries, nonfunctionality rates rose as the number of years since installation increased, though this trend was less marked beyond five years. Results by funding or implementing agency varied. In Liberia, a higher proportion of water points were nonfunctional when installed by NGOs as compared to government. The opposite was observed in Sierra Leone. In Uganda, water points funded by NGOs or local government performed poorly compared to those financed by the national government.

In Uganda, a greater proportion of handpumps was in working order when managed by a water committee that was trained, held regular meetings, had six or more committee members, and had women in key positions.

Across all countries, rates of breakdown were considerably higher where there were no revenue collection arrangements in place. In Sierra Leone, those communities that collected money from users in advance enjoyed higher levels of handpump functionality than those that did so only after breakdown. In contrast, a lower percentage of handpumps were inoperable in

Liberia when a reactive payment system was in place when compared to regular payments in advance.

In Uganda, a lower nonfunctionality rate was evident where regular servicing was carried out. Likewise, handpumps in Sierra Leone were more likely to be working the closer to the community that spare parts were stored or sold, and where a community had access to a trained handpump mechanic (either within or external to the community).

Liberia and Uganda presented conflicting trends by rainfall season—in Liberia, the rate of breakdown was lower for those handpumps inspected during the wet season, while in Uganda performance was better among those handpumps checked during the dry season. Those water points that provided water perceived to be of poor quality exhibited dramatically higher nonfunctionality rates in both Liberia and Sierra Leone.

In all three countries, failure rates were greater the further that water points were located from a district or county capital. In Sierra Leone and Liberia, water points located in administrative units with a high handpump density (>0.4 handpumps per km<sup>2</sup>) exhibited higher functionality rates than those in areas of low handpump density. Conversely, functionality rates in Uganda varied little by localized handpump density.

**Logistic Regression Analysis.** Table 2 presents the logistic regression model for Liberia. The adjusted odds of a handpump being nonfunctional were significantly higher when

Table 4. Unadjusted and Multivariable Logistic Regression Models for Nonfunctional Handpumps in Uganda

| explanatory variables                  | unadjusted               |                      | multivariable adjusted   |                      |
|----------------------------------------|--------------------------|----------------------|--------------------------|----------------------|
|                                        | OR (95% CI) <sup>a</sup> | P value <sup>a</sup> | OR (95% CI) <sup>a</sup> | P value <sup>a</sup> |
| system age (years)                     | 1.16 (1.14–1.18)         | <i>p</i> < 0.001     | 1.14 (1.12–1.16)         | <i>p</i> < 0.001     |
| well type                              |                          |                      |                          |                      |
| shallow well                           | 1                        |                      | 1                        |                      |
| deep borehole                          | 0.48 (0.44–0.52)         | <i>p</i> < 0.001     | 0.68 (0.62–0.74)         | <i>p</i> < 0.001     |
| source of funding                      |                          |                      |                          |                      |
| national government                    | 1                        |                      | 1                        |                      |
| local government                       | 1.83 (1.64–2.06)         | <i>p</i> < 0.001     | 1.39 (1.23–1.58)         | <i>p</i> < 0.001     |
| NGO                                    | 1.62 (1.44–1.82)         | <i>p</i> < 0.001     | 1.37 (1.21–1.56)         | <i>p</i> < 0.001     |
| private                                | 1.10 (0.67–1.80)         | 0.714                | 1.09 (0.65–1.83)         | 0.740                |
| other                                  | 0.84 (0.67–1.06)         | 0.150                | 0.79 (0.62–1.00)         | 0.052                |
| regular committee meetings             |                          |                      |                          |                      |
| yes                                    | 1                        |                      | 1                        |                      |
| no                                     | 2.80 (2.55–3.08)         | <i>p</i> < 0.001     | 1.32 (1.17–1.49)         | <i>p</i> < 0.001     |
| trained committee                      |                          |                      |                          |                      |
| yes                                    | 1                        |                      | 1                        |                      |
| no                                     | 1.30 (1.19–1.42)         | <i>p</i> < 0.001     | 1.07 (0.98–1.17)         | 0.149                |
| no. of committee members               | 0.90 (0.89–0.91)         | <i>p</i> < 0.001     | 0.98 (0.96–1.00)         | 0.065                |
| female in key committee position       |                          |                      |                          |                      |
| yes                                    | 1                        |                      | 1                        |                      |
| no                                     | 1.61 (1.47–1.75)         | <i>p</i> < 0.001     | 1.16 (1.05–1.29)         | 0.004                |
| revenue collection                     |                          |                      |                          |                      |
| yes                                    | 1                        |                      | 1                        |                      |
| no                                     | 3.31 (3.03–3.60)         | <i>p</i> < 0.001     | 1.91 (1.70–2.14)         | <i>p</i> < 0.001     |
| regular servicing                      |                          |                      |                          |                      |
| yes                                    | 1                        |                      | 1                        |                      |
| no                                     | 2.85 (2.61–3.12)         | <i>p</i> < 0.001     | 1.58 (1.40–1.78)         | <i>p</i> < 0.001     |
| rainfall season                        |                          |                      |                          |                      |
| dry                                    | 1                        |                      | 1                        |                      |
| wet                                    | 1.34 (1.22–1.47)         | <i>p</i> < 0.001     | 1.15 (1.04–1.27)         | 0.007                |
| distance to district capital (10 km)   | 1.12 (1.09–1.15)         | <i>p</i> < 0.001     | 1.14 (1.10–1.17)         | <i>p</i> < 0.001     |
| handpump density (hp/km <sup>2</sup> ) | 0.99 (0.82–1.20)         | 0.920                | 1.20 (0.97–1.49)         | 0.095                |

<sup>a</sup>Bold text indicates statistically significant association (*p* < 0.05).

(a) there was no revenue collected from users, (b) water quality was perceived to be poor, and (c) the handpump was mapped during the dry season in rural areas. The adjusted odds of a nonfunctional handpump increased by 17% with each additional year since the handpump was installed, and by 8% with each additional 10 km the handpump was situated from the county capital. There was no significant difference between adjusted odds for India Mark II and Afridev handpumps, nor for boreholes versus hand-dug wells. Neither handpump density nor installing organization demonstrated a significant association with nonfunctionality status in the multivariable adjusted model.

Results of the logistic regression analyses for Sierra Leone are presented in Table 3. After adjustment, the odds of a handpump being nonfunctional were significantly higher when (a) handpumps were installed on hand-dug wells rather than boreholes, (b) the handpump type was uncommon, (c) implementation was conducted by government rather than an NGO, (d) there was no revenue collected from users, (e) spare parts were located more than 20 miles from the handpump, (f) a readily available mechanic was lacking, and (g) water quality was considered poor. The adjusted odds of a nonfunctional handpump increased by 16% with each additional year since the handpump was installed, and by 11% with each additional 10 km the handpump was situated from the district capital. There was no significant difference between adjusted odds for India

Mark II and Afridev handpumps, nor did handpump density have any significant association with nonfunctionality status in the multivariable adjusted model.

Table 4 presents the logistic regression model for Uganda. The adjusted odds of a handpump being nonfunctional were significantly higher when (a) handpumps were installed on shallow wells rather than deep boreholes, (b) installation was funded by local government or an NGO rather than by the national government, (c) there was no revenue collected from users, (d) regular servicing was not carried out, (e) there was no female holding down a key water committee position, and (f) the handpump was inspected in the wet season. The adjusted odds of a nonfunctional handpump increased by 14% with each additional year since the handpump was installed, and by 14% with each additional 10 km the handpump was situated from the district capital. Handpump density did not exhibit any association with functionality in the multivariable adjusted model. Neither the number of water committee members nor the provision of training exhibited a statistically significant association with functionality status in the multivariable adjusted model.

## DISCUSSION

The results provide empirical reinforcement for a number of widely espoused views and observations within the literature. The finding that collection of user fees is a key determinant of

handpump functionality accords with numerous assertions that cost recovery is a prerequisite for effective O&M of rural water supplies.<sup>1,20,33,34</sup> The evidence that women in key water committee positions and spare parts proximity are significant predictors of handpump functionality in Uganda and Sierra Leone, respectively, concur with verdicts from earlier quantitative assessments which incorporated a mix of water supply technologies and geographical regions.<sup>12,23</sup> Positive user perception of water quality has been hypothesized as a critical determinant of users' demand for handpump O&M services,<sup>33</sup> and the large effect sizes observed in both the Liberian and Sierra Leonean regression models attest to this.

At the same time, some results from the multivariable adjusted models appear to deviate from what might be expected. Contrary to common opinion and previous findings,<sup>24</sup> the training of water committees in Uganda bore no significant adjusted association with handpump functionality. This may indicate that training of water committees is poorly designed and delivered, or that even if done well it provides little benefit as a once-off exercise without periodic follow-up. Likewise, despite it being widely viewed as a key driver of spare part supply chain viability,<sup>35</sup> no positive relationship was evident between district handpump density and functionality in the multivariable adjusted models. The associations denoted by the unadjusted odds ratios in Liberia and Sierra Leone were evidently due to confounding factors.

There are, however, plausible explanations for these seemingly counterintuitive results. First, the dichotomous indicator in the Uganda analysis that tells whether or not a committee was trained says nothing about the content, quality, or timing of the training. In contrast, when Whittington et al.<sup>24</sup> found technical training to be a significant predictor of handpump functionality, the sampling frame involved specific targeting of "well-designed demand driven" rural water supply programs. Moreover, the training was targeted at handpump caretakers rather than water committees. Second, the effect of handpump density on spare part supply chain viability may be more important on national or subregional scales than the spatial units opted for in the regression analyses.

Functionality status in Uganda and Liberia exhibited significant relationships with rainfall season, albeit in opposing directions. This may reflect the inconsistent ways in which hydrological variability might impact handpump sustainability. Alternative water sources are less readily available in dry periods, hence communities may increase their reliance on a handpump supply and have a greater propensity to ensure repairs are carried out when needed.<sup>36</sup> The observed association between rainfall season and functionality status in Uganda is consistent with this line of thought. Conversely, during dry periods wells and boreholes equipped with handpumps may also become dry due to a drop in groundwater levels, thereby driving up nonfunctionality rates temporarily. This may explain the relationship between rainfall season and functionality status in Liberia. The association between wet season and functionality in Liberia may also be related to the sequencing of data collection activities. Handpumps inspected in the wet season were situated in urban areas, while those checked during the dry season were in rural areas. Thus, the urban locality could also underlie the observed relationship.

Though an association between revenue collection and functionality was not unexpected, the analysis generates novel insights with respect to payment modality. The multivariable analysis for both Liberia and Sierra Leone failed to reveal any

significant difference in the odds of nonfunctionality between those handpumps accompanied by regular, advance payment arrangements and those which had funds collected only upon breakdown. This runs counter to conventional wisdom that communities are best able to promptly arrange for water point repairs when money is saved and stored in advance of a problem taking place. There are a number of possible explanations why funds collected in advance and stored over time may be insufficient to pay for repairs when the need arises. The first relates to the fact that tariffs for regular payment are rarely, if ever, set according to a handpump's real life-cycle cost.<sup>33,34</sup> Added to this is the unpredictable nature of handpump repairs. Even if a tariff reflects the average life-cycle cost, there will often be a shortfall in the amount collected by virtue of the variability of repair costs. Additionally, it is not uncommon for a proportion of users to avoid paying the prescribed fees levied by a water committee.<sup>34</sup> The well-documented cash storage and savings challenges that water committees face, and the accountability and transparency concerns arising therefrom, may play a further contributing role. These interpretations are coupled with the important proviso that the categorical classifications used in the analysis represent a simplification of what is often a complex revenue collection process involving hybrid and dynamic strategies.

The finding that the adjusted odds of a nonfunctional handpump were higher for shallow/hand-dug wells than for boreholes in Uganda and Sierra Leone both aligns and conflicts with rural water literature. On the one hand, experience shows that the deeper the well, the more frequently the handpump breaks down.<sup>37</sup> On the flipside, deeper boreholes are often located where alternative water sources are scarce. Moreover, when handpumps fail on hand-dug wells, communities are often able to make do with a rope and bucket, a coping strategy not possible with boreholes. Hence while the mean time between failures might be lower for boreholes than shallow wells, the downtime may be shorter due to the imperative to have the handpump repaired promptly. In the cases of Uganda and Sierra Leone, it would seem the latter consideration outweighs the former. This adds weight to the contention that it is not the frequency of breakdown that matters but rather the systems and incentives in place to ensure repairs are promptly undertaken when needed. It is unclear, however, why the same relationship does not hold in Liberia.

It is noteworthy that the adjusted odds for the two major handpump types—the India Mark II and Afridev—did not differ significantly in either Sierra Leone or Liberia. This seems incongruous with the expectation that the Afridev—long considered a classic Village Level Operation and Maintenance (VLOM) handpump<sup>38</sup>—should outperform the India Mark II, which requires more specialist tools and skills to keep in working order. One might argue that although an India Mark II is more difficult to repair than an Afridev, this is offset by its tendency to be located where groundwater is deeper and thus where users have a greater dependence on the handpump. However, there is no significant difference in odds between the two handpump types even when the regression analyses adjust for well type and rainfall season. This supports the notion that handpump repair work is more often obstructed by institutional, social, or financial factors than the degree of technical difficulty.

The analysis provides some backing for handpump standardization policies that are commonly applied by governments in sub-Saharan Africa. In particular, the evidence that the 4.5%

of handpumps categorized as “uncommon” were significantly associated with nonfunctionality in Sierra Leone is supportive of efforts to minimize the number of different handpump types that can be installed within a country. However, this conclusion must be tempered with the observation from Liberia that the performance of the Afridev was not significantly different from other handpump types, despite commanding a market share of 91% within the analyzed subsample.

The results provide strong evidence of negative associations between handpump functionality and both system age and remoteness. Notably, Whittington et al.<sup>24</sup> found neither of these explanatory variables to be associated with handpump functionality status. These inconsistencies could be explained by differences in the sampling frame and methodology adopted—handpumps included in that study fell within a limited age range of four to eight years, while remoteness was measured according to distance to the nearest pump mechanic. System age and distance from a major city also failed to emerge as significant determinants of sustainability in the analysis conducted by Sara and Katz;<sup>12</sup> however direct comparison is difficult given that their data did not specifically focus on handpump supplies.

There could be several reasons for the observed association between handpump functionality status and distance from district/county capital observed in this study. The first is that communities in more remote locations may find the O&M responsibilities required under a CBM arrangement more onerous as the average socio-economic status and educational attainment of community members may be lower. Second, if and where a form of postconstruction support is offered by an external agency, a community located further away from the administrative capital may be less likely to receive such services. Third, the more remote a community, the less viable a spare part supply chain is likely to be. The counterweight to this final point is that distance was still a significant predictor in Sierra Leone when controlling for local availability of spare parts. Whatever the underlying reasons, the consistency of the results across the three countries casts doubt on whether community-managed handpumps are the most suitable water supply solution for remote and isolated communities. Where ground-water levels allow, self-supply strategies that promote low-cost protection of family wells may be more appropriate in such contexts.

Notwithstanding the rural water subsector’s shifting mindset toward service delivery, project implementation is still an important consideration. This is underscored by the significantly different adjusted odds for various implementing and funding agencies in Sierra Leone and Uganda, respectively. The poorer performance of government-implemented handpumps in Sierra Leone may reflect the capacity constraints one might expect in a fragile state. In Uganda, results point to limited capacity at a local government level. Unfortunately, it is not possible to discern how the link between implementing or funding organization and sustainability is mediated, whether via hardware (e.g., quality of design and construction) or software elements (e.g., user participation).

While many of the relationships between explanatory variables and nonfunctionality are in line with conventional wisdom, the relative prevalence of some of these factors is cause for concern. Few would argue against the need for user fee collection, access to a skilled pump mechanic who can conduct repairs, or women to assume key positions on a water committee. Yet across all three subsamples, only 52.6% of

handpumps were coupled with any form of revenue collection. Around half of community-managed handpumps in Sierra Leone lacked a skilled mechanic that could be called upon, and in Uganda more than a quarter of water committees were exclusively managed by men. To be sure, when building blocks are in place, handpump functionality rates appear reasonably high. In the Ugandan sample, where committees have regular meetings, have been trained, have women in key positions, collect revenue and ensure there is regular servicing, handpumps exhibit a functionality rate of 91.7%. Likewise for Sierra Leone—98.0% of handpumps are in working order where there is regular revenue collection, spare parts are kept in the community, and a trained mechanic is available. The problem remains that such a confluence of factors is the exception rather than the norm. In the case of Uganda, only 19.8% of the analyzed sample matched the above criteria. For Sierra Leone, just 0.9% of handpumps enjoyed the prescribed conditions. The critical question then is not whether CBM works effectively when prerequisites for success exist but rather why so few community-managed handpumps possess those criteria.

There is a compelling case to improve the way O&M activities are supported. The relationship evident between system age and functionality status in all three regression models underlines the long-term nature of the supportive measures needed. Collection and storage of funds from users, active committees with genuine female representation, networks of skilled pump mechanics, and the viability of spare part supply chains are all elements which should be sustained indefinitely.

The extent to which greater external support for CBM will improve handpump performance at scale across sub-Saharan Africa remains to be seen. In light of this uncertainty, concurrent assessment of alternative management models might also be prudent. Supra-community management models involving private sector actors, such as water assurance and leasing schemes, have been proposed for handpump supplies for the best part of a decade.<sup>1,18,19,39</sup> Unfortunately, few concrete examples have been documented; thus their potential remains unclear. Bolder efforts are needed to test these service delivery models and examine whether or not they are more likely to lead to the long-term upkeep of handpump supplies. Further analysis of the data generated by water point mapping activities across sub-Saharan Africa could also play an important role in addressing this knowledge gap.

The results and interpretations are subject to a number of caveats. First, as a result of the study’s cross-sectional design, no causal relationships can be conclusively demonstrated between the predictor variables and the outcome variable. Second, as acknowledged earlier, the outcome variable is a narrow proxy measure for sustainability, a concept which often entails considerations of equity, realization of benefits, and multi-dimensional measures of acceptable service levels. A further limitation to the dichotomous outcome variable used is that it sheds no light on how long a handpump has been nonfunctional. It is plausible that different factors underlie “terminally” nonfunctional handpumps that have remained idle for months or years, as opposed to those which are temporarily inoperable for only a brief period.

Finally, the variables included in the analysis do not constitute an exhaustive list of all the possible factors that might influence handpump sustainability. Community-level and system-specific issues not explicitly controlled for in the

multivariable adjusted model include perceived benefits of the handpump supplies,<sup>1,23</sup> the transparency of financial management,<sup>33</sup> the nature of postconstruction support provided to a community,<sup>24,40</sup> the presence of a dynamic leader,<sup>21</sup> the existence of alternative water sources (whether improved or unimproved),<sup>24</sup> the number of users,<sup>24,37</sup> the degree of ethnic homogeneity,<sup>24</sup> construction quality,<sup>12</sup> and the level of user participation during implementation.<sup>12,13</sup> Other conditions associated with sustainable management of common-pool resources may also be relevant, including the existence of shared norms, poverty levels, user group location relative to resource location, rules of access and use, and the ease of enforcing such rules.<sup>41–44</sup> Similarly, hydrogeological characteristics that might affect handpump sustainability were unable to be factored into the regression models. The analyses were also unable to directly assess the role of broader enabling environments at either national or district levels.

Despite over 30 years of effort and investment, sustainable community-based management of rural water supplies remains an elusive goal in sub-Saharan Africa. Over the coming years and decades, handpumps which lift groundwater for drinking and productive uses will continue to be a key strategy for expanding improved water supply access to the 275 million rural sub-Saharan Africans currently without.<sup>45</sup> Unless handpump O&M can be improved, these investments will result in suboptimal human development outcomes. Governments and development partners need to rework and refine their rural water strategies to ensure effective O&M systems are established at the outset and sustained indefinitely. This includes a frank assessment of whether or not conditions for successful CBM are likely to be met.

## ■ ASSOCIATED CONTENT

### ● Supporting Information

Figures S1–S3 and Tables S1–S3. This information is available free of charge via the Internet at <http://pubs.acs.org/>

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### Notes

The authors declare no competing financial interest.

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## **Supporting Information**

Predictors of sustainability for community-managed handpumps in  
sub-Saharan Africa: Evidence from Liberia, Sierra Leone and Uganda

Tim Foster

**Pages:** 5 (including cover page)

**Tables** S1-S3

**Figures** S1-S3

**Table S1. Factors influencing rural water supply sustainability in sub-Saharan Africa<sup>a</sup>**

| Domain                    | Influencing factors                                                                                                                                               |
|---------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Operational & technical   | Design and construction quality; preventive maintenance; handpump technology; access to spare parts, tools and equipment                                          |
| Social & community        | Willingness to pay; number of users; participation of women; training & capacity building; social cohesion; active water committee; dynamic or charismatic leader |
| Institutional & policy    | Post-construction support; regulation; technology standardization; sector coordination; enabling environment                                                      |
| Environmental             | Water quality; availability of alternative sources; groundwater reliability                                                                                       |
| Financing & cost recovery | Revenue collection to cover recurrent costs and capital replacement costs; mechanisms for saving and storing funds                                                |

<sup>a</sup>Adapted from Harvey and Reed,<sup>1</sup> Parry-Jones et al.,<sup>2</sup> Lockwood et al.<sup>3</sup>

**Table S2. Economic, demographic, hydrogeological and water supply conditions in study countries (2010-2012)<sup>4-8</sup>**

|                                                  | Liberia     | Sierra Leone  | Uganda          |
|--------------------------------------------------|-------------|---------------|-----------------|
| GDP per capita PPP (2011 international \$)       | 585.3       | 871.0         | 1344.9          |
| Total rural population (million)                 | 2.1         | 3.6           | 29.1            |
| Total handpumps                                  | 9,388       | 12,003        | 42,151          |
| Non-functional handpumps (%)                     | 25.5%       | 18.7%         | 25.2%           |
| Handpump density (per km <sup>2</sup> )          | 0.10        | 0.17          | 0.23            |
| Dominant handpump type                           | Afridev     | India Mk II   | India Mk II/III |
| % rural population using improved water source   | 66.1        | 48.2          | 67.1            |
| % rural population using protected well/borehole | 64.8        | 38.0          | 38.2            |
| Estimated groundwater storage (km <sup>3</sup> ) | 86 [25-333] | 327 [160-850] | 339 [73-1270]   |
| No. of administrative units                      | 15          | 14            | 79 <sup>a</sup> |
| Ave. number of handpumps per administrative unit | 626         | 857           | 534             |

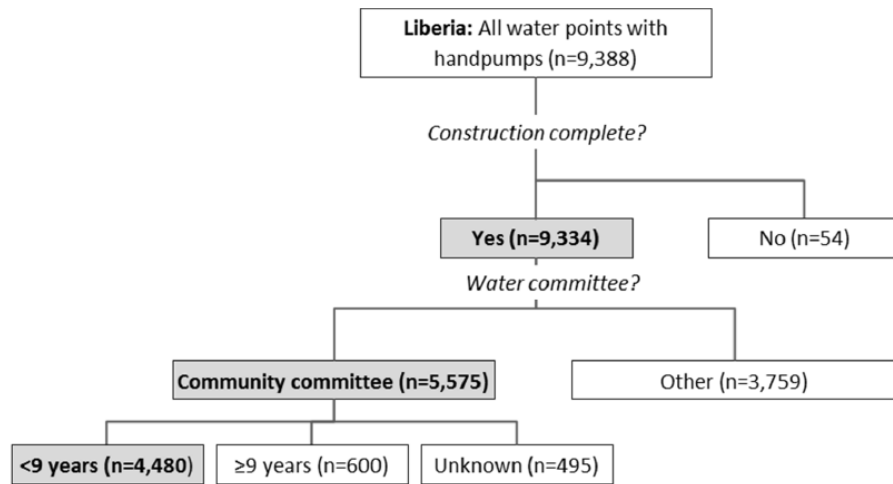
<sup>a</sup>Some administrative units have been sub-divided since the time of data collection

**Table S3. Explanatory variables included in analysis**

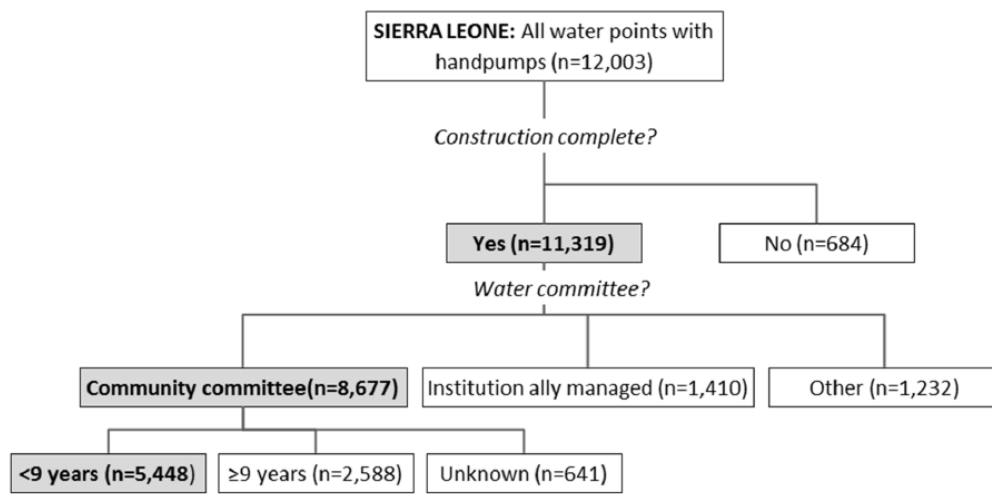
| Variable                                          | Liberia                                                                      | Sierra Leone                                                                 | Uganda                                                                                                                              |
|---------------------------------------------------|------------------------------------------------------------------------------|------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------|
| System age                                        | Years between installation and data collection                               | Years between installation and data collection                               | Years between installation and data collection                                                                                      |
| Well Type                                         | Borehole<br>Hand-dug well                                                    | Borehole<br>Hand-dug well                                                    | Deep Borehole (depth >30 metres)<br>Shallow well (depth <30 metres)                                                                 |
| Handpump type                                     | Afridev<br>India Mk II<br>Kardia<br>Other                                    | India Mk II<br>Afridev<br>Kardia<br>Inkar<br>Other                           |                                                                                                                                     |
| Funding organisation                              |                                                                              |                                                                              | National Government <sup>a</sup><br>Local Government <sup>a</sup><br>NGO <sup>b</sup><br>Private <sup>c</sup><br>Other <sup>d</sup> |
| Implementing/installing organisation <sup>e</sup> | Government<br>NGO <sup>b</sup><br>Private <sup>c</sup><br>Other <sup>d</sup> | Government<br>NGO <sup>b</sup><br>Private <sup>c</sup><br>Other <sup>d</sup> |                                                                                                                                     |
| Committee has been trained                        |                                                                              |                                                                              | Yes<br>No                                                                                                                           |

|                                                         |                                                                               |                                                                                 |                                                                                 |
|---------------------------------------------------------|-------------------------------------------------------------------------------|---------------------------------------------------------------------------------|---------------------------------------------------------------------------------|
| Regular committee meetings                              |                                                                               |                                                                                 | Yes<br>No                                                                       |
| Committee size                                          |                                                                               |                                                                                 | No. of Water User Committee members                                             |
| Women in key committee positions                        |                                                                               |                                                                                 | Yes<br>No                                                                       |
| Revenue collection                                      | Yes - Reactive payment<br>Yes - Advance payment<br>No                         | Yes - Reactive payment<br>Yes - Advance payment<br>No                           | Yes<br>No                                                                       |
| Committee undertakes regular servicing                  |                                                                               |                                                                                 | Yes<br>No                                                                       |
| Distance to spare parts                                 |                                                                               | In community<br><20km<br>>20km                                                  |                                                                                 |
| Availability of trained mechanic                        |                                                                               | Yes<br>No                                                                       |                                                                                 |
| Perceived water quality                                 | Soft, clean, sweet<br>Quality problem                                         | Clean smell, taste & colour<br>Not clean                                        |                                                                                 |
| Rainfall season <sup>f</sup>                            | Dry Season – Rural <sup>g</sup><br>Wet Season – Urban                         |                                                                                 | Dry Season <sup>h</sup><br>Wet Season                                           |
| Distance from administrative capital of county/district | Geodesic distance (in tens of kilometres) between handpump and county capital | Geodesic distance (in tens of kilometres) between handpump and district capital | Geodesic distance (in tens of kilometres) between handpump and district capital |
| District/County handpump density                        | No. of handpumps in county per square kilometre                               | No. of handpumps in district per square kilometre                               | No. of handpumps in district per square kilometre                               |

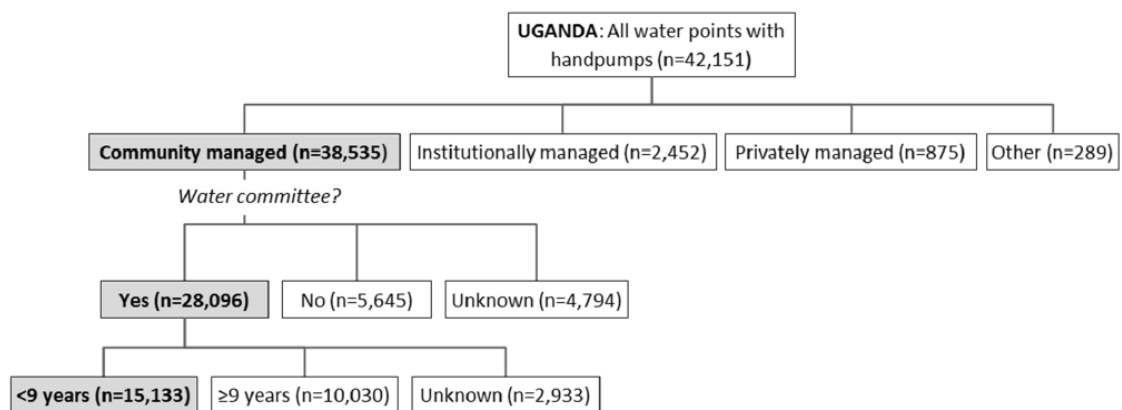
<sup>a</sup>In Uganda, handpumps funded by government may have also included another co-funding organisation. <sup>b</sup>‘NGO’ includes international donors and development agencies, international non-government organisations, local non-government organisations, and faith-based organisations. <sup>c</sup>‘Private’ comprises both private individuals and private companies <sup>d</sup>‘Other’ comprises all those handpumps with an installer or funder that could not be grouped into Government, NGO or Private categories due to inadequate or incomplete information. This includes ‘unknown’, ‘not indicated’ and ‘blank’ responses. <sup>e</sup>Variable relates to implementing organization in Sierra Leone, and installing organization in Liberia. <sup>f</sup>As all data in Sierra Leone was collected during the dry season, rainfall season was not included as a predictor variable. <sup>g</sup>Due to the sequencing of data collection in Liberia, all handpumps in rural areas were mapped during the dry season, while handpumps in urban areas were mapped in the wet season. Thus the categorical variable for rainfall season also includes specification of settlement type. <sup>h</sup>Rainfall season for handpumps in Uganda was determined by ranking monthly rainfalls for each district using historical data (1990-2009) produced by the Climatic Research Unit of University of East Anglia<sup>6</sup>. In each district, the six months with the highest average rainfall were deemed to be the ‘wet season’. Given bimodal rainfall patterns, these six ‘wet season’ months were not necessarily consecutive. The specific rainfall season was then assigned to each handpump based on the district and month of data collection.



**Figure S1.** Sub-sample extracted from the Liberia dataset



**Figure S2.** Sub-sample extracted from the Sierra Leone dataset



**Figure S3.** Sub-sample extracted from the Uganda dataset

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## Chapter 5 – Paper 2

### **A multi-decadal and social-ecological systems analysis of community waterpoint payment behaviours in rural Kenya**

**Tim Foster, Rob Hope**

#### **Abstract**

Community-based financing of rural water supply operation and maintenance is a well-established policy principle in sub-Saharan Africa. Yet our analysis of data from over 90,000 waterpoints in five sub-Saharan African countries suggests a majority of communities fail to establish and sustain a revenue collection system. As a result, insufficient finances to repair waterpoints can lead to lengthy downtimes or abandonment, threatening the health and welfare of millions of water users forced to revert to unsafe or distant alternatives. Applying a social-ecological systems framework to community waterpoints in rural Kenya, we empirically assess the prevalence and determinants of financial contributions among water users. The analysis draws on multi-decadal data integrating 229 years' worth of water committee financial records, a census of 518 community waterpoints, and a survey of 3,233 water users. Results reveal that non-payment and late payment are prevalent, and payment behaviours are predicted by groundwater quality, waterpoint location, group size, and rainfall season. Securing the financial sustainability of waterpoints across heterogeneous and changing environmental and social settings in rural sub-Saharan Africa will be vital if the Sustainable Development Goal of universal access to safe water is to be achieved. Post-construction support and novel service delivery models offer potential pathways to more sustainable outcomes.

**Key words** – rural water supply, social-ecological system, collective action, financial sustainability, groundwater, sub-Saharan Africa

## Introduction

Low levels of water supply sustainability pose a threat to development in rural areas of sub-Saharan Africa. Waterpoints that draw on groundwater – namely wells and boreholes – are the most prevalent and rapidly expanding drinking water supply option across the continent (Banerjee & Morella, 2011), accessed by more than 250 million rural inhabitants. Over the last three decades, community-managed handpumps have been the mainstay techno-institutional approach to rural waterpoint development (Arlosoroff *et al.*, 1987; Harvey & Reed, 2007). Handpumps and community management were seen as ideal bed-fellows: a low-cost and simple technology for lifting groundwater combined with an institutional model premised on the assumption that local users are willing and able to self-organise. However, with an estimated one in three handpumps non-functional at any one time (RWSN, 2009), flaws in this techno-institutional coupling have become apparent. Communities often struggle to carry out operation and maintenance (O&M) responsibilities, and the resultant service disruptions likely force millions of households to revert to unsafe or far-off water sources at any point in time. In an effort to expand safe water supplies to the 270 million rural Africans who still rely on unimproved sources (WHO/UNICEF, 2015), each year governments and development partners spend hundreds of millions of dollars on an estimated 60,000 waterpoints fitted with handpumps (Sansom & Koestler, 2009). Unfortunately, unless there is an improvement in the way O&M is carried out, historical evidence suggests these investments will fail to generate the desired human development outcomes, and safe water access in rural sub-Saharan Africa will continue to lag behind the rest of the world.

One of the foremost collective action challenges of keeping rural waterpoints functional is the financing of O&M activities. Revenue collection from water users has long been considered a cornerstone of community management (Arlosoroff *et al.*, 1987; Briscoe & de Ferranti, 1988), and is widely regarded as critical to sustainability (Carter, Tyrrel, & Howsam, 1999; Harvey, 2007; Foster, 2013). While full cost recovery – including capital costs – is viewed as unrealistic in rural sub-

Saharan Africa (Harvey, 2007), community management proceeds upon the assumption that self-financing of recurrent O&M costs is attainable. Furthermore, it has long been argued that neither governments nor donors can be relied upon to finance O&M costs on a long-term basis (Briscoe & de Ferranti, 1988). As a result, community-based financing of O&M is now formalised in rural water policies across the continent (Banerjee & Morella, 2011; African Development Bank, 2010). However, recently assembled waterpoint datasets suggest this expectation is not being met. Pooling data from 92,594 waterpoints fitted with handpumps across five countries reveals 3 in 5 are not accompanied by any form of revenue collection, and only 1 in 5 water user groups chooses to regularly collect and save funds in advance of a breakdown (Table 1).

Table 1. Prevalence of revenue collection for waterpoints fitted with handpumps in five sub-Saharan African countries

| Country      | Scope                   | No. handpumps | Handpumps with fee collection (%) | Primary revenue collection approach (%) |                                   |
|--------------|-------------------------|---------------|-----------------------------------|-----------------------------------------|-----------------------------------|
|              |                         |               |                                   | Upon breakdown                          | Regularly in advance of breakdown |
| Kenya        | 8 counties <sup>a</sup> | 2,119         | 52.2 <sup>b</sup>                 | 8.1                                     | 44.0                              |
| Liberia      | National                | 9,388         | 46.8 <sup>c</sup>                 | 30.2                                    | 16.6                              |
| Sierra Leone | National                | 12,003        | 20.0 <sup>d</sup>                 | 15.5                                    | 4.5                               |
| Tanzania     | National                | 21,884        | 42.1 <sup>e</sup>                 | 13.2                                    | 28.9                              |
| Uganda       | National                | 47,200        | 42.8                              | -                                       | -                                 |
| <b>Total</b> |                         | <b>92,594</b> | <b>40.4 (37.6<sup>f</sup>)</b>    | <b>17.4<sup>f</sup></b>                 | <b>20.2<sup>f</sup></b>           |

Authors' analysis based on publicly available waterpoint datasets (Virtual Kenya, 2015; National Water Sanitation and Hygiene Promotion Committee, 2014; Sierra Leone, STATWASH Portal 2014; Government of Tanzania, 2014; Government of Uganda, 2012)

<sup>a</sup> Busia, Embu, Isiolo, Kajiado, Kiambu, Kisumu, Kwale, Turkana. <sup>b</sup> Excludes 229 handpumps with unknown revenue collection regime. <sup>c</sup> Excludes 51 handpumps with unknown revenue collection regime. <sup>d</sup> Excludes 682 handpumps which were under construction, and 12 handpumps with unknown revenue collection regime. <sup>e</sup> Excludes 2,899 handpumps with unknown revenue collection regime. <sup>f</sup> Excludes data from Uganda, which do not distinguish between revenue collection approaches.

Even where arrangements are put in place to regularly collect fees, it has been noted that a sizable proportion of waterpoint users fail to meet their payment obligations (Carter, Harvey, & Casey, 2010). However, little effort has been made to quantify the extent of this free-riding problem or empirically evaluate the underlying causes. While national water service regulators regularly publish revenue collection metrics for urban piped schemes in sub-Saharan Africa (EWURA, 2013; NWASCO, 2013; WASREB, 2014), the measurement of financial indicators for rural waterpoint

systems remains a major knowledge gap. Moreover, though there is an established body of literature examining determinants of willingness to pay for hypothetical water services in rural sub-Saharan Africa (World Bank Water Demand Research Team, 1993; Arouna & Dabbert, 2012; Naiga & Penker, 2014), there have been few attempts to evaluate the conditions affecting actual payment behaviours (Hanatani & Fuse, 2012). This is of critical importance given evidence of a divergence between factors which influence a household's willingness to pay and those which determine their actual behaviours (Griffin, *et al.*, 1995).

## **1. Conceptual Framework**

Insights and analytical approaches from collective action and common-pool resource (CPR) literature have the potential to shed more light on why some communities are able to self-finance waterpoint O&M, while others fail. Scholarly interest in collective action and CPR dilemmas emerged more than four decades ago, when Hardin (1968) theorised that commons used collectively would inevitably result in overexploitation, degradation and collapse of the resource. Olson (1965) also postulated dire consequences for large groups entrusted with solving collection action problems. While these seminal works initiated a wave of theoretical and empirical research, their predictions have turned out to be overly pessimistic. This is not to deny that collective management of CPRs can in some instances lead to overuse and destruction, particularly when users are anonymous, do not communicate, and receive no feedback (Basurto & Ostrom, 2009). However, examples of users successfully collaborating and managing resources in a sustainable fashion have been noted across a range of resource types, including fisheries, forests, grazing pastures and water resources (Basurto & Ostrom, 2009).

More recently, CPR scholars have turned their attention to the conditions under which groups successfully self-organise and sustainably manage resources (Ostrom, 1990; Wade, 1994; Baland & Platteau, 1996; Agrawal, 2003). Identification of factors which facilitate or hinder CPR management continues to provoke debate, and disagreement as to the size and direction of

associations endures (Araral, 2009). Given the complexity of collective action and CPR processes, a single and comprehensive explanatory theory has proved elusive. Analysis and interpretation is often complicated by the feedback relationships that cause variables to affect each other recursively (Meinzen-Dick, DiGregorio, & McCarthy, 2004). Moreover, despite a multitude of studies spanning a range of CPR challenges, two key obstacles have thwarted the accumulation and synthesis of insights. First, CPR management inherently involves interaction between human and environmental systems, thereby bringing together disciplines which traditionally adopt discordant languages and methods. Second, variables measured and assessed are often high in number or inconsistent across studies, thereby complicating efforts to compare findings, conduct meta-analyses and formulate global theories (Agrawal, 2003; Ostrom & Cox, 2010).

In order to counter these challenges, Ostrom (2007; 2009) crafted a multilevel social-ecological system (SES) framework as a common diagnostic tool for analysing factors that influence outcomes for complex environmental and human systems. The SES framework is intended to aid cumulative learning by laying out a classificatory system and vocabulary that helps organise analysis and communicate findings (Ostrom & Cox, 2010). Shaped by decades of theoretical and empirical work, the framework is premised upon the logic that SES outcomes can be explained by factors contained within four core sub-systems – resource systems, resource units, governance systems, and users – as well as related ecosystems, and broader social-political-economic settings.

To varying degrees, community waterpoints in rural sub-Saharan Africa possess the hallmarks of a CPR – excluding users can be difficult, and use is rivalrous. Community waterpoints also provide fertile ground for applying Ostrom's SES framework. They lie at the interface between social groups and hydrogeological systems, thus a holistic analysis must traverse both social and natural science disciplines. Yet there has been limited empirical analysis linking CPR theory and rural waterpoint sustainability (Hanatani & Fuse, 2012; Naiga & Penker, 2014). Instead, the vast majority of CPR

works relating to water management have focussed on irrigation systems which supply water for productive rather than domestic purposes (Araral, 2003; Ostrom, 1992; Meinzen-Dick, 2007).

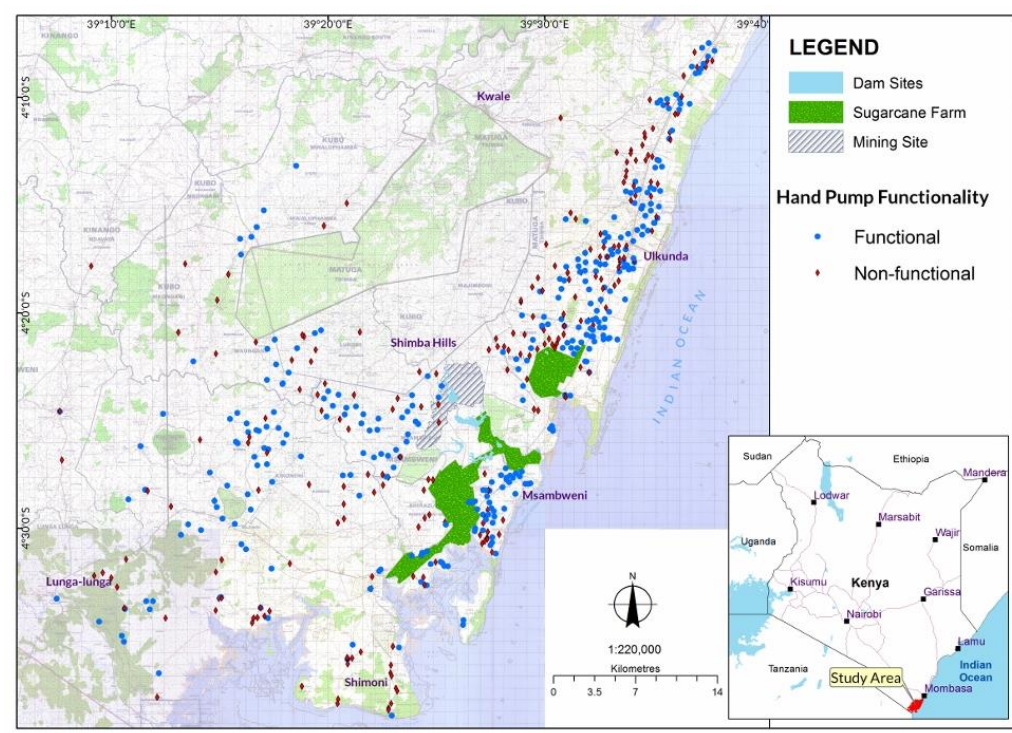
The intent of this paper is to address these lacunae in the literature by empirically assessing the extent and determinants of financial contributions among community waterpoint users on the south coast of Kenya. Drawing on data from a waterpoint census, household survey and water committee financial records, we seek to answer two key questions: (a) what proportion of rural water users contribute finances; and (b) which factors pertaining to the resource system, resource units, governance system, users, and related ecosystem predict collective payment rates.

## **2. Methods**

### **3.1 Study site**

The study site, Kwale County, is situated on the south coast of Kenya, with a population in 2013 of around 730,000 (Commission on Revenue Allocation, 2013). The majority (82%) of Kwale's inhabitants reside in rural areas, and poverty rates are amongst the highest in Kenya (Commission on Revenue Allocation, 2013). Waterpoints drawing on groundwater are the most commonly used water source, accessed by 37% of the county's populace (Government of Kenya, 2009). In particular, boreholes fitted with Afridev handpumps – the focus of this study – are a ubiquitous feature of the rural water supply landscape, owing to successive donor-funded programmes which installed around 580 of these waterpoints between 1983 and 1995 (Figure 1).

Figure 1. Distribution of waterpoints fitted with Afridev handpumps in Kwale, Kenya



### 3.2 Data collection

A waterpoint census of 571 Afridev handpump locations was carried out across Kwale in August 2013.<sup>10</sup> Key technical, social, institutional, operational, financial and geographical information pertaining to the waterpoint and its management were captured through structured interviews with a community member (water committee member where possible). Water quality parameters (pH, EC) were also measured where feasible.

Based on a sampling frame informed by the waterpoint census, a survey was then conducted of 3,361 households<sup>11</sup> between October 2013 and January 2014. The survey was administered to a random sample of households within the service area of 531 waterpoints deemed communal in use (mean of 6.3 households per waterpoint, 4.6 residents per household). An in-depth

<sup>10</sup> This included 19 locations at which Afridev handpumps were originally installed, but had since been replaced by submersible pumps.

<sup>11</sup> 12 cases were subsequently excluded from the dataset as the respondent had a poor understanding of the questions and/or there were concerns about the accuracy of the responses.

questionnaire captured a range of demographic, socio-economic, water use, water payment and health indicators for each household.

Water user payment data were obtained from written financial records kept by water committees who collected regular fees on a weekly, monthly, bimonthly or yearly basis. The participating committees were identified throughout the waterpoint census, during which respondents were asked whether documentation was kept of revenue collected and/or expenses incurred. For those communities who stated they kept written records (n=213), a follow-up visit was then undertaken in January 2014.<sup>12</sup> At 100 communities, financial records were located, reviewed and photographed for data entry and analysis. Of these, 66 communities had explicitly documented the payment history of individual water users. A structured interview with the person presenting the financial records (most commonly a water committee member) was also carried out and additional questions were asked to clarify any uncertainties and ambiguities that were evident in the records.

Prior to all data collection, a research permit was obtained from the Government of Kenya's National Council of Science and Technology, and ethics approval was obtained from the Central University Research Ethics Committee (CUREC) at the University of Oxford. Both the waterpoint census and household surveys were undertaken by trained enumerators and delivered in local languages, predominantly Swahili (53.9% of households) and Digo (42.5% of households).

### **3.3 Analysis and variables**

Data pertaining to the resource system, resource unit, user group and governance system were compiled into a spreadsheet. Waterpoints were only included if they were communally-used Afridev handpumps. Non-functional waterpoints that were communally used prior to breakdown were included, however those that had been upgraded to submersible pumps were not. Household

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<sup>12</sup> Due to security concerns, 18 handpumps north of Tiwi which reportedly had financial records could not be visited.

cases were excluded from the dataset where (a) the enumerator recorded concerns over the accuracy of the responses, (b) the enumerator believed the respondent had a poor understanding of the questions asked, or (c) the household did not use the waterpoint to collect water for any purpose. After these exclusion criteria were applied, the dataset included information from a total of 518 community waterpoints and 3,233 households. Table 2 presents the operational and financial status of all waterpoints that met the inclusion criteria.

Table 2 – Operational and financial status of communal waterpoints fitted with Afridev handpumps

|                      | Functional  | Non-functional (< 1 year) | Non-functional (> 1 year) | Total       |
|----------------------|-------------|---------------------------|---------------------------|-------------|
| <b>Advanced fees</b> | 161 (53.1%) | 19 (46.3%)                | 75 (43.1%)                | 255 (49.2%) |
| Fixed fees           | 86 (28.4%)  | 8 (19.5%)                 | 36 (4.1%)                 | 130 (25.1%) |
| PAYF                 | 75 (24.8%)  | 11 (26.8%)                | 39 (22.4%)                | 125 (24.1%) |
| <b>Reactive fees</b> | 66 (21.8%)  | 7 (17.1%)                 | 16 (9.2%)                 | 89 (17.2%)  |
| <b>No fees</b>       | 76 (25.1%)  | 15 (36.6%)                | 82 (47.1%)                | 173 (33.4%) |
| <b>Total</b>         | 303 (100%)  | 41 (100%)                 | 174 (100%) <sup>a</sup>   | 518 (100%)  |

<sup>a</sup> Includes 1 waterpoint where revenue collection approach could not be determined

Payment data were collated and inputted into a separate spreadsheet. Variables entered included payment period, date, number of recorded users, number of users contributing payments, tariff amount, and total amount of money collected. All monetary values were converted to Kenyan shillings in 2013 by applying deflator factors obtained from the World Bank Development Indicators database (World Bank, 2014). Payment data not coupled with a date were excluded from analysis. Financial, waterpoint and household data were then linked by way of a unique waterpoint identification code. All subsequent analysis was performed using the statistical software package SPSS (Version 21).

Contribution rates were quantified for different payment intervals. Measures assessed were (i) collective payment rate (defined as the percentage of recorded users who contributed fees each payment period), and (ii) revenue collection rate (defined as the percentage of revenue collected relative to the theoretical amount that would have been collected had all recorded users paid the full amount). As the financial data were collected in January 2014, community-level indicators were

split out by short-term (2013 only) and long-term (pre-2013) rates, to account for the time-dependent nature of arrears.

In order to examine the effect of community and household characteristics on the level of financial contributions by water users, multivariable regression analyses were conducted. Collective payment rate (the outcome variable) was subjected to a mixed effect repeated measure modelling technique (linear mixed model, or LMM). This analytical method accounts for the correlation between recurring monthly observations for a given waterpoint, which would otherwise violate the independence assumption underpinning simple regression. The analyses focussed on waterpoints coupled with monthly fee arrangements, as this was the most common revenue collection approach. The analyses were limited to 2013 financial data, as many of the explanatory variables were dynamic in nature and correspond specifically to that year. The Akaike Information Criterion Corrected (AICC) goodness-of-fit measure was utilised to identify the best fitting covariance structures.

Definitions and mean characteristics of the explanatory variables included in the analyses are presented in Table 3. Ostrom's SES framework guided the selection and classification of variables across core sub-systems (Table S1 in Supplementary Material), in conjunction with theoretical and empirical findings from willingness to pay, rural water supply and broader CPR writings (see Supplementary Material). Month was included as an explanatory variable, given the time-dependent nature of financial arrears. Due to the strong association between electrical conductivity (EC) and taste (Figure S1), separate models were run with each variable included. To assess whether results held across distinct geographies, the dataset was split into two subsets based on location ('coastal' and 'interior'), and the same linear mixed models were run on each subset. The conventional threshold of  $\alpha=0.05$  was applied to determine statistically significant predictors.

Table 3. Variable definitions and mean characteristics for communities and waterpoints in Kwale

| Explanatory variables    | Definition                                                                                                                                                        | Mean (SD)            |                         |
|--------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------|-------------------------|
|                          |                                                                                                                                                                   | All WPs <sup>a</sup> | Active WPs <sup>b</sup> |
| <b>Resource system</b>   |                                                                                                                                                                   |                      |                         |
| Distance: WP-HH          | Average distance between waterpoint and user households (m)                                                                                                       | 137 (99)             | 143 (99)                |
| Distance: WP- WP         | Distance between waterpoint and nearest active communal Afridev handpump (m)                                                                                      | 877 (981)            | 806 (909)               |
| Community Mechanic       | 1 = Handpump mechanic lives in same community as waterpoint                                                                                                       | 0.48                 | 0.50                    |
| pH <sup>c</sup>          | 1 = pH of groundwater $\geq 6.5$                                                                                                                                  | 0.70                 | 0.70                    |
| <b>Resource unit</b>     |                                                                                                                                                                   |                      |                         |
| EC <sup>c</sup>          | Electrical conductivity of water (mS/cm)                                                                                                                          | 1.18 (0.98)          | 1.17 (0.98)             |
| Taste                    | Average household rating of water taste across wet and dry season (1 = good, 0 = average, -1 = poor)                                                              | 0.52 (0.53)          | 0.54 (0.53)             |
| Safe                     | Percentage of households who believe water is safe to drink all year round                                                                                        | 0.82 (0.26)          | 0.80 (0.25)             |
| Productive use           | Percentage of households who use waterpoint for livestock or irrigation                                                                                           | 0.26 (0.20)          | 0.26 (0.18)             |
| <b>Governance system</b> |                                                                                                                                                                   |                      |                         |
| Attendant                | 1 = waterpoint has an attendant                                                                                                                                   | 0.65                 | 0.75                    |
| Lock                     | 1 = lock used to prevent unauthorised use of waterpoint                                                                                                           | 0.52                 | 0.60                    |
| Bank                     | 1= funds for O&M stored in a bank account                                                                                                                         | 0.05                 | 0.07                    |
| Monthly fee <sup>d</sup> | Fees per month (Kshs)                                                                                                                                             | 43.6 (24.7)          | 47.5 (23.1)             |
| Ramadan                  | 1 = Gregorian calendar months which overlap with Islamic month of Ramadan                                                                                         | -                    | -                       |
| <b>Users</b>             |                                                                                                                                                                   |                      |                         |
| Group size               | Average number of recorded water users (households) <sup>e</sup>                                                                                                  | 31.8 (20.2)          | 31.8 (20.2)             |
| Welfare index            | Multi-dimensional index incorporating household composition, dwelling structure and asset ownership measures (the higher the index, the higher the welfare level) | 6.4 (2.7)            | 6.6 (2.7)               |
| Night-time lights        | Value of night-time lights derived from satellite imagery                                                                                                         | 5.1 (7.1)            | 5.4 (7.3)               |
| Participation            | Percentage of households who participated in planning and implementation of waterpoint <sup>f</sup>                                                               | 0.31 (0.24)          | 0.28 (0.22)             |
| Years                    | Number of years since handpump installed                                                                                                                          | 21.0 (7.8)           | 20.9 (8.2)              |
| Alternative              | 1 = a secondary drinking water source is used concurrently with the waterpoint                                                                                    | 0.70                 | 0.77                    |
| <b>Related ecosystem</b> |                                                                                                                                                                   |                      |                         |
| Dry season               | 1 = Period of lowest rainfall (Jan-Mar)                                                                                                                           | -                    | -                       |

WP= waterpoint, HH = household

<sup>a</sup> n<sub>WP</sub> = 518<sup>b</sup> Active WPs defined as waterpoints which were functional or had been functional within the previous 12 months (n<sub>WP</sub> = 344)

<sup>c</sup> Water quality characteristics measured for 288 waterpoints (including 281 active waterpoints). EC values were capped at 3999.

<sup>d</sup> Applies to 95 waterpoints at which a monthly fee arrangement was in place and the fee amount could be recalled by the respondent.

<sup>e</sup> Group size could only be reliably determined for waterpoints with written financial records that denoted the number of users in 2013 (all of which were 'active waterpoints'), hence parameters do not differ between 'all waterpoints' and 'active waterpoints'. The figures represent an average across all months for which there were financial records denoting user numbers.

<sup>f</sup> Forms of participation included contributions (cash, land, food or construction materials) and/or decision making (e.g. tariff setting, waterpoint location).

### **3.4 Limitations**

It is important to note that the communities that form the focus of this study are not necessarily representative of rural Kenya or sub-Saharan Africa more broadly. Though surveyed households were randomly selected within waterpoint service areas and share similar traits with households across rural Kenya (Table S3), there are some deviations. In particular, the results relate to one waterpoint technology type, and most of the systems were installed more than 20 years prior to data collection. Moreover, by virtue of the study's inclusion criteria (the documentation of payments, monthly fee collection), the observations analysed are likely biased towards the better performing water committees and wealthier households (Tables S2).

The results and interpretations are subject to a number of other caveats. First, no causal relationships can be conclusively demonstrated between the explanatory and outcome variables. Second, as with any data collection and analysis of this nature, sources of non-sampling error and omitted variable bias cannot be ruled out. Third, the results illuminate conditions that undermine and support financial contributions once revenue collection systems are established, but they do not divulge why such arrangements emerge in the first place.

## **3. Results**

Payment data from which a collective payment rate could be computed spanned a 27 year period from 1987 through to 2013, and covered 229 years' of waterpoint operations. When converted to water-person-years (WPYs), a novel metric for sustainability (Koestler et al. 2010), there were

approximately 31,262 WPYs worth of payment records. Total payments amounted to US\$29,126, with an average of US\$127 collected per waterpoint per year, US\$5.84 per paying household per year, and US\$1.27 per paying person per year.<sup>13</sup>

The revenue collection rate across all financial records obtained was 70.6% (Table 4). For monthly fees, the overall collective payment rate was 71.2%. There was a considerable difference in short- and long-term collective payment and revenue collection rates (Figure 2). For years prior to 2013, 75.4% of households contributed funds each month, falling to 52.8% in 2013. Even within 2013, collective payment rate was highly dependent on the month (Figure 3).

Table 4. Collective payment and revenue collection rates by payment interval

| Measures                                 | Payment interval |         |            |        | All    |
|------------------------------------------|------------------|---------|------------|--------|--------|
|                                          | Weekly           | Monthly | Bi-monthly | Annual |        |
| Financial records                        |                  |         |            |        |        |
| Long term (1987-2012)                    |                  |         |            |        |        |
| Collective payment rate (%) <sup>a</sup> | 64.5             | 75.4    | 90.8       | 86.5   | -      |
| Revenue collection rate (%) <sup>b</sup> | 64.5             | 72.0    | 91.2       | 82.3   | 74.0   |
| Short term (2013)                        |                  |         |            |        |        |
| Collective payment rate (%)              | 77.9             | 52.8    | -          | -      | -      |
| Revenue collection rate (%)              | 76.3             | 52.1    | -          | -      | 53.9   |
| Total                                    |                  |         |            |        |        |
| Collective payment rate (%)              | 75.6             | 71.2    | 90.8       | 86.5   | -      |
| Revenue collection rate (%)              | 74.1             | 68.3    | 91.2       | 82.3   | 70.6   |
| Volume of data (WPYs)                    | 255              | 26,859  | 409        | 3,740  | 31,262 |
| Share of data (%)                        | 0.8              | 85.9    | 1.3        | 12.0   | 100.0  |

<sup>a</sup> Defined as number of water users paying divided by the total number of recorded water users

<sup>b</sup> Defined as revenue collected divided by the theoretical amount that would have been collected had all recorded users paid the full amount.

<sup>13</sup> An exchange rate of US\$1 = 86.1 Kshs is used throughout. Per person annual revenue assumes 4.6 people per household (as determined from household survey).

Figure 2. Collective payment rates 1987-2013

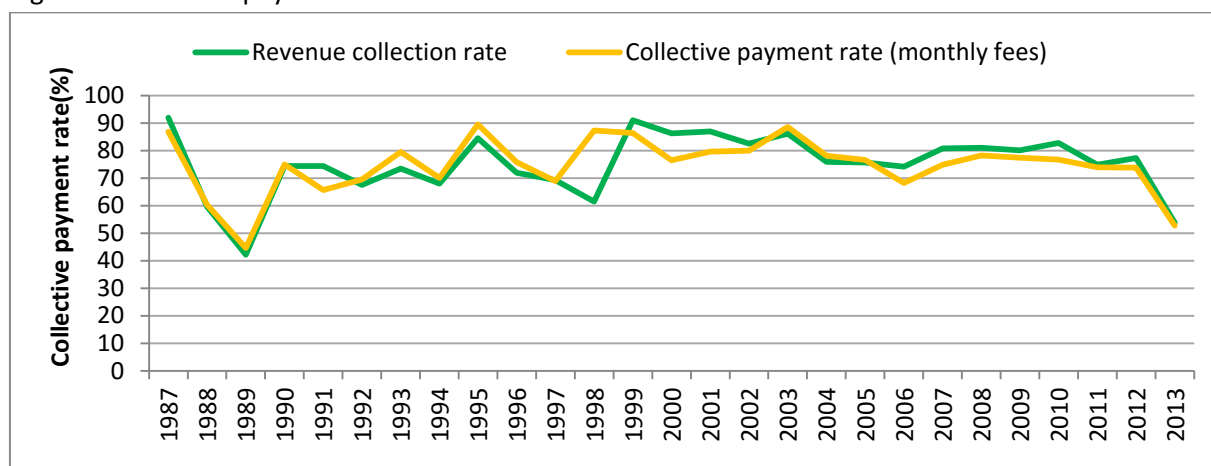
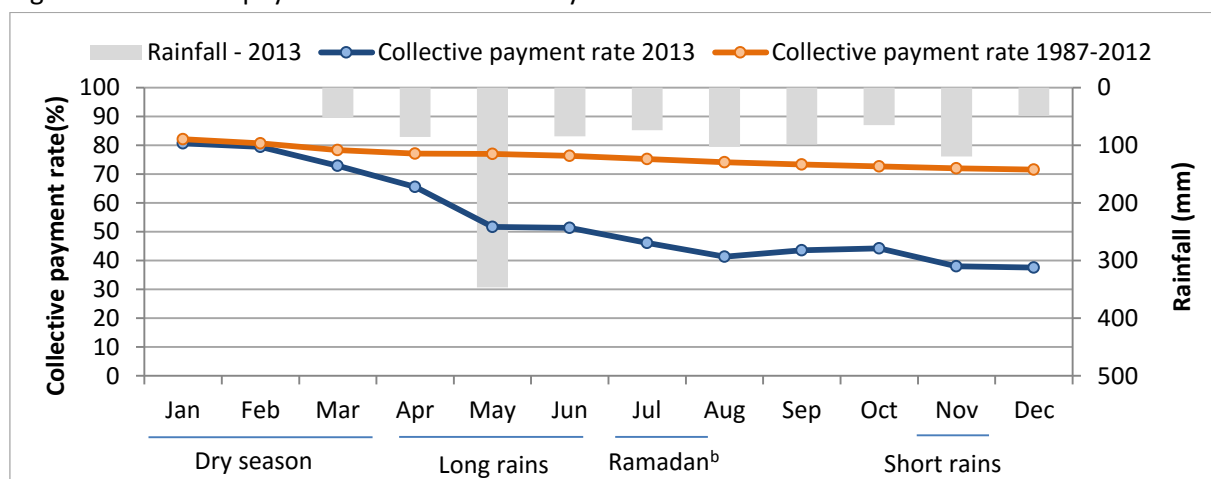


Figure 3. Collective payment rate and rainfall by month<sup>a</sup>



<sup>a</sup> Kwale rainfall data extracted from monthly Kwale Drought Monitoring Bulletins prepared by Kenya's National Drought Management Authority (<http://www.ndma.go.ke/>).

<sup>b</sup> Month of Ramadan specifically refers to 2013. Timing may differ for other years.

Table 5 summarises the results of the collective payment rate linear mixed models. Based on the AICC measure, a random intercept and first-order autoregressive structure with heterogeneous variances led to the best fitting model. This covariance structure accords with the expectation in practice that month-to-month contributions are correlated, with correlations strongest in successive months. Collective payment rate exhibited significant positive associations with groundwater pH, taste and dry season, and negative associations with group size, mean distance between households and the waterpoint, and month. The models for 'coastal' and 'interior' subsets were unable to converge due to the reduction in sample size.

Table 5. Results of collective payment rate linear mixed models<sup>a,b</sup>

| Explanatory variables        | Model 1      |              |                  | Model 2      |              |                  |
|------------------------------|--------------|--------------|------------------|--------------|--------------|------------------|
|                              | B            | SE           | p-value          | B            | SE           | p-value          |
| <b>Resource system</b>       |              |              |                  |              |              |                  |
| Distance: WP-HH              | <b>-0.15</b> | <b>0.07</b>  | <b>0.044</b>     | -0.12        | 0.07         | 0.087            |
| Distance: WP-WP <sup>c</sup> | 38.30        | 23.59        | 0.117            | 35.65        | 22.07        | 0.119            |
| Community mechanic           | -2.56        | 12.66        | 0.842            | 2.57         | 12.13        | 0.834            |
| pH                           | <b>44.06</b> | <b>15.65</b> | <b>0.010</b>     | <b>39.63</b> | <b>13.38</b> | <b>0.007</b>     |
| <b>Resource unit</b>         |              |              |                  |              |              |                  |
| EC                           | -9.21        | 9.11         | 0.324            |              |              |                  |
| Taste                        |              |              |                  | <b>49.61</b> | <b>22.77</b> | <b>0.041</b>     |
| Safe                         | 9.60         | 39.23        | 0.809            | -43.53       | 44.28        | 0.337            |
| Productive use               | 68.70        | 49.88        | 0.181            | 54.21        | 47.24        | 0.263            |
| <b>Governance system</b>     |              |              |                  |              |              |                  |
| Attendant                    | 12.90        | 18.83        | 0.501            | 22.79        | 18.34        | 0.227            |
| Lock                         | -17.13       | 20.75        | 0.418            | -18.65       | 19.47        | 0.348            |
| Bank                         | -38.14       | 26.08        | 0.159            | -24.78       | 24.44        | 0.323            |
| Monthly fee                  | -0.17        | 0.17         | 0.325            | -0.12        | 0.17         | 0.483            |
| Ramadan                      | -0.36        | 2.81         | 0.899            | -0.41        | 2.81         | 0.884            |
| <b>Users</b>                 |              |              |                  |              |              |                  |
| Group size                   | <b>-0.44</b> | <b>0.22</b>  | <b>0.048</b>     | -0.40        | 0.21         | 0.059            |
| Welfare index                | -0.30        | 3.63         | 0.935            | 0.08         | 3.40         | 0.980            |
| Night-time lights            | -0.08        | 0.98         | 0.938            | -0.90        | 1.01         | 0.383            |
| Participation                | -19.58       | 38.03        | 0.612            | 2.30         | 37.26        | 0.951            |
| Years                        | -4.47        | 3.23         | 0.180            | -3.60        | 3.06         | 0.252            |
| Alternative sources          | -16.42       | 19.64        | 0.413            | -25.87       | 17.82        | 0.162            |
| <b>Related ecosystem</b>     |              |              |                  |              |              |                  |
| Dry season                   | <b>4.40</b>  | <b>2.06</b>  | <b>0.036</b>     | <b>4.39</b>  | <b>2.06</b>  | <b>0.036</b>     |
| <b>Time</b>                  |              |              |                  |              |              |                  |
| Month                        | <b>-4.52</b> | <b>0.52</b>  | <b>&lt;0.001</b> | <b>-4.51</b> | <b>0.51</b>  | <b>&lt;0.001</b> |
| Goodness of fit              | AICC: 2976   |              |                  | AICC: 2971   |              |                  |

<sup>a</sup> Bold text indicates statistically significant association ( $p < 0.05$ ).

<sup>b</sup> Linear mixed model with random intercept and first order autoregressive structure with heterogeneous variances (R matrix)

<sup>c</sup> To assist interpretability, units have been changed to kilometres

#### 4. Discussion

The results present two major advances in understanding collective action and payment behaviours among rural water users. First, the study provides empirical backing for what has long been suspected – even where fees are levied, a substantial proportion of rural waterpoint users fail to meet their payment obligations. Second, the results suggest payment behaviours among rural waterpoint users are a complex process determined by characteristics of water quality, waterpoint location, user group size, and climate patterns.

### **5.1 Prevalence of payments**

Despite examining the better managed waterpoints from a highly regarded rural water supply programme, over the long term around one in four households did not pay their fees each month. The decline in payment rate throughout 2013 indicates that among those who do pay fees, between one quarter and one third of the funds are not received in that same calendar year. The total revenue shortfall of 29.4% is in line with the 25-30% gap previously predicted (Carter, Harvey, & Casey, 2010). This is poorer than the performance of Kenya's rural piped water service providers, which recently reported a revenue collection rate of 91% (WASREB, 2014). This disparity perhaps signals some inherent difficulties of extracting payment from users of community waterpoints, as compared to piped connections. The social and operational challenge of excluding defaulters, a lower service level depressing user satisfaction, and the voluntary nature of water committee roles are clear disadvantages for community-managed waterpoints relative to professionally-managed piped water services.

### **5.2 Determinants of collective payment rates**

Payment behaviour determinants emerged across four sub-systems of Ostrom's SES framework, illustrating the complex nature of collective action processes. Though this study does not allow for a definitive pinpointing of causal routes, the direction of significant associations can be plausibly explained with reference to users' willingness to pay, motivation levels of committee members and the burden of revenue collection. Tellingly, all significant determinants map on to service level attributes that shape the relative value users place on a water supply. Unsatisfactory taste, inconvenient location, lower-cost seasonal alternatives, queuing time resulting from large group size, and frequent breakdown rates linked to low pH and a high number of users are all factors that could undermine both the willingness of users to contribute financially and the motivation of committee members to sustain robust revenue collection systems. Equally, two of the predictors

– group size and waterpoint-to-household distance – could conceivably amplify the complexity of collecting payments and enforcing rules, irrespective of users’ willingness to pay.

The results highlight the impact groundwater quality can have on users’ propensity to pay. The association with pH below 6.5 is consistent with the observation that aggressive groundwater rapidly induces corrosion in handpump components made of mild steel (Langenegger, 1989). Although Afridev handpumps are less vulnerable to aggressive groundwater than other prominent handpump models (Baumann & Furey, 2013), the majority of communities in Kwale prefer to purchase lower cost mild steel pump rods rather than corrosion-resistant stainless steel rods. Generally speaking, corrosion could depress user satisfaction by either increasing the frequency of certain failure modes, or causing an undesirable taste and colour (Langenegger, 1989). Service disruption appears to be a more likely mediator in this context, given that there was no obvious association between taste and pH (Figure S1), and pH remained a significant predictor even when taste was included in model 2.

The link between financial contributions and taste rating agrees with previous findings that user perceptions of water quality and palatability impact willingness to pay and sustainability outcomes (World Bank Water Demand Research Team, 1993; Foster, 2013). The association has important implications for Kwale. Although EC was not a significant predictor, the inverse correlation between taste and salinity level is strong (Figure S1). The EC-taste-payment nexus places a spotlight on the importance of monitoring and protecting groundwater quality, particularly given Kwale’s coastal location, history of increasing EC levels (Tole, 1997), and the recent upsurge in groundwater abstraction associated with water-intensive agricultural and mining activities in the region.

Distance between a waterpoint and a household is an important service level attribute known to underlie water source preferences, satisfaction levels and willingness to pay (Mu, Whittington, &

Briscoe, 1990; Masanyiwa, Niehof, & Termeer, 2010; Naiga & Penker, 2014), thus it is logical that waterpoint-to-household proximity translates into healthier contribution rates in Kwale. Additionally, water committees may incur higher transaction costs to collect payments and enforce sanctions in communities with highly dispersed households. Hence the observed relationship may be borne of both the perceived value of a nearby water supply, and the relative difficulty of excluding defaulters.

The negative relationship between user numbers and collective payment rate in this study aligns with the bulk of evidence from major CPR and collective action studies (Wade, 1994; Baland & Plateau, 1996; Araral, 2009). Where group size is large, the burden and complexity of collecting funds and enforcing rules relating to non-payment are likely to be greater. Trust and reciprocity may also be more difficult to maintain when there are more users (Ostrom & Cox, 2010). Moreover, users' cost-benefit calculus for free-riding might be influenced by group size. When there are many users, the relative impact of avoiding payment as a percentage revenue shortfall is lower than if group size is small – hence a user's expectation that the service level will be unaffected by their lack of contribution (Olson, 1965). The negative influence of group size may also be mediated through drivers of water service dissatisfaction, such as higher frequency of service disruptions or longer queuing time.

Rainfall patterns predictably play an important role in shaping households' inclination to pay for an improved water supply. We postulate that water users are less likely to contribute during wet periods because the relative value of the waterpoint is diminished, as surface water becomes more abundant, groundwater tables rise and rainwater harvesting becomes possible. This result is consistent with previous investigations which have identified alternative water sources as a major impediment to willingness to pay and waterpoint sustainability (World Bank Water Demand Research Team, 1993; Whittington et al., 2009; Foster, 2013). Importantly, it was noted in

numerous communities that attendants reduced their hours or ceased monitoring waterpoint use during wetter months. This seasonal waning could itself be an underlying driver of the rainfall association, an exacerbating factor or merely a symptom.

### 5.3 A typology of non-payers

While it is reasonable to describe those households who pay in any given month as “cooperative”, the inverse is not necessarily true. It is important to note that non-payment, as measured in this study, is not synonymous with non-cooperation. There are a number of reasons why waterpoint users might not contribute. Based on interviews with respondents, we classified non-payers into four categories:

- i) **Uncooperative:** free-riders who have no intention to contribute but continue to use the waterpoint in breach of the rules.
- ii) **Unpursued:** those who have an intention to contribute but their contributions have not been sought because (a) revenue collection structures are weak or have collapsed, or (b) lenient grace periods formally afforded by committees allow for debts to be settled into the future.
- iii) **Unserviced:** those who have no intention to contribute during a certain period of time (e.g. wet season) and switch to an alternative water source. As they have temporarily ceased using the waterpoint, they are often (but not always) relieved of their obligation to contribute, and therefore their non-payment may not be considered uncooperative.
- iv) **Unable to pay:** those who have a willingness to contribute but cannot afford to. They are often still permitted to use the waterpoint by way of locally devised rules.

Given the impossibility of retrospectively verifying monthly intentions and waterpoint use for each household, it is difficult to estimate the relative size of these non-payment segments. Nonetheless, we believe the first two categories (“uncooperative” and “unpursued”) make up the bulk of the

measured non-payment rate in 2013 for several reasons. First, the majority of recorded users were registered, paid-up members, and respondents generally asserted that recorded users continued to use the waterpoint year-round. Rather, it was the unrecorded non-members (who usually contributed fees on a pay-as-you-fetch basis) who ceased to use the waterpoint during wetter periods. In any event, the effect size of season – the most likely predictor of “unserved” non-payers – was relatively modest, accounting for a 4 percentage point difference in collective payment rates, all else held constant (compared to an overall non-payment rate of 47.2%). Second, many communities had in place rules whereby the most vulnerable households were excused from paying fees (“unable to pay” non-payers). Though they accounted for anywhere between 0-10% of the users at a given waterpoint, they were not formally listed as users in the financial records, and therefore would not affect the measured non-payment rate. Third, the doubling of non-payment levels in 2013 compared with prior years cannot credibly be attributed to a sudden increase in unaffordability or mass exodus of users to alternative water sources. This leaves “uncooperative” and “unpursued” non-payers as the most likely explanation. Ultimately, whatever the precise mix of non-payers, the broad implications remain the same – a meaningful proportion of households do not contribute financially and a myriad of factors shape the sustainable management, operation, financing and use of rural waterpoints.

#### **5.4 Implications for policy and practice**

Naturally, policymakers and planners have limited ability to control environmental and social factors such as groundwater conditions, seasonal water sources, and settlement patterns. Nonetheless, results point to measures which could improve the financial prospects of rural waterpoints. First, collective action is likely to be enhanced by situating waterpoints as close as possible to where users reside. Second, communities using handpumps which are subject to aggressive groundwater should be fully informed about the short- and long-term cost trade-offs of purchasing corrosion-resistant parts. Third, seasonal variation in tariffs may merit exploration, with

higher dry season fees allowing for a reduction of wet season fees. Fourth, prevailing socio-environmental characteristics may provide guidance as to whether community-managed handpumps are the most appropriate water supply option for a particular setting. For example, low-cost protection of family wells – which are unencumbered by the same collective action burdens – may be a more suitable option where seasonal water sources are abundant, populations are dispersed, and groundwater is shallow. Fifth, groundwater quality should be closely monitored and protected, especially in a region such as Kwale which is experiencing unprecedented levels of groundwater abstraction for agricultural and mining purposes.

Beyond these measures, securing the long-term financial sustainability of rural water supplies will require deeply rooted solutions. If rural communities are to be expected to execute their financial management responsibilities effectively and sustainably across heterogeneous social and environmental settings, they require ongoing external support that includes advice, training, encouragement and monitoring (Harvey, 2007). The long-term nature of this need is clear when one reflects on an early evaluation from the original South Coast handpump installation programme. In 1988, it was reported that all water committees in Kwale regularly collected cash, and all handpumps were functioning (Narayan-Parker, 1998). In 2013, 42.1% of handpumps were non-functional, and funds were regularly collected at 52.3% of active communal waterpoints. This is not to deny pockets of excellence identified during the course of field work, including ten communities possessing financial records spanning 10 years or more, and one community which had meticulously recorded each household monthly payment over 23 consecutive years. However, only a minority of communities were able to produce financial records of any sort, indicating substantial room for improving the transparency and accountability of financial management practices.

Clearly financial management is only one piece of the sustainability puzzle. The nature of the predictors identified in this study reinforce the notion that a high quality water service that meets the needs of users is critical to financial sustainability. If rural communities are to escape a low-level equilibrium trap of poor operational and financial performance, strategies to boost revenue collection must be matched with measures that drive a commensurate improvement in waterpoint reliability. Ongoing external support that spans financial, technical and administrative domains is widely advocated as a pathway to attain these objectives (RWSN, 2010; IRC, 2012). Driving a step-change in waterpoint performance might also be achieved by looking beyond the default community management model and experimenting with novel service delivery and financing approaches that involve different scales, actors, and incentive structures (Hope & Rouse, 2013).

## **5. Conclusion**

This study has empirically demonstrated that financial contributions by rural water users cannot be assumed, and the propensity of users to pay is affected by factors pertaining to the resource system, resource unit, users, and climate patterns. Further research is needed to reveal whether the observed relationships hold in other social-ecological settings. Addressing the financial sustainability of rural waterpoints across heterogeneous and changing social and environmental settings will be vital if the Sustainable Development Goal of universal access to safe water is to be achieved. Provision of ongoing external support to communities and novel service delivery approaches that reallocate risks and responsibilities between water users, governments and private enterprise present potential pathways to more sustainable outcomes.

## **References**

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## **Supplementary Material**

### **S1. Independent variable selection**

#### **Resource system variables**

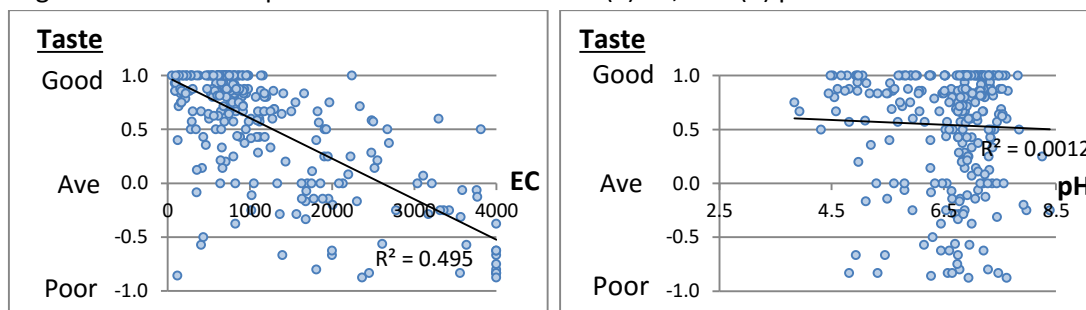
Characteristics of the resource system are those that relate to the aquifer, well and water lifting device. By virtue of the investigation's focus on Afridev handpumps, the variable relating to water-lifting technology was held constant. It was hypothesised that waterpoints situated closer to households would facilitate collective action, given the perceived benefit and value associated with a conveniently located water source (Mu, Whittington, & Briscoe, 1990; Masanyiwa, Niehof, & Termeer, 2014; Naiga & Penker, 2014; Coster & Otufale, 2014). Conversely, proximate alternative waterpoints might undermine motivation to pay, as the adverse ramifications of failing to act collectively would be reduced. In line with previously observed associations with handpump functionality (Foster, 2013; Whittington *et al.*, 2009), it was hypothesised that greater distances to a mechanic would inflate the transaction costs of arranging repairs, consequently lengthening handpump downtime and depressing satisfaction levels. Groundwater pH was selected as an exogenous variable likely to impact breakdown frequency, as the rate of corrosion for mild steel handpump components occurs rapidly once groundwater pH drops below 6.5 (Langenegger, 1989). Though Afridev handpumps are better suited to aggressive groundwater than other handpump models, the majority of communities in Kwale opt for mild steel pump rods which are susceptible to corrosion. It was therefore expected that handpumps drawing groundwater with a pH of less than 6.5 would have less predictable benefits and would suffer from poorer collective action outcomes. Alternative pH cut-off values were also tested to assess the sensitivity of results (see Tables S4).

#### **Resource unit variables**

Characteristics of the resource unit are those which correspond to the water supplied. User perception of water quality is a commonly cited driver of demand and handpump functionality

(World Bank Water Demand Research Team, 1993; Foster, 2013). Thus user perceptions of taste and safety were expected to influence payment behaviours. Groundwater electrical conductivity (EC) – a measure of salinity – was also chosen as an exogenous variable representing water quality. Salinity is a common water quality complaint among handpump users in sub-Saharan Africa (Langenegger, 1989). Because water becomes less palatable as EC increases (Figure S1), a negative association with payment behaviours was expected. While low groundwater pH has also been linked to user dissatisfaction with taste and colour (Langenegger, 1989), the data from Kwale is less supportive of this association (Figure S1), and thus pH was considered more relevant to the resource system (and its implications for reliability) than to the palatability of water. Productive use of water (for livestock or irrigation) was also hypothesised to bolster payment behaviours due to the heightened economic value placed on the resource unit. Prior to data collection, seasonality of groundwater availability was also anticipated to be a salient factor, however all waterpoints included in the regression analyses were found to provide a year-round supply.

Figure S1. Relationships between water taste and (a) EC, and (b) pH in Kwale.



### Governance system variables

Attributes of the governance system pertain to the institutions and rules in place to manage the waterpoint system. Use of a lock to prevent freeriding was representative of an operational rule relating to permitted hours of usage, and hypothesised to boost payment behaviours. It was posited that monthly fee amount would have a negative effect on payment rates, as higher fees would naturally feed into the cost side of a user's decision making calculus. Use of a bank account to store O&M funds was expected to motivate financial contributions by virtue of the increased

security it offered. Presence of a handpump attendant, a role which commonly involves monitoring and sanctioning duties, was postulated to promote collective action. The Islamic month of Ramadan was also expected to influence payment behaviours, as revenue collection arrangements were known to be relaxed during this period.

### **User variables**

User attributes are those characteristics possessed by the group of households that collect water from the waterpoint. Acknowledging the considerable debate among CPR scholars about the influence of group size on collective action outcomes and the relevance of contextual and mediating factors, the number of waterpoint users was expected to exhibit a negative association with collective action success in accordance with major CPR studies (Ostrom, 1990; Wade, 1994; Baland & Platteau, 1996; Araral, 2009).

Socio-economic status was posited to have a positive bearing on payment behaviours. Though there is far from a consensus about the link between CPR management and poverty, a positive relationship was hypothesised here due to the financial nature of the collective action proxy measure, the previously observed association with irrigation fee payment (Araral, 2009), and the parallel findings in willingness to pay studies (World Bank Water Demand Research Team, 1993; Mugabi & Kayaga, 2010; Arouna & Dabbert, 2012; Bogale & Urgessa, 2012). A multi-dimensional welfare index was constructed by applying principal component analysis to a range of variables relating to dwelling structure (floor, walls, roof), household composition (education, employment, adult-child ratio), asset ownership, sanitation and health.

To distinguish between waterpoints in and around towns and trading centres, and those in more remote villages, location-specific light values extracted from a night-time lights satellite image were used as proxy measures for settlement type. A cloud-free composite image of persistent night-time lighting from 2013 was obtained from the website of the Earth Observation Group, National Centers for Environmental Information (Version 4 DMSP-OLS Nighttime Lights Time Series,

image and data processing by NOAA's National Geophysical Data Center).<sup>14</sup> The image was superimposed on waterpoint locations, and light values pertaining to the location of each waterpoint were extracted using GIS software. It was speculated that towns and trading centres might have lower collective payment rates compared with smaller villages, due to the availability of piped and vended water in and around towns and a relative lack of shared norms, values and trust. On the flipside, it was considered plausible that these effects may be offset by better access to spare parts retailers and skilled technicians.

Participation in planning and implementation was expected to exhibit a positive relationship with payment behaviours, in accordance with previous studies which found demand-responsive and participatory approaches led to more sustainable water services and improved willingness to pay (Sara & Katz, 1998; Isham, Narayan, and Pritchett 1995; Narayan 1995; Naiga & Penker, 2014). Though, as the measure in this study captured participation breadth rather than depth, an absence of any positive association would also have been consistent with a recent study from Ghana (Marks, Komives, & Davis, 2014). It was also predicted that payment rates would be superior for those communities that had successfully managed the finances of handpump O&M over a longer period of time. A history of joint efforts was expected to enhance confidence and trust among users that if they contribute, so too will others (Fujiie, Hayami, & Kikuchi, 2005).

A lack of alternative drinking water sources was chosen to represent a community's dependence on the waterpoint. Studies suggest presence of alternative water sources undermine willingness to pay and sustainability (World Bank Water Demand Research Team, 1993; Whittington et al. 2009), hence it was anticipated that a lack of alternative sources would increase users' propensity to pay.

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<sup>14</sup> <http://ngdc.noaa.gov/eog/dmsp/downloadV4composites.html>.

### Related ecosystem variables

Rainfall was hypothesised to have a negative impact on payment rates. Dry periods generally offer fewer alternative water sources, leading to an increased reliance on the waterpoint. Given limitations on available precipitation data, a binary rainfall season measure (dry season/wet season) was utilised.

### Social, economic and political setting variables

As all waterpoints fell within the same local government jurisdiction and were subject to the same national policy and economic settings, variables within this sub-system were not factored into the analysis.

### Time control variable

Given the time-dependent nature of financial arrears, month was included as an explanatory variable within the community payment model.

Table S1. Social-ecological systems framework adapted to rural waterpoints in Kwale<sup>a</sup>

| SES Component             | Adapted second-tier variables hypothesised to affect waterpoint management                       | Explanatory variables included in regression models                                                                                                                                                                                                                                                                     |
|---------------------------|--------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Resource system:</b>   | RS4: Waterpoint technology<br>RS7: Predictability of system dynamics<br>RS9: Waterpoint location | Afridev handpump ( <i>held constant</i> )<br>Low pH of water causing corrosion-related failure modes<br>Location of waterpoint relative to households<br>Location of waterpoint relative to other waterpoints<br>Location of waterpoint relative to mechanic<br>Viable spare part supply chain ( <i>held constant</i> ) |
| <b>Resource units:</b>    | RU2: Groundwater availability by season<br>RU4: Value of water                                   | Year-round reliability ( <i>held constant</i> )<br>Electrical conductivity<br>Taste<br>Safe to drink<br>Productive water use (livestock, irrigation)                                                                                                                                                                    |
| <b>Governance systems</b> | GS5: Operational rules                                                                           | Handpump locked to prevent unauthorised use<br>Funds stored in bank account                                                                                                                                                                                                                                             |

|                           |                                           |                                                                                                |
|---------------------------|-------------------------------------------|------------------------------------------------------------------------------------------------|
|                           |                                           | Monthly fee                                                                                    |
|                           |                                           | Payment obligations during months of Ramadan                                                   |
| <b>Users:</b>             | GS8: Monitoring and sanctioning processes | Presence of a waterpoint attendant                                                             |
|                           | U1: Number of users                       | Number of users                                                                                |
|                           | U2: Socio-economic attributes of users    | Welfare index (household composition, assets, dwelling structure)                              |
|                           |                                           | Settlement type (e.g. town, village) measured through satellite detection of night-time lights |
|                           | U3: History of collective waterpoint use  | Number of years since waterpoint installation                                                  |
|                           |                                           | Participation during planning and implementation                                               |
|                           | U8: Dependence on waterpoint              | Alternative drinking water sources used concurrently with waterpoint                           |
| <b>Related ecosystems</b> | ECO1: Climate patterns                    | Rainfall season                                                                                |

<sup>a</sup> Modified from Ostrom (2009)

## S2. Characteristics of waterpoints and communities in Kwale

Table S2. Mean and median characteristics of waterpoints and communities with and without financial records available<sup>a</sup>

| Characteristics                       | All                       |                             |             |                      | Active waterpoints        |                             |             |                      |
|---------------------------------------|---------------------------|-----------------------------|-------------|----------------------|---------------------------|-----------------------------|-------------|----------------------|
|                                       | Records available (n=100) | Records unavailable (n=418) | All (n=518) | p-value <sup>b</sup> | Records available (n=100) | Records unavailable (n=244) | All (n=344) | p-value <sup>b</sup> |
| Functional (% waterpoints)            | 97.0                      | 49.3                        | 58.5        | <0.001               | 97.0                      | 84.4                        | 88.1        | 0.001                |
| <b>Resource system</b>                |                           |                             |             |                      |                           |                             |             |                      |
| Distance: WP-HH (m)                   | 167 (138)                 | 129 (105)                   | 137 (112)   | 0.001 (<0.001)       | 167 (138)                 | 133. (109)                  | 143.0 (118) | 0.004 (<0.001)       |
| Distance: WP-WP (m)                   | 846 (718)                 | 884 (574)                   | 877 (620)   | 0.657 (0.031)        | 846 (718)                 | 790 (534)                   | 806 (580)   | 0.602 (0.001)        |
| Community mechanic (% waterpoints)    | 52.1                      | 46.5                        | 47.7        | 0.332                | 52.1                      | 49.3                        | 50.2        | 0.651                |
| pH ≥ 6.5 (% waterpoints) <sup>c</sup> | 70.3                      | 70.6                        | 70.5        | 0.968                | 70.3                      | 70.5                        | 70.5        | 0.973                |
| <b>Resource unit</b>                  |                           |                             |             |                      |                           |                             |             |                      |
| EC (mS/cm) <sup>d</sup>               | 1.15 (0.80)               | 1.20 (0.84)                 | 1.18 (0.82) | 0.715 (0.215)        | 1.15 (0.80)               | 1.18 (0.82)                 | 1.17 (0.82) | 0.799 (0.257)        |
| Taste (rating -1 to 1)                | 0.61 (0.80)               | 0.49 (0.71)                 | 0.51 (0.75) | 0.031 (0.126)        | 0.61 (0.80)               | 0.51 (0.74)                 | 0.54 (0.75) | 0.073 (0.380)        |
| Safe to drink (% households)          | 0.87 (1.0)                | 0.80 (1.0)                  | 0.82 (1.0)  | 0.004 (0.060)        | 0.87 (1.0)                | 0.78 (0.88)                 | 0.80 (0.88) | <0.001 (0.006)       |
| Productive use (% households)         | 28.0 (27.6)               | 25.0 (25.0)                 | 25.6 (25.0) | 0.167 (0.099)        | 28.0 (27.6)               | 25.4 (25.0)                 | 26.1 (25.0) | 0.229 (0.197)        |
| <b>Governance system</b>              |                           |                             |             |                      |                           |                             |             |                      |
| Attendants (% waterpoints)            | 63.6                      | 64.9                        | 64.6        | 0.819                | 63.6                      | 79.2                        | 74.6        | 0.003                |

|                                          |             |             |             |                 |             |             |             |                 |
|------------------------------------------|-------------|-------------|-------------|-----------------|-------------|-------------|-------------|-----------------|
| Locks (% waterpoints)                    | 77.8        | 45.9        | 52.2        | <0.001          | 77.8        | 52.9        | 60.2        | <0.001          |
| Bank account (% waterpoints)             | 14.0        | 3.3         | 5.4         | <0.001          | 14.0        | 4.1         | 7.0         | 0.001           |
| <b>Users</b>                             |             |             |             |                 |             |             |             |                 |
| Welfare index                            | 7.0         | 6.3         | 6.4         | 0.014           | 7.0         | 6.5         | 6.6         | 0.113           |
| Night-time lights                        | 4.4 (0.0)   | 5.2 (5.0)   | 5.1 (0.0)   | 0.301 (0.014)   | 4.4 (0.0)   | 5.8 (6.0)   | 5.4 (5.0)   | 0.106 (0.002)   |
| Participation (%)                        | 32.0 (28.6) | 30.5 (26.1) | 30.8 (28.6) | 0.537 (0.373)   | 32.0 (28.6) | 26.8 (25.0) | 28.3 (28.6) | 0.049 (0.027)   |
| Years since installation                 | 23.6 (25.0) | 20.3 (23.0) | 21.0 (23.0) | <0.001 (<0.001) | 23.6 (25.0) | 19.7 (23.0) | 20.9 (24.0) | <0.001 (<0.001) |
| Alternative water source (% waterpoints) | 82.0        | 85.1        | 84.5        | 0.441           | 82.0        | 80.2        | 80.7        | 0.699           |

<sup>a</sup> Median values reported in parentheses for continuous variables. Household-level variables averaged into single measure for each waterpoint.

<sup>b</sup> Chi-square test for categorical variables; Independent samples t-test for continuous variables (with Welch's correction for unequal variances where required); Mann-Whitney U test in parentheses when normality assumption of independent samples t-test violated.

<sup>c</sup> Water quality characteristics measured for 288 waterpoints (including 281 active waterpoints). EC values were capped at 3999.

Table S3 – Comparison of surveyed household characteristics with the most recent census and nationally representative surveys

| Household characteristics | Households surveyed using waterpoints <sup>a</sup> | Rural Kenya              |                         |                          | Kwale                    |                          | Rural Kwale |
|---------------------------|----------------------------------------------------|--------------------------|-------------------------|--------------------------|--------------------------|--------------------------|-------------|
|                           |                                                    | Census 2009 <sup>b</sup> | DHS 2008-9 <sup>c</sup> | NHS 2012-13 <sup>d</sup> | Census 2009 <sup>b</sup> | NHS 2012-13 <sup>d</sup> | Census 2009 |
| Television                | 8.9                                                | -                        | 17.9                    | -                        | 11.4                     | -                        | -           |
| Radio                     | 71.5                                               | -                        | 70.6                    | -                        | 57.5                     | -                        | -           |
| Bicycle                   | 45.2                                               | -                        | 30.1                    | -                        | 33.4                     | -                        | -           |
| Mobile phone              | 84.2                                               | -                        | 53.0                    | -                        | 51.5                     | -                        | -           |
| Motorcycle                | 10.7                                               | -                        | 1.9                     | -                        | 2.1                      | -                        | -           |
| Natural roof              | 68.1                                               | 26.3                     | 21.2                    | 24.2                     | 59.9                     | 52.9                     | 67.1        |
| Natural walls             | 50.9                                               | 54.6                     | 51.1                    | 50.7                     | 56.9                     | 54.8                     | 69.8        |
| Natural floor             | 71.0                                               | 76.9                     | 70.8                    | 66.7                     | 70.2                     | 62.7                     | 82.3        |
| Household size            | 4.6                                                | 4.9                      | 4.6                     | 4.6                      | 5.3                      | 5.3                      | 5.7         |
| Open defecation           | 45.1                                               | 20.7                     | 16.0                    | -                        | 51.1                     | -                        | 62.4        |

<sup>a</sup> n = 3233 (i.e. all households using active communal waterpoints fitted with Afridev handpumps)

<sup>b</sup> Kenyan Population and Housing Census 2009 (KNBS, 2010)

<sup>c</sup> Kenya Demographic and Health Survey 2008-9 (KNBS & ICF Macro, 2010)

<sup>d</sup> Kenya National Housing Survey 2012-13 (MLHUD, 2015)

### S3. Sensitivity of results to different pH cut-off values

The sensitivity of results to different pH cut-off values is presented in Table S4. pH was a significant predictor of collective payment rates for both models when the pH cut-off was between 6.0 and

6.7. Once the cut-off increased beyond 6.7, the association was no longer significant. Based on the AICC goodness of fit measure, the best fitting models coincided with pH values of 6.0, 6.1 and 6.5.

Table S4 – pH p-values and AICC at different pH cut-off values<sup>a,b</sup>

| pH cut-off<br>value | Model 1      |      | Model 2      |      |
|---------------------|--------------|------|--------------|------|
|                     | p-value      | AICC | p-value      | AICC |
| 6.0                 | <b>0.008</b> | 2971 | <b>0.007</b> | 2975 |
| 6.1                 | <b>0.011</b> | 2971 | <b>0.010</b> | 2976 |
| 6.2                 | <b>0.017</b> | 2973 | <b>0.016</b> | 2977 |
| 6.3                 | <b>0.028</b> | 2973 | <b>0.034</b> | 2979 |
| 6.4                 | <b>0.011</b> | 2972 | <b>0.017</b> | 2977 |
| 6.5                 | <b>0.007</b> | 2971 | <b>0.010</b> | 2976 |
| 6.6                 | <b>0.021</b> | 2973 | <b>0.034</b> | 2979 |
| 6.7                 | <b>0.018</b> | 2972 | <b>0.030</b> | 2978 |
| 6.8                 | 0.117        | 2976 | 0.052        | 2980 |
| 6.9                 | 0.627        | 2978 | 0.422        | 2983 |
| 7.0                 | 0.368        | 2978 | 0.237        | 2982 |

<sup>a</sup> Models includes same variables as in Table 5

<sup>b</sup> Bold text indicates statistically significant association ( $p < 0.05$ ).

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## Chapter 6 – Paper 3

### **Assessing the financial, operational and safe water access implications of waterpoint revenue collection approaches in Kwale, Kenya**

Tim Foster,<sup>a</sup> Rob Hope

#### **Abstract**

Water policies across sub-Saharan Africa stipulate that rural communities are responsible for self-financing waterpoint operation and maintenance. However, without a policy consensus on preferred revenue collection strategy, communities adopt a diversity of payment models. Applying collective action and common-pool resource theory, we empirically assess waterpoint sustainability and access outcomes associated with different revenue collection approaches in rural Kenya. Results suggest communities adopting pay-as-you-fetch fees collect 56% more revenue than communities with regular fixed fees, and experience downtime 16.5 days shorter than all other waterpoints. These outcomes are tempered by evidence that households are more likely to opt for an unimproved drinking water source when a pay-as-you-fetch system is in place. The findings point to a possible tension between financial sustainability and universal access. If the Sustainable Development Goal of ‘safe water for all’ is to become a reality, policymakers and practitioners must look to develop and support revenue collection systems that are simultaneously sustainable and inclusive.

**Key words:** rural water supply, sustainability, revenue collection, sub-Saharan Africa, common-pool resources, Sustainable Development Goals

## 1. Introduction

Community-based financing via user contributions is widely regarded as a pre-condition for water supply sustainability in rural sub-Saharan Africa (Churchill et al., 1987; Briscoe et al., 1988; Carter et al., 1996; Carter et al., 1999; Harvey 2007). Community management has been the dominant rural water supply paradigm embraced by governments, donors and non-government organisations (NGOs) for over three decades, and is premised upon the expectation that local water users are willing and able to self-organise and finance operation and maintenance (O&M) activities (Arlosoroff et al., 1987; Harvey & Reed, 2007). Although taxes and transfers play a role in subsidising major repairs (MWE, 2011; MLG, 2007; Jones, 2013), technician salaries and equipment (Hystra, 2011) and spare part supply chains (Harvey, 2007), the bulk of financing for O&M is expected to derive from tariffs paid by waterpoint users. Indeed, the principle of self-financing of O&M is now formalised in policies and assumed in financing plans across the continent (African Development Bank, 2010; Banerjee & Morella, 2011; GLAAS, 2014). However, there is an absence of empirical evidence or policy consensus on the optimal revenue collection approach, and communities adopt a diversity of financing strategies. Understanding the sustainability and access implications of different revenue collection approaches will be paramount if the Sustainable Development Goal (SDG) of universal access to safe water is to be attained.

The arguments in support of community-based financing of rural water O&M are multifold, and sit within a broader debate about user financing of basic social services (Reddy & Vandemoortele, 1996). Governments and donors have long been considered ill-equipped to reliably finance recurrent water service costs in the long-term (Briscoe & de Ferranti, 1988; Churchill *et al.*, 1987). Additionally, as a cornerstone of community management, the expectation of self-financing fits neatly with the predilection of donors and NGOs to approach water supply interventions as one-off projects, as well as a “cultural idealization” that rural communities will harmoniously cooperate and act collectively (Harvey & Reed, 2007). Briscoe & de Ferranti (1988) also advance justifications

based on principles of equity and efficiency, as user contributions raise money in a non-distortionary way, minimise waste, and liberate donor and government funds to expand improved water supply access to the poorest and hardest to reach.

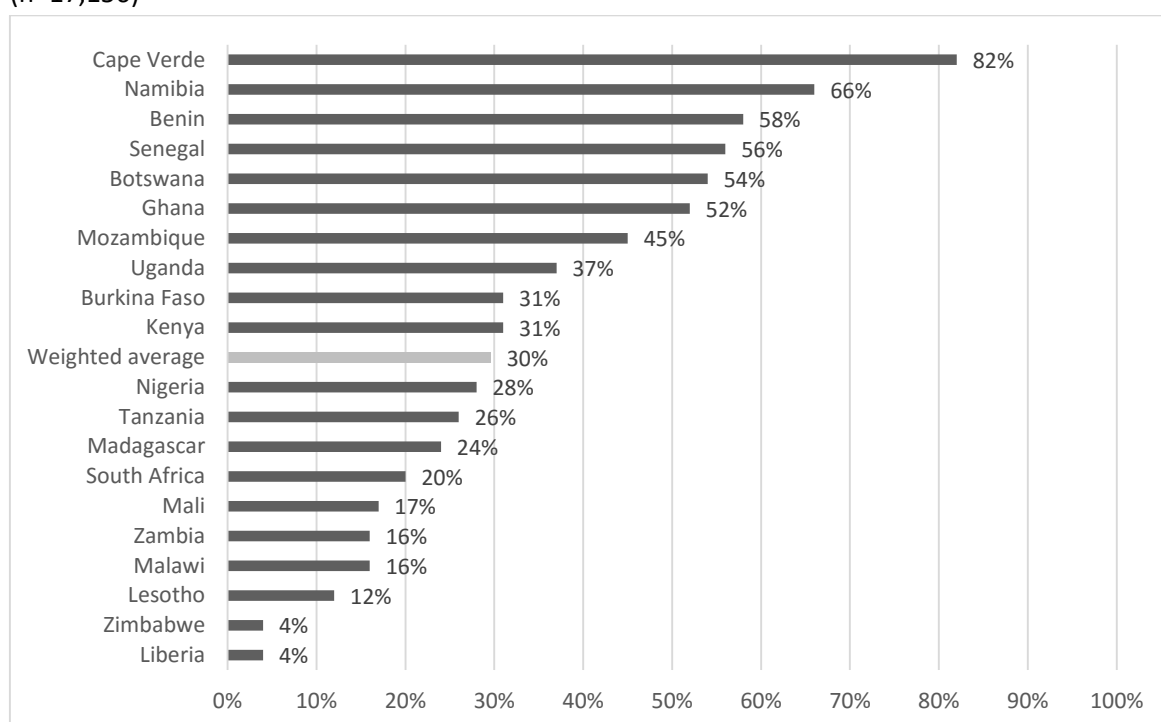
However, there is a mismatch between policy and reality, with evidence suggesting user contributions are the exception rather than the norm in rural areas. Nationally representative surveys across 19 sub-Saharan African countries in 2008-9 found only 30% of rural households pay for water (Figure 1), at a time when improved water coverage in rural areas of those countries collectively stood at 54%.<sup>15</sup> In contrast, the same surveys found three in four of households paid for water in urban settings (Afrobarometer, 2015). The problem is especially acute for community waterpoints fitted with handpumps, with around three in five lacking any form of revenue collection (Foster & Hope, *forthcoming*). Even among those handpumps coupled with regular fee collection, there is evidence that a sizable proportion of users avoid payment and free-ride (Foster & Hope, *forthcoming*).<sup>16</sup>

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<sup>15</sup> Improved water coverage rate calculated using data from UNICEF/WHO (2015b).

<sup>16</sup> There are a number of factors that arguably make O&M cost recovery via user fees more difficult for community waterpoints fitted with handpumps than for piped water services. These relate to differences in a user's willingness to pay, and ability to avoid paying. First, unlike piped water customers who can be disconnected, excluding non-contributing handpump users can be difficult. Second, revenue collection responsibilities for community handpumps are often voluntary in nature, weakening the skills and incentives to collect fees promptly and handle cash effectively. Third, fetching water from a community handpump is less convenient than turning a tap in the home, and the time to collect water has a considerable impact on water source preferences and willingness to pay (Mu *et al.*, 1990; Naiga & Penker, 2014). Fourth, willingness-to-pay may be further dampened by user perceptions of handpump O&M costs which are less perceptible and frequent than the day-to-day expenses and inputs involved in running a piped water scheme.

Figure 1 – Proportion of households that pay for water in rural sub-Saharan Africa in 2008/9 (n=17,156)<sup>a</sup>



<sup>a</sup> Authors' analysis of data from Afrobarometer (2015) household surveys

More effective self-financing strategies could have a considerable impact on both the sustainability of waterpoints and the health and welfare of waterpoint users. The inability of communities to raise the required funds is considered a major reason why an estimated one in three waterpoints fitted with a handpump are non-functional (Carter *et al.*, 1999; Harvey, 2007; RWSN, 2009). It is approximated that there are 823,000 waterpoints fitted with handpumps across the continent serving up to 184 million people (MacArthur, 2015). Hence minor but systematic revenue collection improvements could have far-reaching consequences. Combining these coverage estimates with handpump O&M unit costs formulated by WASHCost (2012), the recurrent handpump expenditure requirements across sub-Saharan Africa may lie between US\$386 million and US\$579 million a year.<sup>17</sup> Furthermore, an estimated 60,000 are fitted with handpumps every

<sup>17</sup> Based on an annual O&M cost requirement of US \$2-3 per person (WASHCost 2011), adjusted to 2014 values.

year (Sansom & Koestler, 2009), thus recurrent expenditure needs could be rising by US\$28 million to US\$42 million annually.

### **1.1 Rural waterpoint revenue collection approaches in policy and practice**

While government involvement in water tariff regulation is widely accepted and practiced in urban settings in sub-Saharan Africa (Banerjee & Morella, 2011), external engagement in rural waterpoint tariff formulation is less pronounced. In contrast to utility-provided piped water services, the distinction between users and water service providers for community-managed rural waterpoints is ambiguous. Concerns about monopolistic profit-making and consumer exploitation therefore take a lower priority. Although price setting for rural waterpoint repair services is not always beyond the purview of local governments (see e.g. Mommen & Nekesa, 2010), policies are commonly agnostic about revenue collection approach. This is perhaps unsurprising given community-based decision-making regarding waterpoint tariffs is a central tenet of community management and participatory planning.

Of those policy documents that venture into the realm of rural water tariffs, most guidance is open-ended. For example, the rural water supply strategy in Sierra Leone advocates for tariffs in the “form of levies, monthly payments per household or periodic harvests” (MWR, 2013). Uganda’s rural water O&M framework leaves it up to communities to choose any one of nine methods (MWE, 2011), and the African Development Bank (2010) guidelines present an even greater multiplicity of possibilities relating to how, when and where funds could be collected. Guidance in Malawi and Tanzania simply advises communities to collect “maintenance funds from each user household” and “establish a mechanism to pay the full costs of O&M” respectively (MIWD, 2010; MWLD, 2002). At the more prescriptive end of the spectrum, Ghana’s Community Water and Sanitation Agency (2011) advises handpumps should be accompanied by pay-as-you-fetch (PAYF) revenue collection systems, while Zambia’s handpump O&M guidelines suggest fixed financial contributions could be made monthly, bi-annually or annually (MLGH, 2007).

Data from over 90,000 waterpoints fitted with handpumps in five countries indicate the most common revenue collection strategy is reactive contributions when a handpump breaks down, followed by fixed fee payments (weekly, monthly, or annual) and volumetric PAYF fees (Table 1). Significant variation in preferred strategies is evident across countries and regions.<sup>18</sup> For instance, while PAYF appears to be relatively uncommon in Table 1, between 50-90% of communities in certain regions of Ghana have such a system in place (Komives *et al.*, 2008; Adank *et al.*, 2013). Diverse approaches have even been noted within individual villages in Mali (Jones, 2010). To add to the complexity, communities sometimes assume hybrid, dynamic or differential tariff permutations based on a host of factors, including membership status, purpose of water use, family size, livestock ownership, religious holidays, and rainfall season.

Table 1 – Prevalence of revenue collection approaches among handpump users in selected sub-Saharan African countries (modified from Foster & Hope (*forthcoming*))

| Country            | Scope      | No. handpumps | Handpumps with fee collection (%) | Frequency of payment (%) |                         |                         |
|--------------------|------------|---------------|-----------------------------------|--------------------------|-------------------------|-------------------------|
|                    |            |               |                                   | Upon breakdown           | Per jerrican            | Fixed (per time period) |
| Kenya <sup>a</sup> | 8 counties | 2,119         | 52.2 <sup>b</sup>                 | 8.1                      | 21.8                    | 22.2                    |
| Liberia            | National   | 9,388         | 46.8 <sup>c</sup>                 | 30.2                     | -                       | 16.6                    |
| Sierra Leone       | National   | 12,003        | 20.0 <sup>d</sup>                 | 15.5                     | 2.3                     | 2.1                     |
| Tanzania           | National   | 21,884        | 42.1 <sup>e</sup>                 | 13.2                     | 6.8                     | 22.0                    |
| Uganda             | National   | 47,200        | 42.8                              | -                        | -                       | -                       |
| <b>Total</b>       |            | <b>92,594</b> | <b>40.4 (37.6<sup>f</sup>)</b>    | <b>17.4<sup>f</sup></b>  | <b>4.7%<sup>f</sup></b> | <b>15.5<sup>f</sup></b> |

Authors' analysis based on publicly available waterpoint datasets (Virtual Kenya, 2015; National Water Sanitation and Hygiene Promotion Committee, 2014; Sierra Leone STATWASH Portal, 2014; Government of Tanzania, 2014; Government of Uganda, 2012)

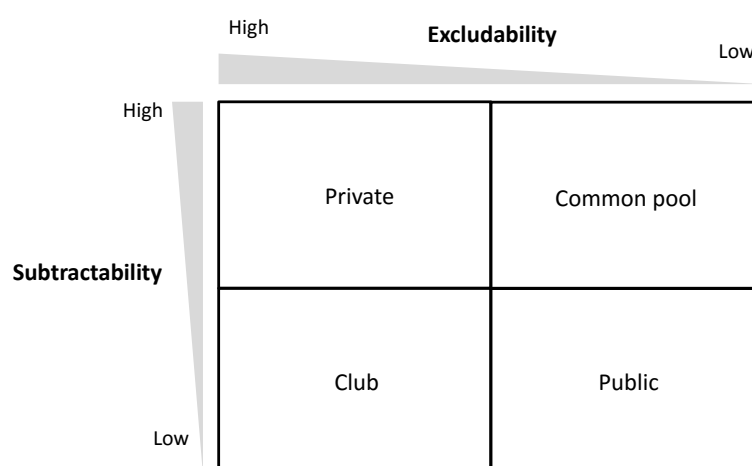
<sup>a</sup> Busia, Embu, Isiolo, Kajiado, Kiambu, Kisumu, Kwale, Turkana. <sup>b</sup> Excludes 229 handpumps with unknown revenue collection regime. <sup>c</sup> Excludes 51 handpumps with unknown revenue collection regime. <sup>d</sup> Excludes 682 handpumps which were still under construction, and 12 handpumps with unknown revenue collection regime. <sup>e</sup> Excludes 2,899 handpumps with unknown revenue collection regime. <sup>f</sup> Excludes data from Uganda, which do not distinguish between payment modalities.

<sup>18</sup> It is unclear why communities adopt the revenue collection approaches they do. Varied strategies may be a reflection of the specific attributes and priorities of each individual community. Users might conceptualise and value the *quid pro quo* for different approaches in various ways. A reactive payment upon breakdown funds a known repair activity, a regular fixed fee payment assures a user unlimited access to the waterpoint for a certain period of time, and under a PAYF model users simply buy a specified volume of water.

## 1.2 Community waterpoints: common-pool resource or private good?

Economists commonly characterise goods and services according to the two-fold criteria of subtractability and excludability (Figure 2). Excludability refers to the degree to which consumption of a good or service can be denied. Subtractability – also known as rivalry – describes the extent to which one’s person consumption reduces the availability of the good or service for others. The criterion of subtractability shot to prominence on the back of a seminal paper by Samuelson (1954), who introduced the concept as a way of distinguishing between private and public goods. In the ensuing years, the importance of excludability received greater attention by way of landmark analyses of collective action (Olson, 1965), common-pool resources (Hardin, 1968) and club goods (Buchanan, 1965). Soon after, Musgrave & Musgrave (1973) combined the attributes of excludability and subtractability into a single framework for the first time, with Ostrom & Ostrom (1977) subsequently populating their two-by-two matrix with four types of goods: (i) private goods, (ii) public goods, (iii) club (toll) goods, and (iv) common-pool resources.

Figure 2 – Classification of goods and services according to excludability and subtractability (based on Musgrave & Musgrave, 1973; Ostrom & Ostrom 1977)



Depending on the context, water can assume features of any of the four types of goods (Haneman, 2006; Young & Loomis, 2014). The same can be said of rural drinking water supplies in sub-Saharan Africa specifically. For example, water delivered by a rural piped scheme could be considered a

private good as it is both excludable and subtractable.<sup>19</sup> A high-yielding open well where abstraction generates virtually zero marginal cost and there is no congestion could take the form of a public good or a club good, depending on access conditions. Community waterpoints fitted with handpumps in rural sub-Saharan Africa have typically been regarded as a common-pool resource (CPR) (Naiga & Penker, 2014; Foster & Hope, *forthcoming*), on the premise that use is subtractable and non-excludable. This assumption of non-excludability is grounded upon the observation that measures to prevent non-contributors from accessing the handpump are often weak or absent. Subtractability reflects the reality that use of the handpump incurs a marginal cost greater than zero. This marginal cost can be realised in several forms. First and foremost, handpump use incurs a unit operation and maintenance cost (i.e. 'wear and tear'). Even though systems are hand-operated, each unit of use reduces the time before the next failure occurs. Second, queues and congestion at waterpoints can occur, particularly at peak times of the day and during periods of low rainfall. At such times every unit of use increases that congestion. Third, where yield or water tables are low enough, each unit of use may temporarily reduce the availability of the resource for others.

In his seminal paper *Tragedy of the Commons*, Hardin (1965) predicted overuse and degradation would be the inevitable fate of CPRs. That is, narrow self-interest of users would trump cooperative endeavours to manage the resource collectively. Applying this pessimistic forecast to communal waterpoints fitted with handpumps, one would expect rampant free-riding, resulting in insufficient funds to carry out repair work when the system breaks down. However, the reality across a range of resource types has proved far more complex than Hardin's simplified prognosis, and there are examples of both successful and failed attempts to sustainably manage CPRs (Wade, 1987; Basurto & Ostrom, 2009). The same is true of community waterpoints in rural sub-Saharan Africa. There are instances of communities continuously collecting high rates of payment and keeping

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<sup>19</sup> Note, characterizing a good as a private good does not necessitate that good is subject to a private property regime.

waterpoints operating over many years, just as there are cases where communities fail to establish and sustain collective payment systems, with waterpoints ultimately falling into a state of disrepair (Foster & Hope, *forthcoming*).

Non-excludability need not be an inherent property of waterpoints if communities are able to apply institutional and physical measures to restrict access (Koehler *et al.*, 2015). Generally speaking, the characteristic of excludability is both mutable and a question of degree (Baumol, 1986). To be effective, waterpoint exclusion measures demand a confluence of reliable information flows so non-payers are identifiable; a motivated management committee or individual so revenue is collected and rules are enforced; and either the deployment of personnel dedicated to regulating access or establishment of strong social norms. The time and location at which funds are collected from water users are likely to be important determinants in how easily these criteria can be met. At the less excludable end of the spectrum, ad hoc payments upon breakdown invariably involve a temporal lag between water use and financial contributions. Under such arrangements, systematically tracking water use is difficult, and users have already obtained the benefit of water consumption by the time the funds are needed. Regular fixed (e.g. monthly) payments and water use are notionally more contemporaneous, although evidence from rural Kenya suggests late payment is the norm, and around one in four households avoid payment altogether (Foster & Hope, *forthcoming*). In contrast, under a PAYF regime use of the waterpoint is contingent on a pre-payment that coincides in both space and time, thereby reducing the risk of free-riding. As excludability is an inherent basis of PAYF arrangements, community waterpoints morph into a private good, and the collective action demands are lessened. Excludability – and by extension PAYF – therefore offers *prima facie* advantages from a financial sustainability perspective.

The excludability sword may be double edged, however. By definition, it results in restricted access for non-payers. The concept of accessibility lies at the heart of global and national policy goals,

frameworks, and laws, most notably the SDG for universal access to safe drinking water and the human right to water (OHCHR, 2002; UNGA, 2010). Any comprehensive evaluation of waterpoint revenue collection approaches must therefore consider both the consequences for the long term performance of the water service, and the drinking water source choices of households. In this way, a holistic analysis of PAYF arrangements must navigate similar equity concerns pertaining to the use of prepaid meters in urban areas (Heymans *et al.*, 2014; Wesson, 2011).

The ramifications of revenue collection approaches extend beyond just a waterpoint's level of excludability, and there are a number of possible trade-offs even within accessibility and sustainability domains. For example, PAYF allows for small incremental payments that may be more conducive to cash flows of low income households compared with lump sum reactive payments or monthly contributions – however this assumes communities enjoy a year-round cash economy and that households have cash-in-hand on a daily basis. Sustainability too points in conflicting directions. PAYF arrangements may be susceptible to misappropriation of saved funds, but they are often coupled with an attendant who is paid a proportion of water sales, and therefore incentivised to ensure a high level of revenue is collected and repairs are carried out as promptly as possible. Conversely, payment upon breakdown circumvents risks pertaining to misuse of funds, but is encumbered with the disadvantage of having no cash immediately available to draw upon when repairs are needed.

The pros and cons are necessarily hypothetical, as there is a dearth of empirical evidence on the sustainability and access implications of different revenue collection approaches. Some observations are supportive of PAYF systems in terms of income, though they reveal little about whether greater revenue levels translate into more reliable water services. Based on findings from a seminal handpump sustainability study, Harvey (2007) asserts that PAYF arrangements draw in the most cash. Private operators of rural waterpoints – though uncommon – also tend to prefer a PAYF revenue model (Keesiga & Kimera, 2014; Haas & Nagarajan, 2011), suggestive of superior

income generation. Even sparser are insights into the access outcomes associated with different approaches. Churchill et al. (1987) ventures a rare opinion on the matter, cautioning that tying waterpoint fees to volumetric consumption could discourage water use among low-income households, or cause them to revert to unimproved sources.

### **1.3 Study aims**

This study seeks to empirically assess whether choice of revenue collection approach – particularly PAYF – impacts the sustainability and use of community waterpoints on the south coast of Kenya. While controlling for potentially confounding factors, the analyses set out to test whether different revenue collection approaches lead to disparities in the amount of cash collected, average waterpoint downtime per breakdown, and use of unimproved drinking water sources. The analyses utilise a unique dataset integrating a county-wide waterpoint census, large-scale household survey and water committee financial records.

## **2. Methods**

### **2.1 Study site**

The study site, Kwale County, is located on the south coast of Kenya. In 2013, Kwale had a population of around 730,000 people; 82% of whom lived in rural areas (Commission on Revenue Allocation, 2013). Based on a poverty gap index measure, the region is one of the most impoverished in Kenya, ranked 41st out of 47 counties (Commission on Revenue Allocation, 2013). According to the census in 2009, 37% of the county's households accessed waterpoints drawing on groundwater (Government of Kenya, 2009). Notably, Kwale was the location for the first ever large-scale deployment of Afridev handpumps, and thus holds an important place in the history of rural water supply programs in sub-Saharan Africa (Baumann & Furey, 2013). Between 1983 and 1995, around 580 boreholes were drilled and fitted with Afridev handpumps, most drawing water from an unconfined aquifer in Pleistocene sands and coral limestones. Community-based committees and revenue collection systems were established alongside the infrastructure investments, and the

early results were hailed as a successful example of community-based water supply management (Rondinelli, 1991; Black, 1998).<sup>20</sup>

## 2.2 Data collection

Data underpinning this study were collected in three separate campaigns: (a) a county-wide census of 571 waterpoints fitted (or formerly fitted)<sup>21</sup> with Afridev handpumps; (b) a survey of 3,361 households<sup>22</sup> within the waterpoint service areas; and (c) an audit of water committee financial records.<sup>23</sup> Both the waterpoint census and household surveys were undertaken by trained local enumerators and delivered in local languages, predominantly Swahili and Digo. Prior to data collection, research permits and approvals were obtained from the Government of Kenya's National Council of Science and Technology and the Central University Research Ethics Committee at the University of Oxford.

The waterpoint census was carried out in August 2013, and captured technical, institutional, operational, financial and geographical information through structured interviews. Waterpoints were excluded from this study if they were not for communal use, or the handpump had been replaced by a submersible pump. Table 2 presents the operational and financial status of all waterpoints that met the inclusion criteria. As part of the waterpoint census, respondents were also asked whether written financial records were kept. For those communities who answered in the affirmative (n=213), a follow-up visit was undertaken in January 2014.<sup>24</sup> At 100 communities, financial records were located and photographed for later analysis.

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<sup>20</sup> A project evaluation report suggests implementers initially urged communities to establish monthly fees (Narayan-Parker 1988).

<sup>21</sup> 19 of these waterpoints were originally fitted with Afridev handpumps but had subsequently been upgraded to submersible pumps.

<sup>22</sup> 12 cases were subsequently excluded from the dataset as respondents had a poor understanding of the questions and/or there were concerns about the accuracy of the responses.

<sup>23</sup> Further details of data collection and summary statistics can also be found in Foster & Hope (*forthcoming*).

<sup>24</sup> For security reasons, 18 handpumps at which financial records were reportedly kept could not be visited.

Table 2 – Operational and financial status of communal waterpoints fitted with Afridev handpumps

|                      | Functional  | Non-functional (< 1 year) | Non-functional (> 1 year) | Total       |
|----------------------|-------------|---------------------------|---------------------------|-------------|
| <b>Advanced fees</b> | 161 (53.1%) | 19 (46.3%)                | 75 (43.1%)                | 255 (49.2%) |
| Fixed fees           | 86 (28.4%)  | 8 (19.5%)                 | 36 (4.1%)                 | 130 (25.1%) |
| PAYF                 | 75 (24.8%)  | 11 (26.8%)                | 39 (22.4%)                | 125 (24.1%) |
| <b>Reactive fees</b> | 66 (21.8%)  | 7 (17.1%)                 | 16 (9.2%)                 | 89 (17.2%)  |
| <b>No fees</b>       | 76 (25.1%)  | 15 (36.6%)                | 82 (47.1%)                | 173 (33.4%) |
| <b>Total</b>         | 303 (100%)  | 41 (100%)                 | 174 (100%) <sup>a</sup>   | 518 (100%)  |

<sup>a</sup> Includes 1 waterpoint where revenue collection approach could not be determined

Between August 2013 and January 2014, an in-depth questionnaire was administered to a random sample of 3,361 households within the service area of 531 communal waterpoints (mean of 6.3 households per waterpoint, 4.6 residents per household). The survey captured demographic, socio-economic, and water use information for each household and its members. Twelve household cases were subsequently excluded from the study as the enumerator recorded concerns over the accuracy of the responses, or believed the respondent had a poor understanding of the questions asked.

### 2.3 Analysis

Analysis of sustainability outcomes was conducted to (a) quantify the amount of revenue collected per waterpoint for both fixed fee and PAYF systems; (b) ascertain whether revenue amounts were significantly different between the two revenue collection approaches; and (c) determine whether revenue collection approach was significantly associated with waterpoint downtime. Access outcomes were evaluated by determining whether any revenue collection approach was significantly associated with choice of unimproved drinking water sources. All analyses were performed using the statistical software package SPSS (Version 21).

Financial data were collated and aggregated separately for three types of recorded revenue: PAYF records presented as daily water sales; fixed fee records in the form of payments itemised by household (hereafter termed “fixed fee payments”); and fixed fee records in the form of general cash flows (hereafter termed “fixed fee cash income”). Although they covered fewer handpumps

than the fixed fee payment records, the fixed fee cash income records had the advantage of including additional revenue that derived from alternative income sources such as non-member PAYF fees, membership registration payments, reactive or special contributions, and fines imposed on rule-breakers. As a result, they were arguably a truer reflection of how funds are cobbled together in different ways. High quality records were denoted where all 12 months of the year were represented, thereby reducing the risk of bias and enabling monthly-standardised totals to be calculated. In order to assess the sufficiency of revenue data, expenditure data were also collated, and denoted as being operation and/or maintenance in nature. As the records spanned between 1987 and 2013, all monetary amounts were converted to 2013 values by applying deflator factors obtained from the World Bank Development Indicators database (World Bank, 2014). Figures in 2013 Kenyan shillings were then converted to US dollars using an exchange rate of 1 USD to 86.1 KES.

To compare financial performance, summary statistics were first calculated for each type of revenue. To ascertain whether there was a significant difference in the revenue amounts raised under different approaches, independent samples t-tests were performed. Where homogeneity of variances was violated the Welch t-test was run instead. Due to concerns regarding presence of outliers and non-normal distributions, Mann-Whitney U tests were also run to determine if there were differences in the median values. Average revenue and expenditure data were then calculated by month to determine the financial performance of different approaches throughout the year, particularly in response to rainfall patterns.

To determine whether revenue collection approach influenced waterpoint performance, a dataset was created which included one outcome variable (downtime), seven control variables, and four dichotomous variables of interest: (i) PAYF vs Fixed, (iii) PAYF vs Ad Hoc, (iv) Fixed vs Ad Hoc, (v) PAYF vs Other. Downtime was defined as the number of days between the point of initial breakdown and subsequent repair. To minimise recall bias, the analysis was limited to those

waterpoints that had broken down and been repaired at least once in the previous 12 months. The number of breakdown events for each waterpoint was limited to five. On the basis that all included waterpoints had undergone at least one repair in the previous 12 months (which must have been financed from some source), communities reporting that they collected no fees were combined with those that reported they collected funds upon breakdown into a single category labelled “ad hoc”. Control variables were chosen based on their plausibility as factors that might influence waterpoint downtime, as drawn from empirical and theoretical rural water literature (Table 3).<sup>25</sup>

Table 3 –Definitions of variables included in the sustainability analysis

| Variables                                | Definition                                                                                                                                                                       | Data source <sup>a</sup> |
|------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------|
| <b>Outcome variables</b>                 |                                                                                                                                                                                  |                          |
| Downtime                                 | Number of days a waterpoint is non-functional for each breakdown event                                                                                                           | WC                       |
| Annual revenue                           | Cash income per waterpoint per year (2013, USD)                                                                                                                                  | FR                       |
| <b>Explanatory variables of interest</b> |                                                                                                                                                                                  |                          |
| PAYF                                     | Pay-as-you-fetch revenue collection (per bucket/jerrican)                                                                                                                        | WC & FR                  |
| Fixed fee                                | Fixed fees paid on a periodic basis (per week, month, year)                                                                                                                      | WC & FR                  |
| Ad Hoc                                   | Fees not regularly collected in advance of breakdown                                                                                                                             | WC                       |
| <b>Control variables</b>                 |                                                                                                                                                                                  |                          |
| WP-HH Distance                           | Average distance between the waterpoint and user households (m)                                                                                                                  | WC & HS                  |
| Community mechanic                       | 0 = Handpump mechanic lives in different community to waterpoint<br>1 = Handpump mechanic lives in same community as waterpoint                                                  | WC                       |
| pH                                       | 0 = pH of groundwater <6.5 <sup>c</sup><br>1 = pH of groundwater ≥ 6.5                                                                                                           | WC                       |
| Taste                                    | Average household rating of water taste across wet and dry season (1 = good, 0 = average, -1 = poor)                                                                             | HS                       |
| Welfare index                            | Multi-dimensional index incorporating household composition, dwelling structure and asset ownership measures                                                                     | HS                       |
| Night-time lights                        | Location-specific light values extracted from a cloud-free composite image of persistent night-time lighting from 2013 <sup>b</sup> (used as proxy measures for settlement type) | EOG                      |

<sup>a</sup> WC = waterpoint census; FR = financial records; HS = household survey; EOG = Earth Observation Group, National Centers for Environmental Information.

<sup>b</sup> Version 4 DMSP-OLS Nighttime Lights Time Series, image and data processing by NOAA's National Geophysical Data Center. See <http://ngdc.noaa.gov/eog/dmsp/downloadV4composites.html>.

<sup>c</sup> A pH value of 6.5 was chosen based on a study by Langenegger (1989) which found the rate of handpump corrosion increased significantly below this point. The sensitivity of results to this chosen cut-off was assessed by rerunning analyses with different cut-offs between 6.0 through to 7.0 at intervals of 0.1. Any significantly different results arising from this sensitivity analysis are indicated in footnotes accompanying results tables.

<sup>25</sup> For a detailed description of why these control variables were chosen, see Foster & Hope (*forthcoming*).

After summary statistics were calculated, Generalised Estimating Equations (GEE) were run to ascertain whether the revenue collection variables of interest exhibited an association with downtime, while controlling for potential confounders. The GEE was the chosen analytical method as it adjusts for the autocorrelation between breakdown events pertaining to the same waterpoint, which would otherwise violate the independence assumption underpinning traditional regression techniques. To assess the influence of outcome variable outliers, GEEs with a log-transformed outcome variable were run, and results were compared. A series of logistic regression GEEs were then run with outcome variables dichotomized at different downtime thresholds, allowing for a more nuanced understanding of the relationship between revenue collection approach and operational performance.

In order to appraise the access implications of each revenue collection approach, first the prevalence of alternative drinking water sources was calculated for all three revenue collection approaches in both wet and dry season. Second, the odds of a household opting for an unimproved drinking water source was determined across revenue collection approaches for both wet and dry season. This regression analysis again employed GEEs to adjust for clustering of households around waterpoints, and controlled for user perceptions of taste and distance between the household and the waterpoint. The definitions of unimproved sources were drawn from the Joint Monitoring Programme classifications (UNICEF/WHO, 2015a). The analysis was disaggregated by welfare thirds (tertiles) to assess whether associations were dependent on socio-economic status. These welfare tertiles were derived from a multi-dimensional welfare index constructed by applying principal component analysis to household socio-economic indicators, including dwelling structure, asset ownership, and education levels.

### **3. Results**

#### **3.1 Sustainability**

Table 4 presents revenue totals for both PAYF and fixed fee revenue collection systems. Financial records used to calculate revenue covered 35.4 years of operation for PAYF waterpoints, 243.4 years for fixed fee payment records, and 89.5 years for fixed fee cash income records. For the fixed fee payment records, monthly payments were the dominant interval, accounting for 81.6% of records by duration, followed by annual (14.4%), bimonthly (2.1%), and weekly (1.9%).

Table 4 – Summary statistics for advanced fee revenue collection

| Measure                                    | All financial records |                  |                   | High quality financial records only <sup>a</sup> |                  |                   |
|--------------------------------------------|-----------------------|------------------|-------------------|--------------------------------------------------|------------------|-------------------|
|                                            | PAYF                  | Fixed (payments) | Fixed (cash flow) | PAYF                                             | Fixed (payments) | Fixed (cash flow) |
| Years of data                              | 35.4                  | 243.4            | 89.5              | 34.4                                             | 223.3            | 76.4              |
| No. waterpoints                            | 18                    | 66               | 40                | 15                                               | 40               | 17                |
| <b>Annual revenue per waterpoint (USD)</b> |                       |                  |                   |                                                  |                  |                   |
| Mean                                       | 441.1                 | 119.2            | 299.6             | 395.5                                            | 124.2            | 253.8             |
| (SD)                                       | (414.1)               | (96.1)           | (294.6)           | (415.3)                                          | (99.0)           | (176.3)           |
| Median                                     | 276.6                 | 90.5             | 219.3             | 255.2                                            | 91.6             | 187.6             |

<sup>a</sup> Annual revenue calculations are month-standardised to account for seasonal differences

On average, PAYF regimes generated more revenue than fixed fee systems based on both payment and cash flow records. High quality annual PAYF sales per waterpoint were 218% greater than fixed fee payment records and 56% higher than fixed fee cash income records. Independent-samples t-tests found the mean difference in revenue between PAYF and fixed fee payment records was statistically significant (all records  $p=0.004$ ; high quality records  $p=0.025$ ) (Table 5). However, the same test found the mean difference between fixed fee cash income records and PAYF records did not attain statistical significance. Due to the presence of outliers and non-normal distribution of residuals, the Mann-Whitney U tests were also run. They yielded similar results, with median revenue collection amount for PAYF significantly higher than for fixed fee payment records (All records  $p<0.001$ ; high quality records  $p=0.001$ ), but not for fixed fee cash income records.

Table 5 – Annual waterpoint revenue differences between revenue collection approaches

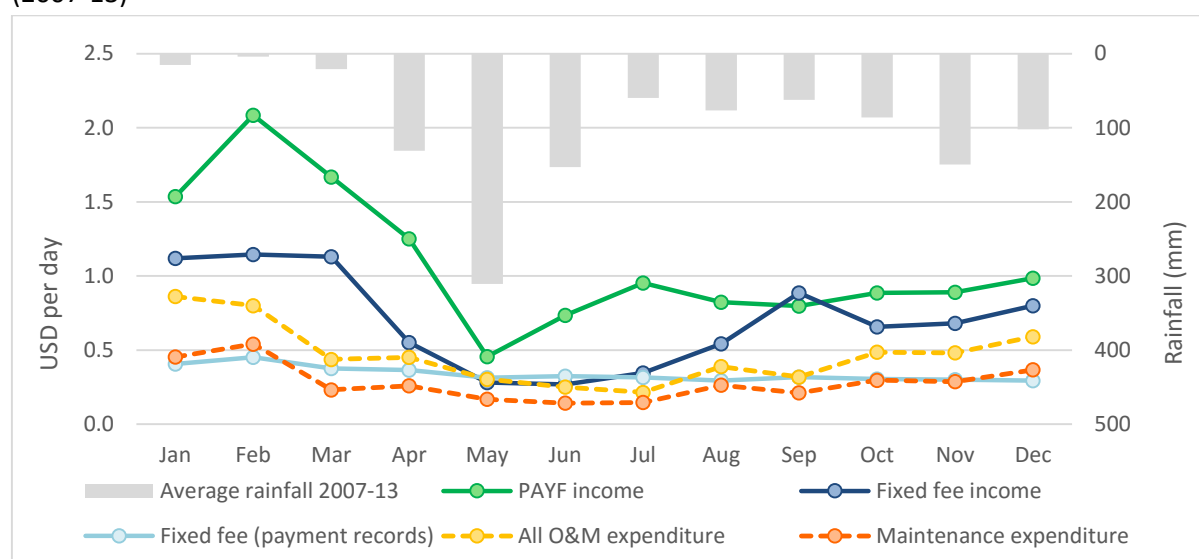
| Records                          | Independent samples t-test             |              | Mann-Whitney U test |                     |                  |
|----------------------------------|----------------------------------------|--------------|---------------------|---------------------|------------------|
|                                  | Mean Diff (95% CI)                     | p            | U                   | Mean rank           | p                |
| <b>PAYF vs Fixed (payments)</b>  |                                        |              |                     |                     |                  |
| All                              | <b>321.9 (114.9-528.9)<sup>a</sup></b> | <b>0.004</b> | <b>992</b>          | <b>64.6 vs 36.5</b> | <b>&lt;0.001</b> |
| High quality                     | <b>271.3 (39.8-502.8)<sup>a</sup></b>  | <b>0.025</b> | <b>470</b>          | <b>39.3 vs 23.8</b> | <b>0.001</b>     |
| <b>PAYF vs Fixed (cash flow)</b> |                                        |              |                     |                     |                  |
| All                              | 141.5 (-49.2-332.2)                    | 0.143        | 444                 | 34.2 vs 27.4        | 0.158            |
| High quality                     | 141.7 (-100.4-383.9) <sup>a</sup>      | 0.235        | 149                 | 17.9 vs 15.2        | 0.433            |

Note: Bold text indicates statistically significant association ( $p < 0.05$ ).

<sup>a</sup> Welch t-test performed as homogeneity of variances was violated

The revenue generated by both PAYF and fixed fee strategies varied considerably by month, and appeared to rise and fall inversely with rainfall levels (Figure 3). A similar pattern was also evident in expenditure. PAYF water sales peaked in February in the midst of the dry season, and reached a minimum in May during the period of heaviest rainfall. Fixed fee cash income followed a comparable trend, with a high point in February and a low point in June. The seasonal fluctuations were less marked for fixed fee payment records, with a maximum in February and minimum in August. Relative to their respective monthly minima, revenue levels in February were 4.6 times greater for PAYF, 4.3 times greater for fixed fee cash income records and 1.5 times greater for fixed fee payment records. Equivalent expenditure ratios were 3.8 for maintenance costs, and 3.7 for all O&M costs. Notably, revenue from fixed fee cash income records was on par with fixed fee payment records during the rainy period (May-Jul) but was discernibly higher during the dry period between January and March. Average monthly PAYF revenue exceeded average O&M costs across all months – in contrast, average fixed fee payments dropped below maintenance costs between December and February.

Figure 3 – Average waterpoint revenue, expenditure and rainfall in Msambweni Sub-County (2007-13)<sup>a</sup>



<sup>a</sup> Monthly rainfall data extracted from Kwale Drought Monitoring Bulletins prepared by Kenya's National Drought Management Authority (<http://www.ndma.go.ke/>)

Table 6 summarizes the characteristics of waterpoints included in the downtime analysis, and Table 7 presents the GEE results. Overall, the mean downtime was 32.3 days (median 7 days), with PAYF waterpoints experiencing average downtime that was 21.8 days and 23.1 days less than fixed fees and ad hoc arrangements respectively. When adjusting for potential confounders, the difference in downtime between PAYF arrangements and both fixed fee and ad hoc revenue collection was statistically significant (equivalent to 15.9 days and 18.6 days respectively). All else held constant, there was no significant difference between fixed fee and ad hoc arrangements. When running the GEEs with the natural log of downtime, the associations were no longer significant, suggestive of influential outliers.

Table 6 – Characteristics of waterpoints included in GEE models

| Variables                | Ad hoc (n=95) |      | Fixed fees (n=62) |       | PAYF (n=43) |      |
|--------------------------|---------------|------|-------------------|-------|-------------|------|
|                          | Mean          | SD   | Mean              | SD    | Mean        | SD   |
| <b>Outcome variable</b>  |               |      |                   |       |             |      |
| Downtime                 | 36.0          | 76.0 | 34.7              | 72.4  | 12.9        | 28.7 |
| <b>Control variables</b> |               |      |                   |       |             |      |
| WP-HH Distance           | 131.2         | 61.2 | 143.5             | 116.3 | 132.6       | 82.1 |
| Community mechanic       | 0.43          | 0.50 | 0.55              | 0.50  | 0.51        | 0.51 |
| pH                       | 0.70          | 0.46 | 0.82              | 0.39  | 0.56        | 0.50 |
| Taste                    | 0.47          | 0.56 | 0.65              | 0.42  | 0.62        | 0.43 |
| Welfare index            | 6.0           | 2.9  | 7.3               | 2.4   | 7.1         | 2.5  |
| Night-time lights        | 4.0           | 6.0  | 5.5               | 6.4   | 7.7         | 10.0 |

Table 7 - Results of GEE multivariable regression analyses with downtime as outcome variable

| Tariff structure                 | Event downtime |            |                  | Log <sub>e</sub> (event downtime) |      |                    |
|----------------------------------|----------------|------------|------------------|-----------------------------------|------|--------------------|
|                                  | B              | S.E.       | p                | B                                 | S.E. | p                  |
| <b>PAYF vs Fixed</b>             | <b>-15.9</b>   | <b>6.5</b> | <b>0.015</b>     | -0.34                             | 0.22 | 0.114              |
| <b>PAYF vs Ad hoc</b>            | <b>-18.6</b>   | <b>6.1</b> | <b>0.002</b>     | -0.34                             | 0.23 | 0.136              |
| <b>Fixed vs Ad hoc</b>           | -4.5           | 8.3        | 0.583            | -0.08                             | 0.22 | 0.716              |
| <b>PAYF vs Other<sup>a</sup></b> | <b>-16.5</b>   | <b>4.3</b> | <b>&lt;0.001</b> | -0.36                             | 0.19 | 0.056 <sup>b</sup> |

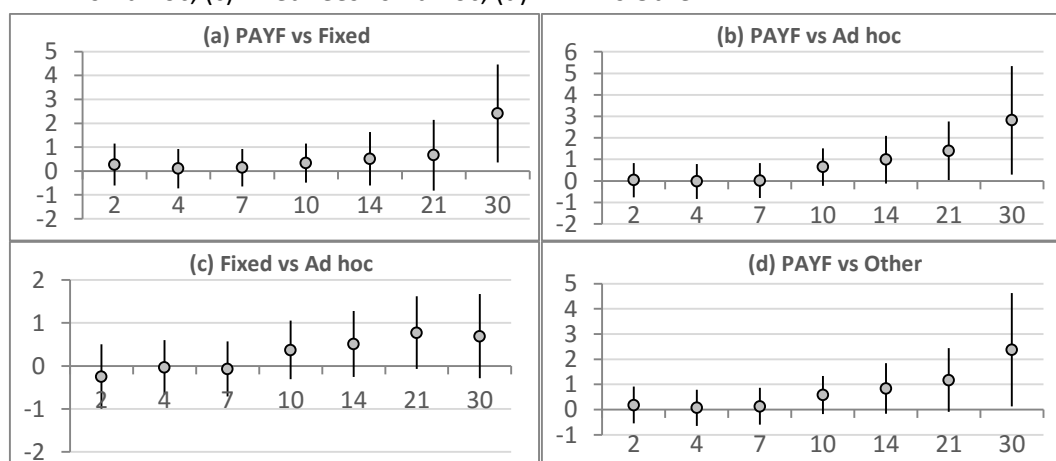
Note: Bold text indicates statistically significant association ( $p < 0.05$ ). Results adjust for WP-HH Distance, community mechanic, pH, taste, welfare index, and night-time lights.

<sup>a</sup> 'Other' comprises fixed and ad hoc fees.

<sup>b</sup> p-value dropped below 0.05 when applying pH cut-offs of 6.6-7.0.

The GEE logistic regression analyses in Figure 4 demonstrate that the adjusted odds of a waterpoint being repaired within 21 days and 30 days were significantly higher with PAYF systems relative to ad hoc payments. Likewise, the adjusted odds of having repairs carried out within 30 days were significantly higher for PAYF systems compared with fixed fees. There was no significant difference in adjusted odds for any payment comparison between the downtime thresholds of 2, 4, 7, 10, and 14 days. Nor was there any significant difference at any threshold between fixed fees and ad hoc payments.

Figure 4 - Log odds and 95% confidence intervals by downtime threshold for (a) PAYF vs Fixed, (b) PAYF vs Ad hoc, (c) Fixed fees vs Ad hoc; (d) PAYF vs Other<sup>a,b</sup>



<sup>a</sup> X-Axis is downtime days, Y-axis is log odds of experiencing downtime less than the number of days specified on the X-axis, for one revenue collection approach relative to another. Vertical lines are 95% confidence intervals. GEEs controlled for WP-HH Distance, community mechanic, pH, taste, productive use, welfare index, and night-time lights.

<sup>b</sup> 'Other' comprises fixed and ad hoc fees.

### 3.2 Access

The proportion of households opting for alternative drinking water sources by revenue collection approach is presented in Figure 5, and adjusted odds ratios for unimproved drinking water source use are summarised in Table 8. In both wet and dry season, use of alternative water sources was highest among households located within the service area of waterpoints coupled with ad hoc payment arrangements (21.7% in dry season; 23.8% in wet season), followed by PAYF (15.4%; 18.1%), and fixed fees (12.3%; 12.3%). When adjusting for distance to water source and perceived taste, households surrounding waterpoints with PAYF fees were significantly more likely to opt for unimproved water sources than those in the vicinity of waterpoints with fixed fees, a relationship which was evident in both wet and dry seasons. However the association was not significant for the lowest welfare third. Relative to ad hoc fees, PAYF arrangements were only associated with use of unimproved drinking water sources during the wet season for the middle welfare tertile. Taste and distance also emerged as significant predictors of unimproved water source use across seasons and welfare strata.

Figure 5 – Percentage of households using alternative drinking water sources by revenue collection approach and season

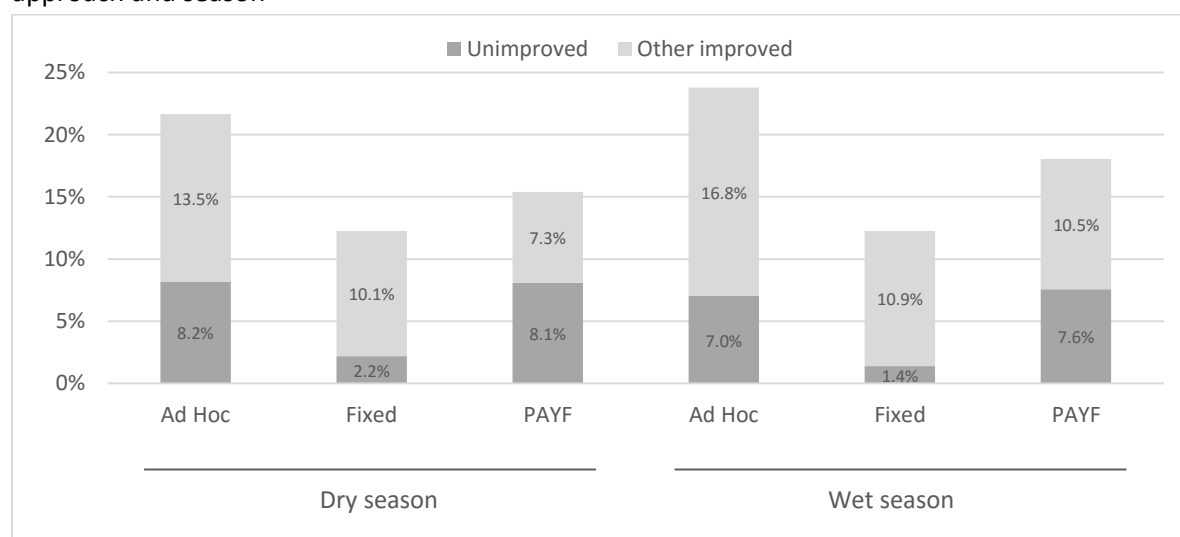


Table 8 - Results of GEE multivariable regression analyses with unimproved drinking water source as outcome variable

| Welfare index          | Variables | Dry season                 |                  | Wet season                 |                  |
|------------------------|-----------|----------------------------|------------------|----------------------------|------------------|
|                        |           | Odds Ratio (95% CI)        | p                | Odds Ratio (95% CI)        | p                |
| Tertile 1<br>(Lowest)  | Tariff    |                            |                  |                            |                  |
|                        | PAYF      | 1                          |                  | 1                          |                  |
|                        | Fixed     | 0.481 (0.131-1.763)        | 0.270            | 0.369 (0.108-1.260)        | 0.112            |
|                        | Ad Hoc    | 1.144 (0.485-2.698)        | 0.758            | 0.849 (0.404-1.788)        | 0.667            |
|                        | Taste     | <b>0.384 (0.248-0.596)</b> | <b>&lt;0.001</b> | <b>0.469 (0.310-0.710)</b> | <b>&lt;0.001</b> |
| Tertile 2              | Distance  | 1.002 (1.000-1.004)        | 0.109            | 1.001 (0.999-1.003)        | 0.341            |
|                        | Tariff    |                            |                  |                            |                  |
|                        | PAYF      | 1                          |                  | 1                          |                  |
|                        | Fixed     | <b>0.158 (0.035-0.718)</b> | <b>0.017</b>     | <b>0.105 (0.025-0.447)</b> | <b>0.002</b>     |
|                        | Ad Hoc    | 0.624 (0.286-1.362)        | 0.237            | <b>0.406 (0.173-0.956)</b> | <b>0.039</b>     |
| Tertile 3<br>(Highest) | Taste     | <b>0.297 (0.184-0.478)</b> | <b>&lt;0.001</b> | <b>0.318 (0.194-0.520)</b> | <b>&lt;0.001</b> |
|                        | Distance  | 1.002 (1.000-1.005)        | 0.074            | <b>1.003 (1.001-1.006)</b> | <b>0.004</b>     |
|                        | Tariff    |                            |                  |                            |                  |
|                        | PAYF      | 1                          |                  | 1                          |                  |
|                        | Fixed     | <b>0.066 (0.004-0.995)</b> | <b>0.050</b>     | n.a.                       |                  |
| All                    | Ad Hoc    | 1.351 (0.509-3.586)        | 0.546            | 0.997 (0.333-2.986)        | 0.995            |
|                        | Taste     | <b>0.271 (0.169-0.436)</b> | <b>&lt;0.001</b> | <b>0.275 (0.160-0.473)</b> | <b>&lt;0.001</b> |
|                        | Distance  | <b>1.004 (1.002-1.006)</b> | <b>&lt;0.001</b> | <b>1.003 (1.001-1.006)</b> | <b>0.018</b>     |
|                        | Tariff    |                            |                  |                            |                  |
|                        | PAYF      | 1                          |                  | 1                          |                  |
|                        | Fixed     | <b>0.107 (0.027-0.427)</b> | <b>0.002</b>     | <b>0.123 (0.048-0.314)</b> | <b>&lt;0.001</b> |
|                        | Ad Hoc    | 0.768 (0.407-1.451)        | 0.416            | 0.769 (0.421-1.404)        | 0.392            |
|                        | Taste     | <b>0.402 (0.313-0.517)</b> | <b>&lt;0.001</b> | <b>0.416 (0.319-0.542)</b> | <b>&lt;0.001</b> |
|                        | Distance  | <b>1.002 (1.001-1.004)</b> | <b>0.002</b>     | <b>1.002 (1.001-1.004)</b> | <b>0.002</b>     |

Note: Bold text indicates statistically significant association ( $p < 0.05$ ).

#### 4. Discussion

The analyses offer new insights into how revenue collection approaches adopted by communities influence waterpoint sustainability and drinking water source choices. First, PAYF revenue collection systems generate significantly more revenue than fixed payments, however this advantage is tempered when factoring in additional sources of revenue. Second, revenue and expenditure fluctuate according to rainfall levels, with cash inflows and outflows peaking during the dry season. Third, there was a significant association between PAYF systems and shorter downtime, with a greater likelihood of repairs being carried out within 3-4 weeks of breakdown compared with other revenue collection approaches. Fourth, relative to fixed fees, the adjusted

odds of a household using an unimproved drinking water source is significantly higher when they are located in the vicinity of a PAYF waterpoint.

The higher levels of revenue generated by PAYF contributions agree with the hypothesis that a waterpoint managed as an excludable private good will prevent free-riding. However, the disparity may also in part be linked to the size and frequency of financial contributions involved. The mean PAYF tariff was USD 0.026 per 20 litres, compared to the mean annualised fixed fee tariff of USD 7.18 per household per year. Therefore, on average, a household could only collect 15 litres (less than one standard-sized jerrican) per day under a PAYF model if they were to spend the same amount as the fixed fee average. In other words, PAYF tariffs not only preclude non-payment, they also likely translate into a higher price per unit of consumption.

Revenue summed from fixed fee cash income records tells a moderated story. The total revenue for fixed fee systems more than doubled when factoring in other sources beyond the standard household fee payments, closing the revenue gap with PAYF systems by around half. Of the additional revenue that had a documented source, 55.2% derived from PAYF sales to non-members, 14.1% from reactive contributions, 13.2% for ad hoc special collections, 10.0% from membership fees, 5.6% from sale of goods or spare parts to other communities, and 1.9% from fines related to rule breaking. This demonstrates that revenue collection strategies are far more complex and dynamic than categorical survey responses suggest. It also indicates that 5-15% of the overall revenue for fixed fee systems comes in the form of reactive payments, presumably to plug a shortfall when repairs are needed. This is consistent with the observation that for three months of the year the average maintenance expenditures surpass the average fixed fee payments. PAYF records lacked a similar diversity of revenue streams, suggesting revenue from PAYF sales are generally sufficient to cover O&M costs when they arise, without the need for additional contributions to make up for any deficit.

Although PAYF systems collect more cash, this may potentially reflect a higher cost base. All else held constant, the unit maintenance expenditure requirements for waterpoints should be broadly the same regardless of tariff structure. In contrast to the results, one might expect the total revenue collected under different payment regimes to converge in the long term, once factoring in additional reactive payments. The disparity between PAYF and fixed fee cash income figures could be influenced by usage differences and the need to remunerate PAYF attendants. If PAYF arises where user groups are large, this would clearly translate into more cash income, but could concurrently increase the frequency of failures and drive up annual maintenance costs. The counter argument is that the volumetric nature of PAYF fees might discourage handpump use for needs where water quality is deemed less important, such as bathing and productive uses. Hence, although the analysis divulges differences in the gross income generated by each revenue collection approach, further analysis is needed to determine whether the net incomes exhibit the same variance.

To our knowledge, this is the first time a seasonal trend in revenues and expenditures has been documented for community waterpoints in rural sub-Saharan Africa. This mirrors the observed impact of rainfall on both water consumption and maintenance workloads in rural areas of Kenya and Burkina Faso (Foster, 2012; Curtis et al., 1993). The inverse relationship between revenue and rainfall is likely linked to the increase in availability of alternative water sources during wet season brought about by the creation of surface water bodies, rising groundwater tables, and opportunities to harvest rainwater. During wetter periods, users may switch from the waterpoint to a more convenient or lower-cost alternative source for some or all of their water needs. As one would expect, volumetric PAYF systems appear to be more heavily influenced by rainfall patterns than fixed fee payments. Concurrent with a reduced dependence on the waterpoint, monitoring and enforcement of PAYF access rules may also weaken during wetter periods. In contrast, fixed fees would still be payable regardless of any decrease in abstraction, except where waterpoint use ceases altogether. When factoring in additional revenue sources, fixed fee cash incomes exhibited

far more seasonal variation than fixed fee payments. This discrepancy is probably due to the additional PAYF contributions by non-members and reactive payments which are included in cash flow calculations, both of which are more likely to fall within drier months. This is corroborated by the fact fixed fee cash income from January through to March was 2.5-3.0 times what fixed fee payments were, yet the two data sources yielded similar estimates for the wetter period from April through to July.

The significant relationships observed in the GEEs provide evidence that PAYF systems lead to improved waterpoint performance, to the magnitude of 15-20 days fewer downtime days per breakdown. Greater reserves of cash at hand and stronger incentives to repair waterpoints promptly may both be contributing factors. Surprisingly, there was no significant difference in average downtime between communities contributing fixed fees and those collecting funds on an ad hoc basis, defying the theory that cash at hand would allow for prompter repairs. A possible explanation is that the amount saved in advance under a fixed fee arrangement is often insufficient to cover the cost of a repair and reactive payments are still required anyway. This hypothesis is supported by the cash flow data, which shows reactive contributions are still often needed where fixed fee arrangements are in place. Moreover, although average fixed fee cash income exceeded average maintenance expenditure for all months, the buffer is smaller than that enjoyed by PAYF systems, and therefore less well equipped to handle lumpy and irregular maintenance costs (Hope et al., 2012). Adding weight to this argument is the conclusion that PAYF downtimes are more likely to be kept below 30 days relative to fixed fee arrangements. This may be indicative of costly major repairs which exceed cash reserves for fixed fee systems but not PAYF.

Despite these findings, revenue collection approach is not a panacea for rural water sustainability. While PAYF may reduce the complexity of the collective action challenge, it by no means absolves communities from working collaboratively. Communities and water committees that decide to adopt PAYF still need to agree on, and maintain oversight of, roles, responsibilities and rules. Their

willingness and ability to carry out these tasks effectively are likely influenced by a myriad of social, institutional, and environmental factors (Whittington *et al.*, 2009; Foster, 2013). Though it achieved the shortest downtime relative to other approaches, repairs for PAYF waterpoints in Kwale still took an average of 12.9 days to effect. By most measures, service disruptions of such length are unsatisfactory, and adverse health ramifications of switching to unimproved water sources are likely to materialise before this threshold is reached (Brown & Clasen, 2012). While bolstering revenue collection is critical if waterpoints are to shift from a low-level equilibrium to a virtuous cycle of strong financial and operational performance, so too are other measures to support waterpoint reliability. For this reason, external support is advocated across the spectrum of financial, administrative and technical responsibilities that communities currently assume (Harvey & Reed, 2007; RWSN, 2010; IRC, 2012). Alternative management models that reallocate roles, responsibilities, incentives and risks among communities, government and private enterprise have also been proposed as a pathway forward (Harvey & Reed, 2007; Hope *et al.*, 2012).

While PAYF is associated with superior operational outcomes, it appears to have perverse implications that undermine global and national goals pertaining to safe water access. It is impossible to conclude whether or not the impact of PAYF on safe water access is more borne of users' unwillingness to pay or inability to pay. Interestingly, the increased odds of choosing an unimproved drinking water source for PAYF arrangements relative to fixed fees was significant for households in the top two welfare tertiles. This suggests local cross-subsidies or payment exemptions for the most vulnerable households would be unable to fully address the issue.

Irrespective of whether the results can be explained by an unwillingness or inability to pay, the findings reveal a possible tension between policy prescriptions pertaining to financial sustainability and goals targeting expanded coverage of safe water supplies. On the one hand, the global SDG and the Government of Kenya's Vision2030 promote universal safe water access. So too does the human right to water, as recognised under international law and enshrined in the Kenyan

constitution (UNGA, 2010; Government of Kenya, 2010). At the same time, it is assumed in Kenya, and in most other countries in sub-Saharan Africa, that responsibility for financing rural water supply O&M rests with communities. Yet in Kwale, the revenue collection strategy that leads to the more sustainable operation of community water supplies also appears to deter the highest proportion of households from using the water source.

While the objective of universal access to safe drinking water is indisputable, the evidence in this study casts some doubt on whether there is universal willingness and ability to fully cover the costs of operation and maintenance among water users. This challenge is by no means a new one. It is a key reason why a supply-driven approach to rural water programming once met with disappointing results (Briscoe & de Ferranti, 1988). A demand-responsive paradigm has since been adopted to circumvent these issues. However, with the escalated ambition to achieve universal access, policymakers and practitioners will need to devise strategies that concurrently expand coverage and ensure sustainable systems of operation and maintenance, even where users lack the willingness and ability to act collectively and cover those costs.

There are several possible pathways to bridge the gap between service delivery costs and user demand. First, aforementioned strategies that improve the operational performance of community water supplies might drive a commensurate increase in willingness to pay. Second, greater demand for safe drinking water might be stimulated through social marketing and behaviour change techniques. Third, in certain contexts self-supply approaches – such as low cost protection of family wells – might better match the means and desires of users to real water supply costs. Fourth, there may be a need for carefully designed subsidies to cover the shortfall between the true costs of sustainable service delivery and what users are willing and able to pay.

#### **4.1 Study limitations**

The analysis and interpretations in this study come with a number of qualifications and limitations. First, the operational outcome indicator utilised in the sustainability analyses was self-reported downtime for the previous 12 months, and therefore susceptible to recall bias. To mitigate this issue, future studies should seek to measure downtime in a more robust fashion, possibly through the use of remote monitoring technologies. Second, the results may be affected by selection bias, as the inclusion criteria limited the financial analysis to those committees keeping financial records, the operational analysis was focussed on those waterpoints which had had at least one breakdown and repair in the previous 12 months, and all analyses was restricted to waterpoints that had been functional at some point within the previous 12 months. Third, no causal relationships can be conclusively demonstrated between explanatory and outcome variables. Finally, the accuracy of the revenue calculations is ultimately dependent on the quality of the original records kept by water committees. Though any anomalies and ambiguities evident in the records were discussed and clarified with water committee members, the possibility of undetected errors or omitted information cannot be ruled out.

#### **5. Conclusion**

This study has shed some preliminary light on how waterpoint revenue collection approaches can impact the amount of cash collected, the speed at which repairs are carried out, and household choices regarding drinking water sources. Though it remains an uncommon revenue collection strategy in rural sub-Saharan Africa, the results provide evidence that PAYF arrangements can generate more income and result in shorter downtime than other approaches. However, the flipside is that a higher proportion of households opt to use an unimproved drinking water source. Further investigations are required to test the generalizability of these findings across other social and environmental settings. By bolstering the evidence base regarding the sustainability and

access implications of waterpoint revenue collection approaches, such research will play an important role in advancing the SDG of safe water for all.

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## Chapter 7 – Paper 4

### Critical mass dynamics and community water supplies in rural Kenya

Tim Foster

#### Abstract

Critical mass dynamics have been widely used to explain the initiation and spread of collective behaviours, from protests and political representation, through to vaccinations and adoption of new technologies. For the first time, this study applies critical mass theory to community waterpoint financial contributions in rural sub-Saharan Africa. The presence of self-reinforcing dynamics and critical mass points is empirically evaluated through assessment of waterpoint financial records from rural Kenya, comprising 43,020 household contributions over a 26 year period. An examination of collective payment rates of change and financial record continuity suggests user contributions remain relatively stable between 61-100%, although become unstable and prone to collapse below this level. Despite evidence of a critical mass point at a collective payment rate of 60%, there is little indication of self-reinforcing growth dynamics. Results highlight the fragility of community-based financing, and its vulnerability to small perturbations. If the Sustainable Development Goal of universal access to safe water is to be achieved, measures to boost the resilience of revenue collection arrangements and strengthen payment incentives are needed.

**Keywords:** rural water supply, critical mass, collective action, revenue collection, waterpoint, Kenya

## 1. Introduction

Critical mass concepts have been applied to a range of social phenomena and collective behaviours, from protests, migration, online activism and political representation, through to diffusion of new technologies, uptake of vaccinations, and adoption of birth control devices (Yin, 1998; Childs & Krook, 2008; Macdonald & Macdonald, 1964; Ghobadi & Clegg, 2015; Markus, 1987; Hershey *et al.*, 1994; Rogers & Kincaird, 1981). Defined by Centola (2013) as “the level of activity above which a behaviour becomes self-sustaining”,<sup>26</sup> the critical mass argument has played an important role in explaining collective action in a way that harmonises rational choice theory with sociological perspectives (Oliver *et al.*, 1985). The critical mass theory responds to the so called ‘social trap’ in which groups might find themselves with respect to non-excludable collective goods (Platt, 1973; Macy, 1990). The dilemma is twofold: actors can enjoy the benefit of a collective good without contributing (the free-rider problem), and actors who contribute may not fully benefit from their contributions (the efficacy problem).

At the heart of critical mass theory is the interdependence of actors’ decision-making. That is, one’s decision to participate in a collective endeavour is dependent on the participation of others. While Olson (1965) famously predicted rational actors would inevitably be motivated by narrow self-interest and free-ride if non-contributors could not be prevented from consuming a collective good, his logic assumed decisions made by actors were independent (Oliver & Marwell, 2001). In a marked departure, Granovetter (1978) proposed a threshold model to explain collective behaviours in recognition that people’s propensity to participate in collective efforts was influenced by the number of people already participating. Central to Granovetter’s argument was

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<sup>26</sup> Note, there is some disagreement about the precise definition of critical mass in a collective action context. Although critical mass generally refers to a minimum number of people who initiate collective behaviours, the concomitant outcomes differ. Various definitions specify that this subset of participants leads to (a) the production of all or most of the collective good (b) a sustaining of collective behaviour, or (c) continued growth of collective behaviour (Marwell & Oliver, 2001; Centola, 2013a; Schelling, 1978). For the purposes of this study, we adopt a definition of critical mass as the number of participants needed to sustain collective behaviours.

an individual's threshold, which referred to the minimum level of overall participation at which they would be prepared to join in. In the language of rational choice, this threshold represents the point at which an individual's perceived net benefit from participation turns positive. Interdependence and threshold models have since commonly formed the basis of theoretical and empirical analysis of collective behaviours (Granovetter & Soong, 1983; Oliver *et al.*, 1985; Macy 1991).

A key concept linking threshold models with critical mass dynamics is that of threshold heterogeneity. Variation in individual thresholds is what allows a chain reaction of collective behaviours to spread (Granvotter, 1978; Oliver *et al.*, 1985). As proffered by Naylor (1990), if groups are homogenous in terms of interest and resources (and thus individual thresholds are the same), then collective action equilibria can only be achieved with full and zero participation. As critical mass dynamics require a subset of actors who are willing to participate early on, the presence of individuals with thresholds lower than the average is critical (Oliver *et al.*, 1985). Significant heterogeneity is therefore a favourable condition for collective action to be kick-started. Moreover, a spread of thresholds allows for a subsequent snowballing of involvement as more and more participants join in.

The extent to which collective behaviours gain a foothold is ultimately dependent on the distribution of thresholds within a group. Somewhat surprisingly, Granovetter (1978) found even minor shifts in individual thresholds can lead to dramatically different aggregate results. For example, the emergence of a small gap in threshold distributions may cause the spread of collective behaviours to grind to an early standstill (Granovetter & Soong, 1983). Of particular interest to collective action scholars have been threshold distributions that give rise to self-reinforcing dynamics, whereby collective behaviours snowball once the critical mass is achieved (Centola, 2013). These chain reactions can manifest themselves as either strongly or weakly self-reinforcing dynamics, also known as "bandwagon" and "snob" effects respectively (Leibensten,

1976). Strongly self-reinforcing dynamics mimic the nuclear metaphor, whereby incentives to join continue to grow as overall involvement spreads, up until full participation. In contrast, where weakly self-reinforcing dynamics prevail, incentives are maximised prior to full participation, leaving a proportion of free-riders who defect once the good is guaranteed. Strongly self-reinforcing systems are intuitively preferred, however modelling suggests that on average weakly self-reinforcing dynamics may be more stable and sustainable in the long term (Centola, 2013). Although strongly self-reinforcing systems tend to full participation, in some situations a downward perturbation might lead to a cascading series of defections. In comparison, a similar slide can be halted and reversed by a weakly self-reinforcing system, as free-riders can re-join and restore the system back to a cooperative equilibrium (Centola, 2013).

Community waterpoints in rural sub-Saharan Africa – and the associated revenue collection systems – possess traits that make them amenable to a critical mass analysis. As a collective good, it is often difficult to exclude actors from using waterpoints, and free-riding appears to be a significant issue (Carter *et al.* 2010; Foster & Hope, *forthcoming*).<sup>27</sup> Evidence also suggests user payment behaviours are interdependent. For example, trust in peers paying was a significant predictor of water user payments in rural Senegal (Hanatani & Fuse, 2012), and an autoregressive covariance structure was the optimal fit for repeated measure analysis of monthly collective payment rates in rural Kenya (Foster & Hope, *forthcoming*).<sup>28</sup> Given the small-scale, community-based nature of rural waterpoints, the assumption that each actor is aware of others' decisions and behaviours is realistic, and arguably more so than many other collective action situations that have been analysed through the prism of critical mass dynamics.

A critical mass perspective could help unravel why revenue collection represents such a widespread and chronic issue for rural water supplies across sub-Saharan Africa. Despite

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<sup>27</sup> Though institutional and physical excludability measures are possible (see Koehler *et al.*, 2015)

<sup>28</sup> This covariance structure assumes month-to-month contributions are correlated, with correlations strongest in successive months.

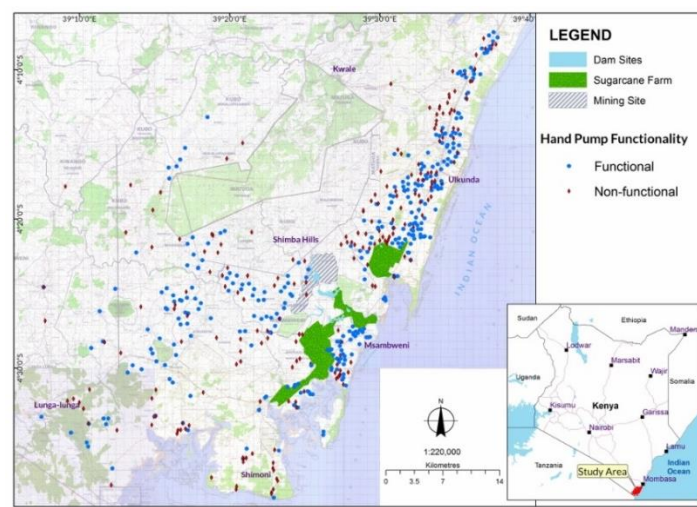
community-based financing being the dominant policy prescription, previous studies have found only a third of rural households pay for water, and less than half of communities served by waterpoints fitted with handpumps are able to establish and sustain a system for collecting funds from users (Foster & Hope, *forthcoming*). This situation has well-documented ramifications for the operational sustainability of water supplies (Harvey, 2007; Foster, 2013), and ultimately the health and welfare of millions of water users. Addressing this collective action conundrum is pivotal if the Sustainable Development Goal of universal access to safe water supplies is to be achieved in rural sub-Saharan Africa. This study therefore seeks to understand if and how critical mass dynamics apply to collective action among rural water users. Drawn from financial records kept by community-based water committees in Kwale, Kenya, monthly water fee payments are assessed in order to identify the existence of (a) critical mass points above which participation is sustained or spreads; and (b) self-reinforcing dynamics whereby growth in payments is self-sustaining.

## **1. Methods**

### **2.1 Study site**

Kwale County is situated on the south coast of Kenya (Figure 1). Approximately 82% of the county's 730,000 inhabitants live in rural areas (Commission on Revenue Allocation, 2013). Waterpoints drawing on groundwater are the most prevalent drinking water source in the county, serving around 37% of households (Government of Kenya, 2009). In particular, boreholes fitted with Afridev handpumps are the dominant water supply technology, with an estimated 580 of these waterpoints installed across the county between 1983 and 1995 (Foster & Hope, *forthcoming*). Community-based water committees and monthly revenue collection systems were also established alongside these infrastructure investments (Rondinelli, 1991; Narayan-Parker 1988).

Figure 1 – Study site of Kwale, Kenya with location of waterpoints fitted with Afridev handpumps (Foster & Hope, *forthcoming*)



## 2.2 Data collection

Prior to data collection, ethics approval was obtained from the Central University Research Ethics Committee at the University of Oxford and a research permit was granted by the Government of Kenya's National Council of Science and Technology. Payment data were extracted from written financial records kept by water committees who collected monthly fees from water users. The participating communities were identified during a waterpoint mapping exercise carried out in August 2013, which sought to locate and collect data on all waterpoints in Kwale fitted with Afridev handpumps. Of the 571 Afridev installations identified,<sup>29</sup> 518 were classified as communal Afridev waterpoints.<sup>30</sup> Of these, 58.5% were functional, and around one half had a regular revenue collection system in place (or did have prior to breakdown) (Table 1).<sup>31</sup>

<sup>29</sup> This includes 19 waterpoint sites at which Afridev handpumps were originally installed but had subsequently been replaced by submersible pumps.

<sup>30</sup> Communal waterpoints were defined as those serving two or more households. Waterpoints serving only an institution (e.g. school, health centre) were deemed non-communal.

<sup>31</sup> Additional information on data collection and waterpoint characteristics can be found in Foster & Hope (*forthcoming*).

Table 1 – Operational and financial status of communal waterpoints fitted with Afridev handpumps

|                      | Functional  | Non-functional          | Total                   |
|----------------------|-------------|-------------------------|-------------------------|
| <b>Advanced fees</b> | 161 (53.1%) | 94 (43.7%)              | 255 (49.2%)             |
| Fixed fees           | 86 (28.4%)  | 44 (20.5%)              | 130 (25.1%)             |
| PAYF                 | 75 (24.8%)  | 50 (23.3%)              | 125 (24.1%)             |
| <b>Reactive fees</b> | 66 (21.8%)  | 23 (10.7%)              | 89 (17.2%)              |
| <b>No fees</b>       | 76 (25.1%)  | 97 (45.1%)              | 173 (33.4%)             |
| <b>Total</b>         | 303 (100%)  | 215 <sup>a</sup> (100%) | 518 <sup>a</sup> (100%) |

<sup>a</sup> Includes 1 waterpoint where revenue collection approach could not be determined

As part of the mapping process, a respondent at each waterpoint was asked whether documentation was kept of waterpoint revenue and/or expenditure. A subsequent field work campaign was then conducted to collect the financial data contained in these records. For those communities where respondents stated written financial records were kept (n=213), a follow-up visit was undertaken in January 2014 to locate the records.<sup>32</sup> At 100 communities, financial records were identified, reviewed and photographed. An interview with each individual presenting the financial records was also conducted and additional questions were asked to clarify any ambiguities that were apparent in the records.

Payment data were inputted into a spreadsheet, including variables pertaining to payment period, date, number of recorded users, number of users contributing payments, tariff amount, and total amount of cash collected. Monthly payments were of particular interest for this study because it was the most common revenue collection approach with clear documentation of household payments for each payment period. Data from 2013 was excluded from the analysis, as the years' proximity to the point of data collection made it difficult to distinguish between non-payment and late payment. An additional variable – collective payment rate ( $p$ ) – was calculated by dividing the number of paying water users for each payment period by the total number of recorded water users for that payment period. To aid the analysis, collective payment rates were categorised into collective payment intervals of ten (0, 1-10, 11-20, 21-30, 31-40, 41-50, 51-60, 61-70, 71-80, 81-90,

<sup>32</sup> Waterpoints north of Tiwi which reportedly had financial records (n=18) could not be visited due to security concerns.

91-100). In total, the data set included 43,020 monthly contributions covering 1,876 months and 57 waterpoints.

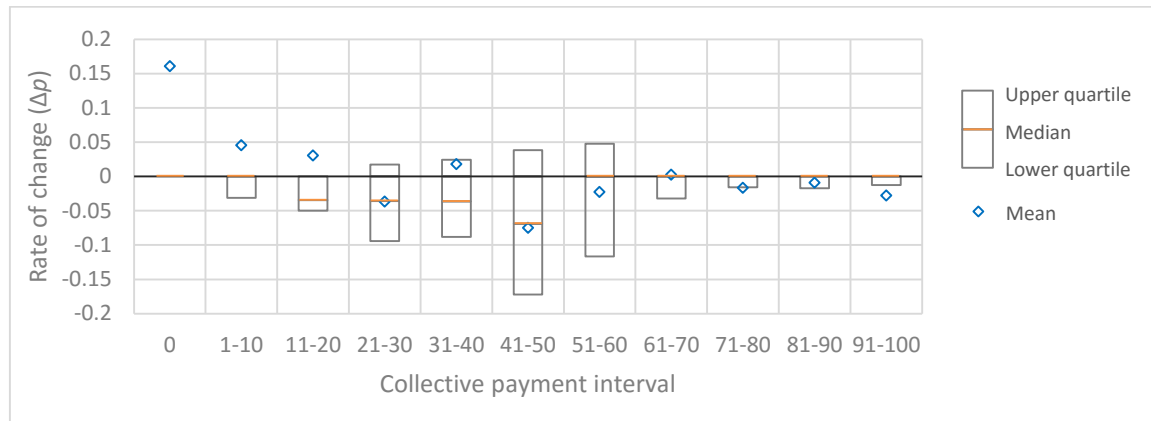
### **2.3 Analysis**

Four types of analyses were undertaken to identify collective payment points of critical mass and zones of self-reinforcing dynamics. First, collective payment rates of change ( $\Delta p$ ) were calculated (mean, median, upper and lower quartiles) for each collective payment interval of ten. Collective payment rate of change was defined as the change in collective payment rate from one month to the next. Second, probabilities for rate of change direction (negative, no change, positive) were calculated for each collective payment interval of ten. Third, recorded revenue 'survival' rate was plotted for each of the 12 months after a collective payment rate was documented, again with disaggregation of analysis by collective payment intervals of ten. Recorded revenue survival was defined as the documentation of revenue exceeding zero, thus a lack of records and recorded revenue of zero were treated equally. Fourth, collective payment rates of 'high performing' communities with 5 or more consecutive years of financial records were plotted and key parameters (mean, median, upper and lower quartiles) were assessed.

## **3 Results**

Figure 2 illustrates the rates of change ( $\Delta p$ ) by collective payment interval. Results suggest contributions are unstable between 11-60, with rates of change characterised by high variability and a negative tendency. The largest declines in contributions follow collective payment rates between 41-50%. Stability increases substantially once collective payments exceed 60%. Contributions then remain relatively stable through to full participation, as indicated by small average changes, medians of zero, and narrow interquartile ranges.

Figure 2 – Mean, median, upper quartile and lower quartile for collective payment rates of change ( $\Delta p$ )



The rate of change direction probabilities reveal a similar story (Figure 3). When collective payments lie between 11-60, the rate of change is unstable, with declines being the predominant direction. Between 21-50, payment rates remain static less than 10% of the time. In a marked contrast, 'no change' becomes the most common result once collective payments surpass 60%. In other words, within the 61-100 zone, month-to-month contributions are more likely to remain unchanged than not. Strikingly, a collective payment rate between 61-64 is 7 times more likely to remain stable than a collective payment rate of 51-54. Stability is highest in the 91-100 payment bracket, with 'no change' in payment rate occurring 68.6% of the time. Notably, the probability of an uptick in contributions once collective payments collapse to zero is just 24.3%, suggesting efforts to resurrect collapsed revenue collection are the exception rather than the norm.

Figure 3 – Direction of collective payment rate of change ( $\Delta p$ )

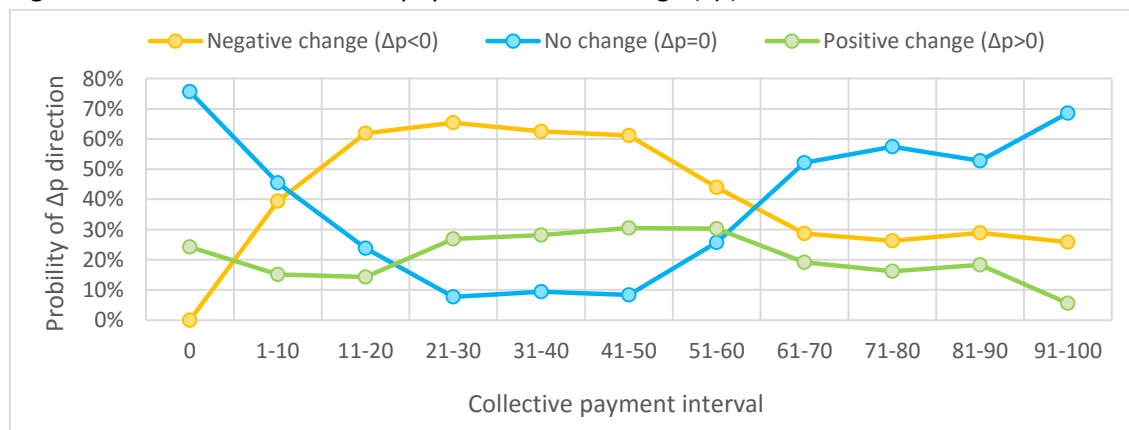
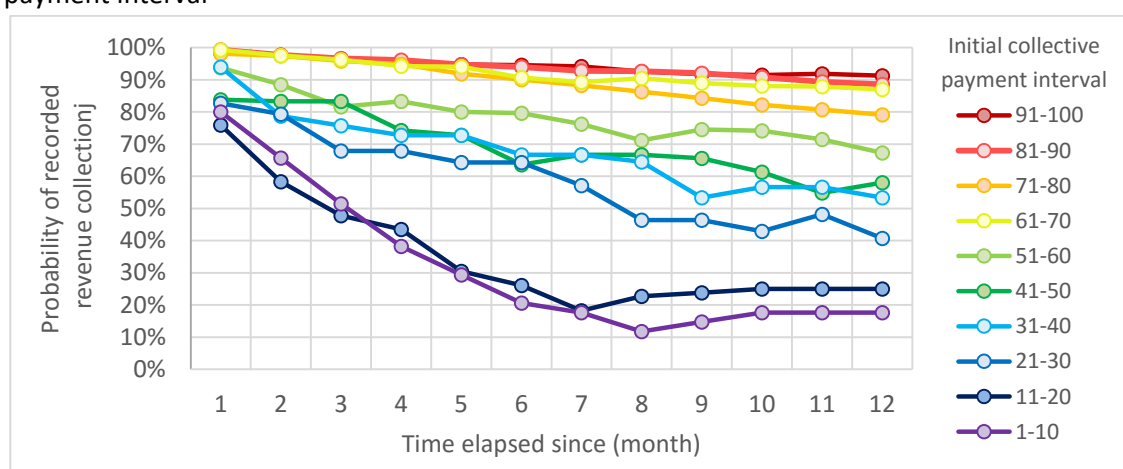


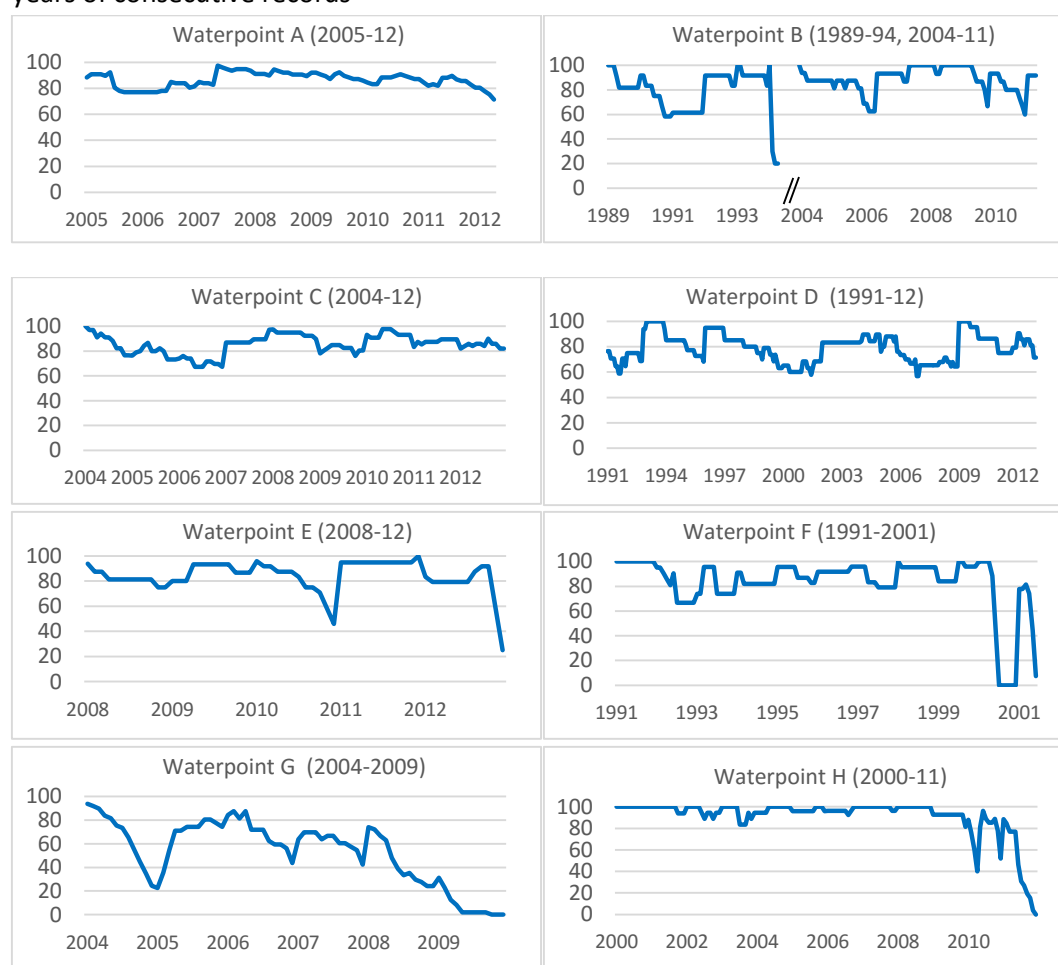
Figure 4 presents the recorded revenue survival rates 1 to 12 months following a documented collective payment rate. From the outset, divergent trajectories are apparent between the 51-60 and 61-70 brackets, with the former ten times more likely to lack recorded revenue in the following month, 4.9 times more likely after 3 months, and 2.5 times after 12 months. Although the 12 month survival rate was highest for the 91-100 bracket (91.3%), the survival rate for the 61-70 bracket (87.1%) differed little to the aggregate survival rate of 71-100 (87.8%).

Figure 4 – Probability of revenue collection being recorded in 1-12 months by initial collective payment interval



Collective payment rates for 8 ‘high performing’ communities with five or more years of consecutive financial records are presented in Figure 5 and Table 2. The majority of high performing communities realise monthly payment rates that fluctuate between 61-100, with measures of centrality between 75-95. Overall, high performing communities attained collective payment outcomes superior to other communities across all measures. Notably, though, only one high performing community (waterpoint H) consistently attained full contributions (47.2% of the time), and based on this measure there was little difference between high performing and other communities (13.4% vs 14.3%). In contrast, a performance gap was clearly evident when applying a collective payment threshold of 60% - high performing communities only dropped below this point on 7.6% of occasions, compared with 26.9% for all other communities.

Figure 5 – Monthly collective payment rates for high performing communities with five or more years of consecutive records<sup>a</sup>



<sup>a</sup> The x-axis represents time, the y-axis represents collective payment rate ( $p$ )

Table 2 – Summary statistics for waterpoints with 5 years or more of consecutive records

| Waterpoint                             | Years     | Months      | Median (Q1-Q3)          | Mean (SD)          | CPR=100 (%) <sup>a</sup> | CPR>60 (%) <sup>b</sup> |
|----------------------------------------|-----------|-------------|-------------------------|--------------------|--------------------------|-------------------------|
| A                                      | 2005-12   | 88          | 87.7 (83.0-91.0)        | 86.5 (5.8)         | 0.0                      | 100.0                   |
| B                                      | 1989-94   | 65          | 83.3 (61.5-91.7)        | 79.0 (18.1)        | 9.2                      | 90.8                    |
| B                                      | 2004-11   | 89          | 91.7 (86.7-100.0)       | 89.1 (10.1)        | 25.8                     | 98.9                    |
| C                                      | 2004-12   | 108         | 86.8 (80.4-91.2)        | 85.5 (7.9)         | 0.9                      | 100.0                   |
| D                                      | 1991-12   | 264         | 80.0 (70.0-85.7)        | 79.2 (11.1)        | 6.8                      | 95.1                    |
| E                                      | 2008-12   | 60          | 87.1 (79.8-93.3)        | 84.2 (12.8)        | 1.7                      | 93.3                    |
| F                                      | 1991-2001 | 126         | 90.7 (79.6-95.7)        | 83.0 (22.6)        | 15.1                     | 92.9                    |
| G                                      | 2004-09   | 72          | 61.6 (32.8-73.6)        | 52.9 (27.3)        | 0.0                      | 52.8                    |
| H                                      | 2000-11   | 144         | 96.2 (92.6-100.0)       | 91.1 (18.6)        | 47.2                     | 93.1                    |
| <b>All high performing<sup>c</sup></b> |           | <b>1016</b> | <b>85.7 (75.0-93.8)</b> | <b>82.0 (18.1)</b> | <b>13.4</b>              | <b>92.4</b>             |
| <b>All others</b>                      |           | <b>860</b>  | <b>78.5 (57.1-90.7)</b> | <b>68.3 (31.0)</b> | <b>14.3</b>              | <b>73.1</b>             |

<sup>a</sup> Proportion of months where collective payment rate equalled 100%

<sup>b</sup> Proportion of months where collective payment rate exceeded 60%

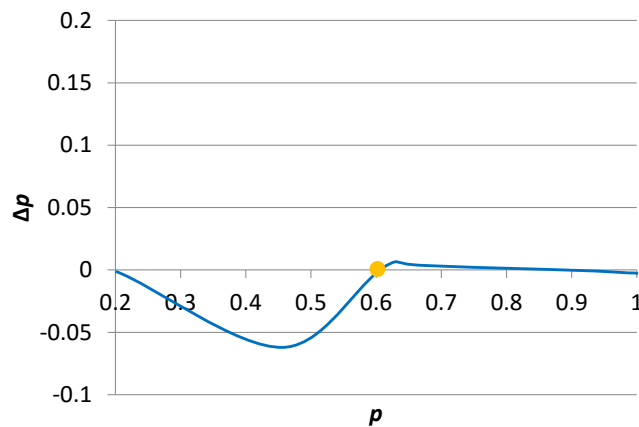
<sup>c</sup> Defined as those waterpoints with 5 or more consecutive years of financial records.

#### 4. Discussion

Applying critical mass theory and analyses yields important insights into why the financial sustainability of rural water supplies in Kwale remains an elusive goal. The finding that rates of change and recorded revenue survival clearly differ across payment rate intervals provides strong evidence of decision-making interdependence. All four types of analyses suggest a critical mass point exists at around the 60% contribution mark. Rate of change mean, median, quartiles and direction all point to an unstable zone predominantly characterised by decline between 21-60, and a stable zone where contributions remain relatively unchanged between 61-100. The results are therefore suggestive of a critical mass point at around 60%, below which users no longer expect they will benefit from cooperating and the urge to free-ride predominates.

Despite the evidence of a critical mass point, it is difficult to characterise rural waterpoint revenue collection systems as either strongly or weakly self-reinforcing. With little evidence of zones of self-sustaining growth, there is an argument that on average the dynamics are barely self-reinforcing at all. Figure 6 depicts an approximated and simplified phase portrait based on results. The point at which the line crosses the x-axis at  $p=0.6$  appears to be the critical mass point. While collective payment levels do not necessarily grow above this point (as with self-reinforcing dynamics), they remain stable as  $p$  moves through towards full participation. However, as with weakly self-reinforcing systems, the best performing communities need not attain full contributions to be sustainable. Below the critical mass point, contributions tend to deteriorate, suggestive of an unstable system vulnerable to perturbations. This is the trait upon which the long term viability of the revenue collection system ultimately hinges.

Figure 6 – Approximated phase portrait for rural waterpoint payments in Kwale, Kenya<sup>a</sup>



<sup>a</sup> The *x-axis* represents collective payment rate ( $p$ ), and *y-axis* represents the collective payment rate of change ( $\Delta p$ )

The challenge then is for communities to not only initiate contributions so that they exceed the critical mass point, but attain a level such that an accidental deviation will not send the system into a rapid decline. It is thus unsurprising that although the best performing communities would at times record collective payment rates within the 61-70 range (a level which offers stability), the measures of centrality were generally between 75-95, far enough from the critical mass point so as not to be dramatically affected by minor perturbations or defections. This is not to suggest the situation is irredeemable once contributions slip below the critical mass point. Notably, the upper quartile for collective payment rates between 21-60 are higher than any other interval, and the mean changes for 0-20 are positive and greater than all others. However, what matters is the probability of these positive rebounds, and whether their magnitude is likely to push collective contributions back past the critical mass point. The recorded revenue survival rate suggests this is not as common as one might hope.

The absence of self-reinforcing dynamics may provide an instructive diagnosis as to why community-based financing of rural water supplies has met with mixed results across sub-Saharan Africa. Indeed, the results suggest monthly payments for community waterpoints in Kwale is almost a doomed endeavour. There is no strong “basin of attraction” (Centola, 2013) that precipitates a snowballing or bandwagon effect, which would otherwise underpin collective

success. Communities also need to overcome a start-up problem that either defies or leap frogs the unstable zone between 21-60. This requires a concerted level of mobilization, coordination and reciprocal communication, such that gaps in threshold distributions can be overcome, and the critical mass surpassed. There is evidence of coordinated efforts to jump start collective action: a recording of zero contributions was followed by collective payment rates of 60 or more in 15.8% of occasions. This indicates the critical mass point is surpassed from a standing start of zero in approximately 1 in 6 recorded attempts.

With the stability of revenue collection above 60%, critical mass theory would suggest this is the point above which many water users perceive a net benefit from their investment. In other words, beyond this threshold water users expect their contribution will ensure the realisation of the collective good.<sup>33</sup> Whether this is true or not in this case is difficult to conclude. Based on the high-performing communities, it would seem an average contribution rate of 75-95% is what is needed to ensure a reliable rural water supply over a period ranging from 5 to 22 consecutive years. Thus, while attaining contributions from 60-75% of users may preclude a collapse in revenue collection in the short term, it may ultimately be insufficient to cover the cost of O&M in the medium to long term. Generalisations on this matter are somewhat problematic, as the payment rates needed to secure a sustainable service will be dependent on the level at which the tariff is set, and the local factors that influence a waterpoint's lifecycle cost.

It would come as no surprise if there were a gap between the perceived and actual collective payment rates needed to provide a reliable water service. Macy (1990) questions whether participants in a collective endeavour will possess the information or skill to assess the marginal impact of their investment. In the context of rural water supplies, a forward looking computation would require accurate forecasts of the timing and magnitude of maintenance costs, and an

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<sup>33</sup> Indeed, the original conceptualisation of 'critical mass' was simply the number of participants needed to secure a collective good (Oliver & Marwell, 2001).

understanding of the distribution of resources and interests within the group. A further complication is how to characterise a waterpoint's jointness of supply and the shape of its production function. Clearly it is unrealistic to expect water users to navigate such complex calculations. Given the recurring nature of monthly payments, backward looking learning and adaptation is a more credible way in which water users would assess the cost-effectiveness of their contributions (Macy, 1990).

While a lack of self-reinforcing dynamics may in part explain why financial sustainability of community water points is such a chronic problem across sub-Saharan Africa, policy interventions may be able to harness critical mass dynamics and interdependence of decision-making in order to improve the resilience of revenue collection systems. Even if individual thresholds remain unchanged, there may be ways to kick-start payments to ensure they enter and remain in a zone that is both a stable equilibrium, and sufficient to ensure the collective good. For example, many policies require communities to provide a small upfront contribution (often around 5%) before a water supply system is installed (African Development Bank, 2010). This sum could be channelled towards a maintenance fund in order to overcome the initial critical mass 'start-up' problem.

However, results from Kwale suggest many communities are able to initiate revenue collection in the first instance – the difficult part is sustaining collective payment rates over time, and rebooting them once they stall. One hypothesis for the lack of continuity is that funds are at times insufficient to cover the costs of low frequency-high cost repairs, leading to lengthy downtimes and the need for additional fundraising. That is, an efficacy problem arises. These negative experiences may subsequently increase contribution thresholds of users, making it more difficult to overcome the critical mass. Pooling finances among many communities could help smooth out unpredictable cost profiles (Hope *et al.*, 2012), thereby preventing these efficacy problems. Finance pooling may also offer the opportunity to leverage heterogeneous thresholds across social networks and take advantage of weak social ties, which may be advantageous in bridging chain reaction gaps,

achieving critical mass, and creating bandwagon effects (Granovetter, 1973; Chiang, 2007). External fund matching or cost sharing might also bolster the propensity of water users to pay in the knowledge that a minimum level of funds will be contributed into the overall pool by government or donors.

Operational changes may also serve to increase payment incentives. Maintenance improvements that reduce downtime may lead to the positive experiences users need to continue contributing financially. In other words, a more reliable water service with minimal disruptions will provide greater assurance to early contributors that they will enjoy the benefits of the collective good. Alternatively, measures to transform waterpoints from non-excludable to excludable resources may change the expectations of aggregate participation. These might include institutional or physical strategies that prevent free-riding (Koehler *et al.* 2015). Excludability and reliability could therefore increase the likelihood of a critical mass being attained, and rearrange thresholds to promote self-reinforcing behaviours. However, the potentially adverse equity implications arising from stricter enforcement of access rules would require careful monitoring.

A key caveat to the preceding analysis and interpretations is that the dynamics and behaviours assessed represent average behaviour. In reality, threshold distributions may vary from month to month and community to community, in response to dynamic environmental, social, institutional and operational factors. Likewise, thresholds likely evolve as actors learn about the net benefits of previous contributions (Macy, 1991), and their aggregation is contingent on the exact time-sequence of each individual's decision. It is also important to note that payment levels are not shaped solely by individual decisions of water users. An active and motivated water committee is critical to the maintenance of a strong revenue collection system. Hence the negative impact of an ineffective committee may at times outweigh a group's threshold distribution in determining aggregate payment rates.

## **5. Conclusion**

This study has, for the first time, applied critical mass theory to the enduring puzzle of community-based financing of rural water supplies in sub-Saharan Africa. The empirical analysis is based on a unique dataset, and provides fresh insights into how sustainability is undermined and promoted. Despite evidence of a critical mass point, results suggest collective payment systems lack self-reinforcing dynamics. Contributions remain relatively stable above a collective payment rate of 60%, and there is a discernible deterioration once payment rates drop below this point. However, results from higher performing water committees suggest a collective payment rate of at least 75% may be needed to ensure the sustained operation of a waterpoint. These dynamics shed some light on why community-based financing of rural water supplies has yielded mixed results. Further investigations are needed to assess whether similar dynamics are evident in other social and environmental settings, and to evaluate the efficacy of measures aimed at strengthening payment incentives.

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## Chapter 8 – Conclusions

### 8.1 Findings & original contributions

The four papers advance new knowledge and complementary empirical insights into the prevalence, predictors, patterns and operational implications of community-based financing for handpump water supplies. Paper 1 reveals that collection of user fees is a significant predictor of waterpoint sustainability, alongside other institutional, technical, geographical and environmental variables. Notably, though, regular pre-payments did not necessarily lead to better operational outcomes than reactive contributions upon breakdown. Paper 2 provides a possible explanation, by revealing how regular monthly tariffs are beset by non-payment and late payment, particularly if rainfall levels are high, group size is large, households are far away, and water is aggressive and unpalatable. Likewise, Paper 4 highlights the fragility of regular monthly payment regimes, by showing how contributions are prone to collapse once collective payment rates fall below 60%. In comparison, Paper 3 puts forward evidence that pay-as-you-fetch regimes are associated with improved operational performance. The flipside is that such arrangements result in a higher proportion of households opting for an unimproved water source.

In addition to the discrete insights from each individual study, there are common threads and cross-cutting themes that bind the research together. Papers 1 and 2 both reveal the mismatch between policies promoting community-based financing of waterpoint O&M and the reality on the ground. Waterpoint mapping data from five countries suggest only a minority of handpumps are coupled with fee collection. Even in communities where regular fees are collected in Kwale, the non-payment rate in the short term is 47.2% and 24.6% in the long term. This, to my knowledge, is the first time empirical evidence of handpump payment prevalence has been presented, and confirms the hypothesis of Carter et al. (2010). Paper 2 provides novel evidence of how social-ecological factors influence payment behaviours. Namely, communities are more likely to achieve high payment rates if they reside close to the waterpoint, user group size is small, pH is greater

than 6.5 and water taste is rated highly. Unsurprisingly, these determinants point to water service attributes upon which households place a high value – i.e. the waterpoint is reliable, uncongested, provides palatable water, and is conveniently located. Likewise, Paper 3 identifies taste and distance as significant predictors of whether or not a household chooses an unimproved water source over the handpump. Papers 2, 3 and 4 highlight how household payment decisions are dynamic over time and closely interact with climate (rainfall) and the decisions of other households (interdependence). In particular, revenue collection systems tend to decline during wet periods and also when aggregate contribution rates drop below 60%. Papers 1 and 3 demonstrate how financial risks impact upon operational performance and water source choices. Paper 1 reveals a significant association between the absence of revenue collection and handpump non-functionality. Paper 3 illustrates how revenue collection approach can result in disparities in the time taken to carry out repairs, and the drinking water source choices of households.

The joint findings also signify that the issue of revenue collection cannot be addressed in isolation from other elements of the rural water sustainability conundrum. Paper 1 yields the conclusion that revenue collection is but one factor that needs to be tackled, alongside other institutional, environmental, and technical determinants of sustainability. Similarly, Paper 2 supports the assertion that financial sustainability will continue to be compromised if service levels are unsatisfactory. Paper 3 reveals that even with the operationally optimal approach of PAYF, average downtime is still 12.9 days. Service disruptions of this length could negate the health benefits usually associated with a safe water supply (Brown & Clasen, 2012), and will act as a serious drag on efforts to achieve universal safe water access.

## **8.2 Reflections on theoretical frameworks**

By extending collective action and CPR theory and frameworks to the challenge of rural waterpoint sustainability, the research reaffirms their enduring value and general applicability. Paper 2 highlights the utility and flexibility of Ostrom's SES diagnostic framework by being able to

accommodate the complex, multifaceted set of factors that shape rural water sustainability outcomes. The comparative assessment of different revenue collection approaches reinforces the importance of excludability as a distinguishing characteristic, as theorized in some of the earliest writings on collective action and CPR management (Olson, 1965; Hardin, 1968). Equally, applying the critical mass theory of collective action to community-based financing recognises the interconnectedness of household payment decisions, and the feedback loops between household- and community-level outcomes.

The headline findings from each study accord with what theory would predict. First and foremost, the four papers demonstrate that collective action can both succeed and fail, depending on characteristics and context (Basurto & Ostrom, 2009). On the one hand, 2 in 5 handpumps in Kwale were non-functional, a situation that is incompatible with the standards needed to attain universal safe water access. On the other, 3 in 5 communities had managed to successfully finance the O&M of their waterpoint over a 20 to 30 year period. The research therefore vindicates the subsequent rejection of the overly simplistic predictions of Olson (1965) and Hardin (1968) – equally, it provides further confirmation that community management is not the panacea many once anticipated. Collectively managed goods and services may or may not suffer from degradation – neither outcome is preordained. The challenge for the rural water sector is that global standards and targets no longer accept such mixed results.

Paper 2 provides validation of Ostrom's SES framework in a broad sense - that is, sustainability of complex human and environmental systems is moulded by characteristics of the resource, governance system and users. Specific associations unearthed also corroborate theoretical reasoning and previous empirical observations – particularly those relating to group size, predictability of system dynamics, value of the resource, and resource location (Ostrom, 2009). Couching the analysis within the SES framework and vocabulary makes these results translatable

across sectors and disciplinary boundaries, thereby contributing to the broader sustainability science knowledge base.

Findings from Paper 3 support the theoretical prediction that the degree of excludability of a good or service does impinge upon collective action outcomes. Moreover, as Baumol (1986) argued, excludability is mutable, and is not necessarily an inherent quality of a good or service. Communities switching to PAYF are therefore, in the words of Ostrom (2003), changing “the structure of the problem they face”. Yet this action in itself requires a degree of cooperation in the first instance. Introducing excludability measures may alleviate the ongoing burdens of collective action, but it will not eliminate them altogether. Drinking water, of course, is a human right as well as an economic good. The complicating challenge then is to harmonize institutional measures that promote water services that are simultaneously sustainable and inclusive.

By illustrating how propensity to pay is dependent on aggregate contribution levels, results from Paper 4 accord with the interdependence assumption that underpins threshold models of collective behaviour and critical mass theory (Granovetter, 1978; Granovetter & Soong, 1983; Oliver et al., 1985; Macy 1990). The study also empirically confirms another central tenet of critical mass theory – that in some instances the collective good can be realised and sustained even without unanimous participation (Oliver & Marwell, 2001). The highest performing communities attained a full contribution rate no more frequently than other communities. They did, however, manage to keep their payment rates above 60% to a much greater extent, indicative of the group of highly interested and/or resourceful users with which critical mass theory is so concerned.

Perhaps the most significant contribution this research makes to the fields of collective action and CPR management, is the marrying of theoretical frameworks with advanced analytical methods. Although the SES framework has been applied to a variety of natural resource contexts, the authors have tended to adopt qualitative approaches (e.g. Cole et al., 2014; Partelow & Boda, 2015). Quantitative appraisals of excludability and implications for collective action also look to be

uncommon. By employing multivariable techniques such as logistic regression, linear mixed models and generalised estimating equations, this research breaks new ground in testing and validating these theoretical and conceptual frameworks. Importantly, the analytical techniques account for the multidimensional and dynamic nature of CPR and collective action situations: all three methods cater for multiple predictors and the latter two accommodate a multi-tiered structure of variables nested in space and time. Although critical mass models of collective behaviour have more of a tradition of quantitative analysis, this academic terrain has been dominated by simulations and mathematical models populated by theoretical data (e.g. Macy, 1991; Centola, 2013). The utilisation of empirical data in Paper 4 is unique in that it observes critical mass and threshold effects in actuality.

### **8.3 Implications and recommendations for policy and practice**

The papers collectively characterise several key policy challenges. Fundamentally, there is a mismatch between policy and reality regarding community-based financing. Although community-based financing is widely promoted in rural water policies and assumed in financing plans, this research reveals only a minority of communities are able to establish and sustain a revenue collection system, and amongst those that do, non-payment and late payment are rife. This casts doubt on the assumption that there is universal willingness and ability to self-organise and pay for handpump water services.

How then to bridge the gap between what handpump users currently pay and what is needed to ensure sustainable water services? And how can this be achieved in light of socio-ecological heterogeneity, the reciprocal relationship with service quality, and goals targeting universal access? I argue policies can look to tackle these dilemmas in three broad ways. First, strategies can seek to bolster water users' willingness to pay and reduce the ability to avoid paying. Second, taxes and transfers could be used to bridge the financing gap between what water users are willing and able

to pay and the true costs of service delivery. Third, techno-institutional approaches could be adapted so that lifecycle costs are better matched to users' willingness to pay.

In order to bolster willingness to pay, the value users place on the handpump water supply must increase. A step change in operational performance is likely to be critical (see e.g. Koehler et al., 2015), and ongoing external support and/or professionalised management models with performance-based incentives present potential pathways to achieve this objective (Harvey & Reed, 2004, 2007; IRC, 2012; Schweitzer & Mihelcic, 2012; Oxford/RFL, 2014; Koehler et al., 2015; Moriarty et al., 2013). In addition to improving waterpoint performance, these efforts might also directly strengthen community-level revenue collection systems and increase trust and accountability with respect to stored funds. Professionalised management models operating across multiple communities could pave the way for finance pooling, which could help spread financial risk, and provide the assurance that an average lifecycle cost tariff will be sufficient to cover major repairs (Carter, 2009; Hope et al., 2012). Social marketing and behaviour change techniques have become common features of sanitation, hygiene and point-of-use water treatment initiatives (Evans et al., 2014; Luoto et al., 2015) and could also potentially play a role in increasing the value users place on a safe water source, particularly during the wet season when unprotected water sources become more prevalent. Furthermore, results from Paper 2 suggest siting waterpoints as close as possible to users and promotion of more durable handpump components could bolster payment behaviours.

In some instances, users may be notionally willing to pay, however community-based revenue collection systems weaken or collapse as water committees become dysfunctional. In other words, the problem does not lie in a lack of demand for handpump water supplies per se, but rather stems from an institutional failure. It is important to note here, that even if alternative management models were to be introduced, there is no getting around the need for some degree of community-level financial management and self-organisation. Systematic and structured external support

could help prevent these situations arising, or if they do, assist communities in re-establishing and strengthening revenue collection systems and access rules. However, the extent to which this could be achieved may be limited so long as water committee roles and responsibilities are voluntary. Encouraging pay-as-you-fetch systems that remunerate attendants for their work is one way to circumvent this issue (as illustrated by Paper 3), however the potentially adverse consequences for safe water access would need to be addressed.

Targeted subsidies might be needed to make up the difference between what users are willing and able to pay and the true costs of providing a reliable water service. Recent evidence suggests financial support is an important success factor for rural water supplies (Hutchings et al., 2015). While external subsidies already play a role in supporting major handpump repairs, technician salaries and spare part supply chains (MWE, 2011; MLG, 2007; Hystra, 2011; Jones, 2013), these are often ad hoc and lack coordination. Transparent and coordinated cost sharing mechanisms could be more carefully targeted and better coordinated so that they help overcome specific bottlenecks (e.g. high cost – low frequency repairs, or capital maintenance expenditure) and encourage users to contribute on the basis of confidence that the collective good will be realised. The extent of cost sharing would also ideally vary according to social and environmental parameters, reflecting the corresponding variance in willingness and ability to pay.

With universal access to safe water now embedded as a Sustainable Development Goal, efforts to expand coverage will inevitably need to target the poorest and hardest to reach communities. This will likely make cost recovery via user fees even more difficult. In some situations, self-supply approaches – such as low cost protection of family wells – may prove to be a more appropriate alignment of ongoing costs and users' willingness and ability to pay (Sutton, 2009; 2011). The case for self-supply may be particularly relevant to remote areas with high rainfall, sparse populations, and aggressive groundwater, given their observed influence on payment rates for communal handpump water supplies.

Equally, as population densities increase and socio-economic statuses improve, more advanced water supply options will become increasingly viable. Though the upfront and ongoing unit costs of small piped systems or kiosks may be greater than handpumps in rural areas, in certain contexts the concomitant uptick in willingness to pay for a more convenient water supply may outweigh this. Nevertheless, small piped schemes and kiosks do not represent a silver bullet solution. Evidence suggests revenue collection and functionality rates for public taps in rural areas are no higher than for handpumps (MWE, 2011b; Hirn, 2011, 2012; Foster, 2015).

Recognising that the aforementioned strategies vary in terms of existing evidence base, feasibility, and scalability, I propose three overarching recommendations for policymakers and practitioners to achieve more financially and operationally sustainable rural waterpoint services in Kwale and beyond. The empirical findings of the research provide rationales for these recommendations, however it is important to acknowledge they echo proposals and arguments that have been advanced and detailed elsewhere (Harvey & Reed, 2004, 2007; Lockwood & Smits, 2011; IRC, 2012; Moriarty et al., 2013). Indeed, they have been advocated as essential 'building blocks' to drive transformational change across the rural water sector (Harvey & Reed, 2004, 2007; Lockwood & Smits, 2011; Moriarty et al., 2013). Admittedly, the recommendations are not limited to financial aspects of rural waterpoint management. To do so would ignore the strong linkages and interdependencies between financial, institutional, operational, technical and social dimensions of sustainability, as reinforced by this thesis. Any solutions must therefore be holistic in their approach.

**Recommendation 1: Provide structured and systematic ongoing support to rural communities.**

Widely advocated across the sector, post-construction support can directly buttress financial aspects of rural waterpoint management, as well as other administrative, operational, and technical functions. There is growing evidence about the value of such support (Whittington et al., 2009; Schweitzer & Mihelcic, 2012; Hutchings et al., 2015). This assistance should take many forms,

including training, advice, conflict resolution, monitoring, and encouragement, enacted through regular visits to communities. Targeted and coordinated subsidies should be aimed at easing identified bottlenecks (e.g. major repairs, replacement), and if possible, deployed in a way that promotes cost sharing, so as to incentivise rather than undermine community-level revenue collection. Training, guidance and troubleshooting should aim to build the capacity of community-based water committees to manage finances in a more transparent and accountable fashion, so as to inspire greater confidence among water users. Where community management is in place, a structured system of external support should also span technical, operational and administrative domains to bolster waterpoint performance more generally. In Kwale, external support responsibilities would naturally fall to the County Government to administer and execute. However, allocation of the necessary funds may ultimately require support from the national government and donors. This in turn may require a shift in outlook and political prioritisation from installing hardware in pursuit of safe water coverage targets, to a longer term commitment to sustainable water service delivery.

**Recommendation 2: Test and rigorously evaluate professionalised waterpoint management models.** Professionalised approaches have been proposed for handpump O&M for several years (Harvey & Reed, 2007). Notwithstanding recent developments (Oxford/RFL, 2014; Koehler et al., 2015) and the continued growth in professionalised management of rural piped schemes, the implementation of such models for handpumps remains rare (Kleemeier, 2010). Professionalised models may be delivered by private sector entities, but they need not be. What matters is that incentives – whether sticks or carrots – are structured in a way that drives a high standard of performance. In the context of handpump O&M, this chiefly means a rapid response to breakdowns and high quality repairs. The logic then, is if professionalised management models can drive operational performance improvements, then the willingness to contribute funds will be more forthcoming (Koehler et al., 2015). However, evidence on the impact of professionalised

handpump management models on payment behaviours remains limited, hence further testing and evaluation is needed to determine whether this theory of change holds true in practice.

**Recommendation 3: Consider alternative techno-institutional approaches in accordance with social and environmental conditions.** Household-level self-supply should be considered as an alternative option when conditions are less conducive to sustainable handpump services and their financing (e.g. sparsely populated and remotely located areas). This approach is becoming increasingly recognised as feasible and effective (Sutton, 2009, 2011), and is devoid of the collective action burdens associated with community handpumps. The key drawback that needs careful consideration is the water quality risk associated with more rudimentary water source protection. Just as importantly, to roll out this option by way of formal programmes will likely require greater policy recognition, and a shift in attitudes of both governments and donors (see e.g. Butterworth et al., 2013).

These recommendations are subject to two important caveats. First, a complex challenge like rural water sustainability does not present simple answers or quick fixes. Scholarly reviews of the chequered history of CPR management have concluded that the search for panaceas or cure-alls is a fraught exercise (Meinzen-Dick, 2007; Ostrom, 2007). Solutions are unlikely to reside solely in collective, market or state institutions – rather each will have a role to play, the precise nature of which will depend on the context. Second, these recommendations fall within a broader suite of strategies and policies that are important for sustainable rural water service delivery, such as capacity building of local government, asset management, regulation, and sector-wide coordination (Lockwood & Smiths, 2011).

## **8.4 Directions for future research**

The analyses and results generate a myriad of future research questions. First and foremost, further studies are needed to determine whether the findings hold across varying social-ecological

systems. In this respect, it is important to note that the results from Kwale are not necessarily generalizable to other parts of rural sub-Saharan Africa. In particular, the financial analysis has focussed on communities that have invariably established a revenue collection system. Further inquiries are needed as to why many communities fail to even take this first step.

The papers have left open the question as to what proportion of the financial shortfalls can be attributed to users being unwilling to pay (i.e. free-riders) as opposed to those who would pay but for weak or absent revenue collection systems (i.e. institutional failure). Attempts to size up these two issues would help determine whether measures should be aimed at bolstering users' willingness to pay, or strengthening the institutions and incentives to sustain an effective revenue collection system. Likewise, a more nuanced understanding is still needed of how financial and operational elements of handpump water supplies interact. For example, the relationship between repair cost and downtime remains unexplored.

Future investigations into determinants of operational sustainability could build on Paper 1 by (i) applying more sophisticated outcome variables beyond point-in-time functionality (e.g. length of downtime); (ii) incorporating additional variables relating to hydrogeology, waterpoint clustering, socio-economics status of users, and proximity to surface water bodies; and (iii) assessing predictors in different countries as more waterpoint data sets become available. Such studies would benefit from additional measures to verify data quality (e.g. 'ground-truth' data for a random selection of waterpoints), and cohort-based longitudinal analysis to filter out potential effects of reverse causation.

Based on Papers 2, 3 and 4, I would argue there is a case for carrying out a randomised control trial to provide a more rigorous assessment of disparities in operational performance and access outcomes associated with pay-as-you-fetch arrangements compared with fixed fees and reactive fees. Ideally, this would entail a method of measuring waterpoint performance that is impervious to the recall bias that may affect self-reported downtime assessments. A study of this nature would

benefit from multiple treatment groups to determine whether the disparities associated with a pay-as-you-fetch arrangement stem from the volumetric nature of the tariff, the excludability characteristic with which it is inherently coupled, or the remuneration which incentivises the attendant to ensure repairs are carried out promptly. Additional elements to concurrently test may include the impact of behaviour change techniques and lifeline tariffs on drinking water source choices. A full cost-benefit analysis would also ideally include assessment of the broader health and welfare impacts of service disruptions.

Even if a larger body of evidence regarding optimal revenue collection approaches is established, little has been documented about how and why communities make the revenue collection choices they do. An application of behavioural economic (e.g. Thaler & Sunstein, 2003) and social choice theories (e.g. Sen, 1995) to community tariff decisions could yield important insights in this respect. A better understanding of these processes could provide guidance as to how communities can best be nudged towards decisions that maximise waterpoint sustainability and overall welfare.

Finally, all four papers have flagged possible pathways to improve the financial and operational sustainability of community waterpoints. In particular, maintenance models that deliver a step-change in reliability and ongoing external support. While evidence is beginning to emerge about the potential of these concepts (Koehler et al., 2015; Hutchings et al., 2015), further investigations are required to assess their efficacy. Comprehensive cost-benefit comparisons with self-supply initiatives would also serve to broaden the knowledge of what trade-offs are at stake.

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# Appendices

## Appendix I – Waterpoint Mapping Data Collection Form

Enumerator name: \_\_\_\_\_ Date: \_\_\_\_\_, 2013 Time: \_\_\_\_:\_\_\_\_ AM/PM

UNIQUE ID: \_\_\_\_\_ (format: unique letter / hour start / day, i.e. R/02/05)

### Introduction –

- “Good morning/afternoon, I am conducting a study on handpumps in Kwale/Msambweni with support from the District Water Officer. My name is \_\_\_\_ and I am part of a research team led by Rural Focus Ltd, Kenya with the support of the Coast Water Services Board.
- I would like to ask you about your handpump to help the Government of Kenya improve water service delivery.
- The survey should take around 15minutes and will provide important information.
- All the information will be strictly confidential and remain anonymous.
- The data will be given to the DWO or you can contact me for the results on (cell) xxxxxxxxxxxx.”

Are you are willing to participate? Yes ☐ No ☐

\*\*\*If the respondent does not give INFORMED CONSENT, thank him/her and move to next person.

| TECHNICAL                                                                                        |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |        |      |      |        |    |  |  |
|--------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------|------|------|--------|----|--|--|
| 1. Community name:                                                                               |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |        |      |      |        |    |  |  |
| 2. Respondent<br><br>(preferably a water committee member, or owner if handpump privately owned) | <p>Name: _____</p> <p><b>Role:</b> Chair <input type="checkbox"/>; Treasurer <input type="checkbox"/>; Secretary <input type="checkbox"/>; Other committee member <input type="checkbox"/></p> <p>Pump attendant <input type="checkbox"/>; Private owner <input type="checkbox"/>; Other <input type="checkbox"/> (specify): _____</p> <p>Mobile: _____</p> <p>Name/numbers of up to 3 Water User Committee members (if applicable)</p> <table border="1"> <thead> <tr> <th>Name</th> <th>Role</th> <th>Mobile</th> </tr> </thead> <tbody> <tr> <td>1.</td> <td></td> <td></td> </tr> </tbody> </table> |        | Name | Role | Mobile | 1. |  |  |
| Name                                                                                             | Role                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | Mobile |      |      |        |    |  |  |
| 1.                                                                                               |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |        |      |      |        |    |  |  |

|                                                                                            |                                                                                                                                                                                                                             |    |  |    |    |             |  |
|--------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----|--|----|----|-------------|--|
|                                                                                            | <table border="1"> <tr> <td>2.</td><td></td><td></td></tr> <tr> <td>3.</td><td></td><td></td></tr> </table>                                                                                                                 | 2. |  |    | 3. |             |  |
| 2.                                                                                         |                                                                                                                                                                                                                             |    |  |    |    |             |  |
| 3.                                                                                         |                                                                                                                                                                                                                             |    |  |    |    |             |  |
| 3. Handpump location (GPS):                                                                | Latitude:_____ Longitude:_____<br>Datum: WGS 84, hdd.ddddd                                                                                                                                                                  |    |  |    |    |             |  |
| 4. GSM signal strength:                                                                    | a) Safaricom: _____<br>b) Airtel: _____<br>c) Orange: _____<br>d) Yu: _____                                                                                                                                                 |    |  |    |    |             |  |
| 5. Handpump type<br><i>(by observation and take photos including one of <b>handle</b>)</i> | a) Afridev <input type="checkbox"/><br>a. <u>Handle welded</u> ? Yes <input type="checkbox"/> No <input type="checkbox"/><br>b) India Mk II <input type="checkbox"/><br>c) Other <input type="checkbox"/> (specify)_____    |    |  |    |    |             |  |
| 6. Well type                                                                               | a) Borehole <input type="checkbox"/><br>b) Shallow well <input type="checkbox"/><br>a. With lid locked <input type="checkbox"/><br>b. With lid unlocked <input type="checkbox"/>                                            |    |  |    |    |             |  |
| 7. Well depth (by asking)                                                                  | _____ metres; Don't know <input type="checkbox"/> ; <i>No response</i> <input type="checkbox"/>                                                                                                                             |    |  |    |    |             |  |
| 8. <b>Today's</b> functional status:                                                       | a) Functional <input type="checkbox"/><br>b) Partly functioning <input type="checkbox"/> (specify) _____<br>c) Non-functional <input type="checkbox"/> (specify) _____<br>d) Other <input type="checkbox"/> (specify) _____ |    |  |    |    |             |  |
| 9. Water quality results (Hanna tester)                                                    | <table border="1"> <tr> <td>EC</td><td></td></tr> <tr> <td>pH</td><td></td></tr> <tr> <td>Temperature</td><td></td></tr> </table>                                                                                           | EC |  | pH |    | Temperature |  |
| EC                                                                                         |                                                                                                                                                                                                                             |    |  |    |    |             |  |
| pH                                                                                         |                                                                                                                                                                                                                             |    |  |    |    |             |  |
| Temperature                                                                                |                                                                                                                                                                                                                             |    |  |    |    |             |  |

**SURVEY with handpump user OR Water Committee member OR handpump owner**

| 10. When was the well first dug or borehole drilled?                                     | <p>_____ year</p> <p>Don't know <input type="checkbox"/>; <span style="float: right;">No response <input type="checkbox"/></span></p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |       |                  |   |  |   |  |   |  |   |  |   |  |
|------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------|------------------|---|--|---|--|---|--|---|--|---|--|
| 11. When was <u>the current</u> handpump installed?                                      | <p>_____ year</p> <p>Don't know <input type="checkbox"/>; <span style="float: right;">No response <input type="checkbox"/></span></p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |       |                  |   |  |   |  |   |  |   |  |   |  |
| 12. Who <b>funded</b> the installation of the handpump?<br><b>(**Do NOT prompt**)</b>    | <p><input type="checkbox"/> Government of Kenya - <i>Specify</i> (if known): _____</p> <p><input type="checkbox"/> Faith group - <i>Specify</i> (if known): _____</p> <p><input type="checkbox"/> SIDA</p> <p><input type="checkbox"/> Private individual</p> <p><input type="checkbox"/> Other (specify): _____</p> <p><input type="checkbox"/> Don't know; <span style="float: right;">No response <input type="checkbox"/></span></p>                                                                                                                                                                                                          |       |                  |   |  |   |  |   |  |   |  |   |  |
| 13. Has the handpump <b>not</b> been working at any time in the <b>last 12 months</b> ?  | <p>a) Yes <input type="checkbox"/> How many times has it broken? _____</p> <p>b) No <input type="checkbox"/> - <i>SKIP to Q. 15</i></p> <p>c) Don't know <input type="checkbox"/> - <i>SKIP to Q. 15</i> <span style="float: right;">No response <input type="checkbox"/></span></p>                                                                                                                                                                                                                                                                                                                                                              |       |                  |   |  |   |  |   |  |   |  |   |  |
| 14. For how many <b>days</b> was the handpump not working in the last <b>12 months</b> ? | <p><b>Total days not working:</b> _____</p> <p>Don't know <input type="checkbox"/> <span style="float: right;">No response <input type="checkbox"/></span></p> <p><i>If known list down-time for each failure (with 1 being the <b>most recent</b>):</i><br/> <i>[** include current breakdown if handpump is currently non-functional]</i></p> <table border="1"> <thead> <tr> <th>Event</th> <th>Days not working</th> </tr> </thead> <tbody> <tr><td>1</td><td></td></tr> <tr><td>2</td><td></td></tr> <tr><td>3</td><td></td></tr> <tr><td>4</td><td></td></tr> <tr><td>5</td><td></td></tr> </tbody> </table> | Event | Days not working | 1 |  | 2 |  | 3 |  | 4 |  | 5 |  |
| Event                                                                                    | Days not working                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |       |                  |   |  |   |  |   |  |   |  |   |  |
| 1                                                                                        |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |       |                  |   |  |   |  |   |  |   |  |   |  |
| 2                                                                                        |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |       |                  |   |  |   |  |   |  |   |  |   |  |
| 3                                                                                        |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |       |                  |   |  |   |  |   |  |   |  |   |  |
| 4                                                                                        |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |       |                  |   |  |   |  |   |  |   |  |   |  |
| 5                                                                                        |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |       |                  |   |  |   |  |   |  |   |  |   |  |

|                                                                                                                                                                                |                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                                                                                                                                                                                                          |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 15. Does the well/borehole normally supply water all year round?                                                                                                               | a) Yes – ALWAYS supplies water all year <input type="checkbox"/> - <i>SKIP TO Q. 18</i><br>b) Yes – normally supplies water all year EXCEPT IN VERY DRY YEARS <input type="checkbox"/><br>c) No – water is SEASONAL <input type="checkbox"/><br>d) Never – it is PERMANENTLY DRY <input type="checkbox"/><br>e) Don't know <input type="checkbox"/> <span style="float: right;"><i>No response</i> <input type="checkbox"/></span>                                 |                                                                                                                                                                                                          |
| 16. Is the borehole/well <b>currently</b> dry?                                                                                                                                 | a) Yes <input type="checkbox"/><br>b) No <input type="checkbox"/>                                                                                                                                                                                                                                                                                                                                                                                                  |                                                                                                                                                                                                          |
| 17. In the last 12 months, in which month(s) and for how many days has the well/borehole been <b>dry</b> ?<br>[***if not known, enter 'DK']<br>[*** if no dry days, enter '0'] | <u><b>2013</b></u><br>a) Jul: ____days<br>b) Jun: ____days<br>c) May: ____days<br>d) Apr: ____days<br>e) Mar: ____days<br>f) Feb: ____days<br>g) Jan: ____days                                                                                                                                                                                                                                                                                                     | <u><b>2012</b></u><br>h) Dec: ____days<br>i) Nov: ____days<br>j) Oct: ____days<br>k) Sep: ____days<br>l) Aug: ____days<br><span style="float: right;"><i>No response</i> <input type="checkbox"/></span> |
| 18. Have you ever had to deepen the well?                                                                                                                                      | a) Yes <input type="checkbox"/> → When did you last deepen the well? _____ (Year)<br>b) No <input type="checkbox"/><br>c) Don't know <input type="checkbox"/> <span style="float: right;"><i>No response</i> <input type="checkbox"/></span>                                                                                                                                                                                                                       |                                                                                                                                                                                                          |
| 19. Number of handpump <b>users</b><br>(circle households <b><u>OR</u></b> people)                                                                                             | Wet season: _____ households/people<br>Dry season: _____ households/people                                                                                                                                                                                                                                                                                                                                                                                         |                                                                                                                                                                                                          |
| 20. Who is responsible for <b>managing</b> the handpump?<br>(e.g. organising repairs, setting tariffs, collecting payments etc.)<br>(Tick <u>ALL</u> that apply)               | a) Community-based water committee <input type="checkbox"/><br>b) School <input type="checkbox"/><br>c) Health Centre <input type="checkbox"/><br>d) Private owner/operator <input type="checkbox"/><br>e) Other <input type="checkbox"/> (specify): _____<br>f) No one is responsible for managing the handpump <input type="checkbox"/><br>g) Don't know <input type="checkbox"/> <span style="float: right;"><i>No response</i> <input type="checkbox"/></span> |                                                                                                                                                                                                          |

| 21. Are user fees collected?                                                                | a) Yes –all fees collected <b>in advance</b> of breakdown <input type="checkbox"/><br>b) Yes - fees collected <b>both before and after</b> breakdown <input type="checkbox"/><br>c) Yes –fees collected <b>only after</b> breakdown <input type="checkbox"/> → <i>SKIP TO Q. 25</i><br>d) No fees collected at all <input type="checkbox"/> → <i>SKIP TO Q. 27</i><br>e) Don't know <input type="checkbox"/> → <i>SKIP TO Q. 27</i> <span style="float: right;"><i>No response</i> <input type="checkbox"/></span>                                                                                                                                                                                                                                                                                                           |       |                   |       |                          |       |                          |           |  |  |  |     |  |               |  |  |  |     |  |               |     |  |  |  |  |             |     |  |  |  |  |                           |  |  |  |  |  |
|---------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------|-------------------|-------|--------------------------|-------|--------------------------|-----------|--|--|--|-----|--|---------------|--|--|--|-----|--|---------------|-----|--|--|--|--|-------------|-----|--|--|--|--|---------------------------|--|--|--|--|--|
| 22. If fees are paid <b>in advance</b> , how often are they collected?                      | a) Once a year <input type="checkbox"/><br>b) Monthly <input type="checkbox"/><br>c) Pay as you fetch (e.g. per bucket / jerrican) <input type="checkbox"/><br>d) Other <input type="checkbox"/> (specify): _____ <span style="float: right;"><i>No response</i> <input type="checkbox"/></span>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |       |                   |       |                          |       |                          |           |  |  |  |     |  |               |  |  |  |     |  |               |     |  |  |  |  |             |     |  |  |  |  |                           |  |  |  |  |  |
| 23. What are the current fees to use the handpump? (in Ksh)                                 | <table border="1" style="width: 100%; border-collapse: collapse;"> <thead> <tr style="background-color: #d3d3d3;"> <th style="width: 30%;"></th><th style="width: 10%;">Bucket / jerrican</th><th style="width: 10%;">Month</th><th style="width: 10%;">Yearly</th><th style="width: 10%;">Visit</th><th style="width: 30%;">Other (specify)<br/>_____</th></tr> </thead> <tbody> <tr> <td>Member HH</td><td></td><td></td><td></td><td>n/a</td><td></td></tr> <tr> <td>Non-member HH</td><td></td><td></td><td></td><td>n/a</td><td></td></tr> <tr> <td>Cattle (head)</td><td>n/a</td><td></td><td></td><td></td><td></td></tr> <tr> <td>Goat (head)</td><td>n/a</td><td></td><td></td><td></td><td></td></tr> <tr> <td>Other (specify):<br/>_____</td><td></td><td></td><td></td><td></td><td></td></tr> </tbody> </table> |       | Bucket / jerrican | Month | Yearly                   | Visit | Other (specify)<br>_____ | Member HH |  |  |  | n/a |  | Non-member HH |  |  |  | n/a |  | Cattle (head) | n/a |  |  |  |  | Goat (head) | n/a |  |  |  |  | Other (specify):<br>_____ |  |  |  |  |  |
|                                                                                             | Bucket / jerrican                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | Month | Yearly            | Visit | Other (specify)<br>_____ |       |                          |           |  |  |  |     |  |               |  |  |  |     |  |               |     |  |  |  |  |             |     |  |  |  |  |                           |  |  |  |  |  |
| Member HH                                                                                   |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |       |                   | n/a   |                          |       |                          |           |  |  |  |     |  |               |  |  |  |     |  |               |     |  |  |  |  |             |     |  |  |  |  |                           |  |  |  |  |  |
| Non-member HH                                                                               |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |       |                   | n/a   |                          |       |                          |           |  |  |  |     |  |               |  |  |  |     |  |               |     |  |  |  |  |             |     |  |  |  |  |                           |  |  |  |  |  |
| Cattle (head)                                                                               | n/a                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |       |                   |       |                          |       |                          |           |  |  |  |     |  |               |  |  |  |     |  |               |     |  |  |  |  |             |     |  |  |  |  |                           |  |  |  |  |  |
| Goat (head)                                                                                 | n/a                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |       |                   |       |                          |       |                          |           |  |  |  |     |  |               |  |  |  |     |  |               |     |  |  |  |  |             |     |  |  |  |  |                           |  |  |  |  |  |
| Other (specify):<br>_____                                                                   |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |       |                   |       |                          |       |                          |           |  |  |  |     |  |               |  |  |  |     |  |               |     |  |  |  |  |             |     |  |  |  |  |                           |  |  |  |  |  |
| 24. Where is the money usually stored before a breakdown happens?                           | a) Home of the treasurer <input type="checkbox"/><br>b) Home of other water committee member <input type="checkbox"/><br>c) Home of the handpump attendant <input type="checkbox"/><br>d) Bank account <input type="checkbox"/><br>e) Rotating savings and credit association <input type="checkbox"/><br>f) Money invested in productive activities (e.g livestock) <input type="checkbox"/><br>g) Other <input type="checkbox"/> (specify): _____<br>h) Don't know <input type="checkbox"/> <span style="float: right;"><i>No response</i> <input type="checkbox"/></span>                                                                                                                                                                                                                                                 |       |                   |       |                          |       |                          |           |  |  |  |     |  |               |  |  |  |     |  |               |     |  |  |  |  |             |     |  |  |  |  |                           |  |  |  |  |  |
| 25. Did committee have sufficient money collected in advance to pay for most recent repair? | a) Yes <input type="checkbox"/> → <i>SKIP TO Q.27</i><br>b) No <input type="checkbox"/><br>c) Don't know <input type="checkbox"/> <span style="float: right;"><i>No response</i> <input type="checkbox"/></span>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |       |                   |       |                          |       |                          |           |  |  |  |     |  |               |  |  |  |     |  |               |     |  |  |  |  |             |     |  |  |  |  |                           |  |  |  |  |  |
| 26. If not, how long after the handpump broke down did                                      | _____ days<br>Don't know <input type="checkbox"/> ; <span style="float: right;"><i>No response</i> <input type="checkbox"/></span>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |       |                   |       |                          |       |                          |           |  |  |  |     |  |               |  |  |  |     |  |               |     |  |  |  |  |             |     |  |  |  |  |                           |  |  |  |  |  |

|                                                                                               |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |
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| it take to collect all the money?                                                             |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |
| 27. What was the <b>total cost</b> of the last repair?                                        | _____Ksh<br>Don't know <input type="checkbox"/> ; <span style="float: right;">No response <input type="checkbox"/></span>                                                                                                                                                                                                                                                                                                                                                                                                             |
| 28. Is any money still owed to the fundi for handpump repair work done previously?            | a) Yes <input type="checkbox"/> (how much? _____Ksh)<br>b) No <input type="checkbox"/><br>c) Don't know <input type="checkbox"/> <span style="float: right;">No response <input type="checkbox"/></span>                                                                                                                                                                                                                                                                                                                              |
| 29. Does the water committee (or pump attendant or pump owner) keep accounting records/books? | a) Yes <input type="checkbox"/><br>b) No <input type="checkbox"/><br>c) Don't know <input type="checkbox"/> <span style="float: right;">No response <input type="checkbox"/></span>                                                                                                                                                                                                                                                                                                                                                   |
| 30. Who repaired the handpump last time it broke down?                                        | a) Fundi living in this community <input type="checkbox"/><br>b) Fundi living in nearby community (<10km away) <input type="checkbox"/><br>c) Fundi living in community >10km away <input type="checkbox"/><br>d) Pump attendant living in this community <input type="checkbox"/><br>e) Other <input type="checkbox"/> (specify): _____<br>f) Pump has never broken down or been repaired <input type="checkbox"/><br>g) Don't know <input type="checkbox"/> <span style="float: right;">No response <input type="checkbox"/></span> |
| 31. Could you provide details of the fundi or other person who usually repairs this handpump  | Name: _____ Mobile No: _____<br>Community: _____ <span style="float: right;">Don't know <input type="checkbox"/></span>                                                                                                                                                                                                                                                                                                                                                                                                               |
| 32. When the handpump needs new parts, who usually purchases them?<br>(***Do NOT prompt***)   | a) Water committee member <input type="checkbox"/><br>b) Other community member <input type="checkbox"/><br>c) Pump attendant <input type="checkbox"/><br>d) Fundi <input type="checkbox"/><br>e) NGO/Faith-based organisation <input type="checkbox"/><br>f) Don't know <input type="checkbox"/><br>g) Other <input type="checkbox"/> (specify): _____<br>h) Don't know <input type="checkbox"/> <span style="float: right;">No response <input type="checkbox"/></span>                                                             |

|                                                                                                               |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                                                                                                                                                                                                                                                                                                                                                                                              |
|---------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <p>33. Where are the spare parts usually purchased?<br/>(***Do NOT prompt***)</p>                             | <p><b><u>Minor parts</u></b></p> <p>a) Parts kept in community <input type="checkbox"/></p> <p>b) Ukunda/Diani <input type="checkbox"/></p> <p>c) Mombasa <input type="checkbox"/></p> <p>d) Msambweni <input type="checkbox"/></p> <p>e) Other <input type="checkbox"/> (specify): _____</p> <p>f) Don't know <input type="checkbox"/>      <i>No response</i> <input type="checkbox"/></p>                                                                                                                                              | <p><b><u>Major parts</u></b></p> <p>a) Parts kept in community <input type="checkbox"/></p> <p>b) Ukunda/Diani <input type="checkbox"/></p> <p>c) Mombasa <input type="checkbox"/></p> <p>d) Msambweni <input type="checkbox"/></p> <p>e) Other <input type="checkbox"/> (specify): _____</p> <p>f) Don't know <input type="checkbox"/>      <i>No response</i> <input type="checkbox"/></p> |
| <p>34. Has any <b>preventative</b> handpump maintenance been carried out in the last 12 months?</p>           | <p>a) Yes <input type="checkbox"/></p> <p>b) No <input type="checkbox"/> → <i>SKIP TO Q.36</i></p> <p>c) Don't know <input type="checkbox"/> → <i>SKIP TO Q.36</i>      <i>No response</i> <input type="checkbox"/></p>                                                                                                                                                                                                                                                                                                                   |                                                                                                                                                                                                                                                                                                                                                                                              |
| <p>35. Who carried out this <b>preventative</b> maintenance?</p>                                              | <p>a) Fundi living in this community <input type="checkbox"/></p> <p>b) Fundi living in nearby community (&lt;10km away) <input type="checkbox"/></p> <p>c) Fundi living in community &gt;10km away <input type="checkbox"/></p> <p>d) Pump attendant in this community <input type="checkbox"/></p> <p>e) Water committee member in this community <input type="checkbox"/></p> <p>f) Other <input type="checkbox"/> (specify): _____</p> <p>d) Don't know <input type="checkbox"/>      <i>No response</i> <input type="checkbox"/></p> |                                                                                                                                                                                                                                                                                                                                                                                              |
| <p>36. Are there any women on the water committee?</p>                                                        | <p>a) Yes <input type="checkbox"/></p> <p>b) No <input type="checkbox"/> → <i>SKIP TO Q.38</i></p> <p>c) <i>Handpump not managed by a committee</i> <input type="checkbox"/> → <i>SKIP TO Q.38</i>      <i>No response</i> <input type="checkbox"/></p>                                                                                                                                                                                                                                                                                   |                                                                                                                                                                                                                                                                                                                                                                                              |
| <p>37. Are there any women in key positions on the water committee?<br/><br/>[tick <u>ALL</u> that apply]</p> | <p>a) Yes – Chairman <input type="checkbox"/></p> <p>b) Yes – Treasurer <input type="checkbox"/></p> <p>c) Yes – Secretary <input type="checkbox"/></p> <p>d) No <input type="checkbox"/></p> <p>e) Don't know <input type="checkbox"/>      <i>No response</i> <input type="checkbox"/></p>                                                                                                                                                                                                                                              |                                                                                                                                                                                                                                                                                                                                                                                              |
| <p>38. How many meetings has the water committee had in the last 12 months?</p>                               | <p>_____ times</p> <p>Don't know <input type="checkbox"/>; <i>Handpump not managed by a committee</i> <input type="checkbox"/>;      <i>No response</i> <input type="checkbox"/></p>                                                                                                                                                                                                                                                                                                                                                      |                                                                                                                                                                                                                                                                                                                                                                                              |

| <p>39. Has the water committee ever received any formal training?<br/>[tick <u>ALL</u> that apply]</p>                                                       | <p>a) No training received <input type="checkbox"/></p> <p>b) Technical training (e.g. handpump repairs) <input type="checkbox"/></p> <p>c) Financial management training <input type="checkbox"/></p> <p>d) Hygiene &amp; health promotion training <input type="checkbox"/></p> <p>e) Other <input type="checkbox"/> (specify): _____</p> <p>f) Don't know <input type="checkbox"/></p> <p>g) Handpump not managed by a water committee <input type="checkbox"/> No response <input type="checkbox"/></p>                                                                                                 |                          |                          |         |      |       |                          |                          |                          |        |                          |                          |                          |       |                          |                          |                          |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------|--------------------------|---------|------|-------|--------------------------|--------------------------|--------------------------|--------|--------------------------|--------------------------|--------------------------|-------|--------------------------|--------------------------|--------------------------|
| <p>40. What external support has the community received to help with their handpump water supply in the last 12 months?<br/>[tick <u>ALL</u> that apply]</p> | <p>a) No support received <input type="checkbox"/> → SKIP TO Q. 42</p> <p>b) Technical training <input type="checkbox"/></p> <p>c) Financial management training <input type="checkbox"/></p> <p>d) Free repair services <input type="checkbox"/></p> <p>e) Free spare parts <input type="checkbox"/></p> <p>f) Other <input type="checkbox"/> (specify): _____</p> <p>g) Don't know <input type="checkbox"/> → SKIP TO Q. 42 No response <input type="checkbox"/></p>                                                                                                                                      |                          |                          |         |      |       |                          |                          |                          |        |                          |                          |                          |       |                          |                          |                          |
| <p>41. Who has provided that external support?<br/>[tick <u>ALL</u> that apply]</p>                                                                          | <p>a) Government/District water office <input type="checkbox"/></p> <p>b) NGO <input type="checkbox"/></p> <p>c) Church/faith based organisation <input type="checkbox"/></p> <p>d) Other <input type="checkbox"/> (specify): _____</p> <p>e) Don't know <input type="checkbox"/> No response <input type="checkbox"/></p>                                                                                                                                                                                                                                                                                  |                          |                          |         |      |       |                          |                          |                          |        |                          |                          |                          |       |                          |                          |                          |
| <p>42. How would you describe the <b>DRINKING</b> water from the handpump?</p>                                                                               | <table border="1"> <thead> <tr> <th></th> <th>Good</th> <th>Average</th> <th>Poor</th> </tr> </thead> <tbody> <tr> <td>Taste</td> <td><input type="checkbox"/></td> <td><input type="checkbox"/></td> <td><input type="checkbox"/></td> </tr> <tr> <td>Colour</td> <td><input type="checkbox"/></td> <td><input type="checkbox"/></td> <td><input type="checkbox"/></td> </tr> <tr> <td>Smell</td> <td><input type="checkbox"/></td> <td><input type="checkbox"/></td> <td><input type="checkbox"/></td> </tr> </tbody> </table> <p>No response <input type="checkbox"/></p> |                          | Good                     | Average | Poor | Taste | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | Colour | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | Smell | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
|                                                                                                                                                              | Good                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | Average                  | Poor                     |         |      |       |                          |                          |                          |        |                          |                          |                          |       |                          |                          |                          |
| Taste                                                                                                                                                        | <input type="checkbox"/>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | <input type="checkbox"/> | <input type="checkbox"/> |         |      |       |                          |                          |                          |        |                          |                          |                          |       |                          |                          |                          |
| Colour                                                                                                                                                       | <input type="checkbox"/>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | <input type="checkbox"/> | <input type="checkbox"/> |         |      |       |                          |                          |                          |        |                          |                          |                          |       |                          |                          |                          |
| Smell                                                                                                                                                        | <input type="checkbox"/>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | <input type="checkbox"/> | <input type="checkbox"/> |         |      |       |                          |                          |                          |        |                          |                          |                          |       |                          |                          |                          |
| <p>43. How often is the <b>water quality</b> from the handpump tested?</p>                                                                                   | <p>a) Never <input type="checkbox"/> → SKIP TO Q. 46</p> <p>b) When installed only <input type="checkbox"/></p> <p>c) Monthly <input type="checkbox"/> (number of times last year? _____)</p> <p>d) Once per year <input type="checkbox"/></p> <p>e) Irregularly <input type="checkbox"/> (last year tested? _____)</p> <p>f) Don't know <input type="checkbox"/> No response <input type="checkbox"/></p>                                                                                                                                                                                                  |                          |                          |         |      |       |                          |                          |                          |        |                          |                          |                          |       |                          |                          |                          |
| <p>44. Who conducted the water quality tests?</p>                                                                                                            | <p>a) Community <input type="checkbox"/></p> <p>b) Government <input type="checkbox"/></p> <p>c) Other <input type="checkbox"/> (specify): _____</p> <p>d) Don't know <input type="checkbox"/> No response <input type="checkbox"/></p>                                                                                                                                                                                                                                                                                                                                                                     |                          |                          |         |      |       |                          |                          |                          |        |                          |                          |                          |       |                          |                          |                          |

|                                                                                                                                                                                                                         |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
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| <p>45. What were the water quality results?</p>                                                                                                                                                                         | <p>a) Potable water (safe to drink) <input type="checkbox"/></p> <p>b) Contaminated (needs treatment) <input type="checkbox"/></p> <p>c) Don't know <input type="checkbox"/></p> <p style="text-align: right;"><i>No response</i> <input type="checkbox"/></p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |
| <p>46. In addition to the handpump, what other <b>DRINKING</b> water sources are commonly used by people who use this handpump?</p> <p><b>(***Do NOT prompt***)</b><br/>[tick <u>ALL</u> the apply]</p>                 | <p>a) Piped into dwelling/plot <input type="checkbox"/></p> <p>b) Piped into neighbour's dwelling/plot <input type="checkbox"/></p> <p>c) Public tap/standpipe/kiosk <input type="checkbox"/></p> <p>d) Public protected well/borehole <input type="checkbox"/></p> <p>e) Private protected well/borehole <input type="checkbox"/></p> <p>f) Public unprotected (open) well <input type="checkbox"/></p> <p>g) Private unprotected (open) well <input type="checkbox"/></p> <p>h) Protected spring <input type="checkbox"/></p> <p>i) Unprotected spring <input type="checkbox"/></p> <p>j) Rainwater <input type="checkbox"/></p> <p>k) Tanker truck <input type="checkbox"/></p> <p>l) Cart/bicycle with small tank/drums/jerricans <input type="checkbox"/></p> <p>m) Surface water (river/ dam/ lake/ ponds/ stream/ irrigation channel) <input type="checkbox"/></p> <p>n) Other <input type="checkbox"/> (specify): _____</p> <p>o) No other sources used – only this handpump <input type="checkbox"/></p> <p style="text-align: right;"><i>No response</i> <input type="checkbox"/></p> |
| <p>47. When the handpump <u>breaks down</u>, what alternative sources are used by those who usually get <b>DRINKING</b> water at this handpump?</p> <p><b>(***Do NOT prompt***)</b><br/>[tick <u>ALL</u> the apply]</p> | <p>a) Piped into dwelling/plot <input type="checkbox"/></p> <p>b) Piped into neighbour's dwelling/plot <input type="checkbox"/></p> <p>c) Public tap/standpipe/kiosk <input type="checkbox"/></p> <p>d) Public protected well/borehole <input type="checkbox"/></p> <p>e) Private protected well/borehole <input type="checkbox"/></p> <p>f) Public unprotected (open) well <input type="checkbox"/></p> <p>g) Private unprotected (open) well <input type="checkbox"/></p> <p>h) Protected spring <input type="checkbox"/></p> <p>i) Unprotected spring <input type="checkbox"/></p> <p>j) Rainwater <input type="checkbox"/></p> <p>k) Tanker truck <input type="checkbox"/></p> <p>l) Cart/bicycle with small tank/drums/jerricans <input type="checkbox"/></p> <p>m) Surface water (river/ dam/ lake/ ponds/ stream/ irrigation channel) <input type="checkbox"/></p> <p>n) Other <input type="checkbox"/> (specify): _____</p> <p>o) Handpump has never broken down <input type="checkbox"/></p> <p style="text-align: right;"><i>No response</i> <input type="checkbox"/></p>             |



|                                                                                         |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |
|-----------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <p>54. Why has the fundi not yet repaired the handpump?<br/>[FINISH SURVEY HERE]</p>    | <p>a) Not possible to repair the problem <input type="checkbox"/></p> <p>b) Money not yet raised to pay the fundi and/or buy the part(s) <input type="checkbox"/></p> <p>c) Money raised but community hasn't purchased the part(s) yet <input type="checkbox"/></p> <p>d) Money raised but cannot find where to buy the part(s) <input type="checkbox"/></p> <p>e) Money raised but waiting for fundi to come and do repairs <input type="checkbox"/></p> <p>f) Disagreement with fundi about how much he will charge <input type="checkbox"/></p> <p>g) Other (specify): _____</p> <p>h) Don't know <input type="checkbox"/> <i>No response</i> <input type="checkbox"/></p> |
| <p>55. Why has there been no attempt to contact the fundi?<br/>[FINISH SURVEY HERE]</p> | <p>a) Contacted DWO instead and waiting for them to fix pump <input type="checkbox"/></p> <p>b) Fundi did a poor job repairing the handpump last time <input type="checkbox"/></p> <p>c) Fundi charges too much <input type="checkbox"/></p> <p>d) Fundi is currently away <input type="checkbox"/></p> <p>e) Don't know of a fundi to call <input type="checkbox"/></p> <p>f) Water committee no longer active <input type="checkbox"/></p> <p>g) There are other water sources to use <input type="checkbox"/></p> <p>h) Other <input type="checkbox"/> (specify): _____</p> <p>i) Don't know <input type="checkbox"/> <i>No response</i> <input type="checkbox"/></p>       |

**Thank you for participating in our survey. If you have any questions, you can contact the team leader on the no 0739 449700**

## Appendix II – Household survey data collection form

NB: Data collection was conducted using tablet devices with in-built question logic

| ENGLISH                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | SWAHILI                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Enumerator Initials:</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | <b>Mwandishi</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |
| <b>Date:</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | <b>Tarehe</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
| <b>District:</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | <b>Wilaya</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
| <b>Location / Town / Village:</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | <b>Kijiji</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
| <b>Handpump ID:</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | <b>Nambari ya handpump(bomba la maji)</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
| <b>What is the functionality status of the handpump?:</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | <b>Je bomba linafanya kazi?</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |
| <input type="checkbox"/> Functional                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | <input type="checkbox"/> Ndio, linafanya kazi                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
| <input type="checkbox"/> Non-functional (less than 1 year)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | <input type="checkbox"/> Halifanyi kazi (chini ya mwaka moja)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
| <input type="checkbox"/> Non-functional (more than 1 year)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | <input type="checkbox"/> Halifanyi kazi (zaidi ya mwaka moja)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
| <p><i>"Good morning/afternoon, I am conducting a study on handpumps in Kwale with support from the Ministry of Water and the National Council of Science and Technology. My name is _____ and I am part of a research team led by Rural Focus Ltd, I would like to ask you about your handpump to help the Government of Kenya improve water service delivery. The survey should take around 30minutes and will provide important information. All the information will be strictly confidential and remain anonymous. The data will be given to the Minister of Water or you can contact me for the results on (cell) xxxxxxxxxx." Participation in this survey is voluntary, and if we should come to any question you don't want to answer, just let me know and I will go on to the next question, or you can stop the interview at any time. However, we hope that you will participate in this survey since your views are important."</i></p> | <p><i>Habari ya asubuhi/jioni, ninafanya utafiti kuhusu handpumps hapa Kwale nikiwa na ruhusa kutoka Wizara ya Maji na Baraza la kitaifa la Sayansi na Teknologia (National Council of Science and Technology). Jina langu ni _____ na mimi ni miongoni mwa watafiti wanaoongozwa na kampuni ya Rural Focus Ltd.</i></p> <p><i>Ningependa kukuuliza maswali kuhusu handpump iliyo karibu na nyumba yako ili kusaidia Serikali ya Kenya kuimarisha huduma ya maji katika eneo hili. Zoezi hili litachukua takriban dakika 30 na litatoa habari muhimu. Maelezo utakayonipa yatakuwa ya siri na hakuna yeyote atakaye jua majibu yako. Habari utakayonipa yatakuwa ya kisiri na hakuna mtu wa nje atajua majibu yako. Maarifa haya yatapelekwa kwa Wizara ya Maji ama unaweza nipigia simu kujua matokeo kwa hii namba 0739449700. Kushiriki kwa hili zoezi ni kujitolea na kama kuna maswali hutataka kujibu nitayaruka ama pia unaweza simamisha zoezi zima wakati utataka lakini natumai utashiriki katika hili zoezi kwa sababu maoni yako ni ya muhimu mno.</i></p> |
| <b>Is respondent over 18 years?:</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | <b>Je, mhusika ana umri zaidi ya miaka 18?</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |
| <input type="checkbox"/> Yes                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | <input type="checkbox"/> Ndio,                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |
| <input type="checkbox"/> No                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | <input type="checkbox"/> La                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |
| <i>If 'no', end interview and thank him/her and move to the next person</i>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | <i>Kama la, umshukuru na uende kwa mwingine</i>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |
| <b>Is respondent willing to participate?:</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | <b>Je mhusika amekubali kushiriki?</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
| <input type="checkbox"/> Yes                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | <input type="checkbox"/> Ndio                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
| <input type="checkbox"/> No                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | <input type="checkbox"/> La                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |
| <i>If 'no', end interview and thank him/her and move to the next person</i>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | <i>Kama la, umshukuru na uende kwa mwingine</i>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |
| <i>"Now I'm going to ask a few questions about you":</i>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | <i>Sasa ningependa kukuuliza maswali machache</i>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
| <b>FULL NAME of respondent:</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | <b>Majina kamili ya mhusika</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |
| <b>GENDER of respondent:</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | <b>Jinsia ya mhusika</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |
| <input type="checkbox"/> Male                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | <input type="checkbox"/> Mume                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
| <input type="checkbox"/> Female                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | <input type="checkbox"/> Mke                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |
| <b>AGE of the respondent in years:</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | <b>Umri wa mhusika</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
| <b>What is the your current JOB STATUS?:</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | <b>Je, unafanya kazi gani?</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |

|                                                                                                                                 |                                                                                                                          |
|---------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------|
| <input type="checkbox"/> Full time wage                                                                                         | <input type="checkbox"/> Ameajiriwa                                                                                      |
| <input type="checkbox"/> Part time wage                                                                                         | <input type="checkbox"/> Kibarua                                                                                         |
| <input type="checkbox"/> Self employed                                                                                          | <input type="checkbox"/> Amejiajiri mwenyewe                                                                             |
| <input type="checkbox"/> Study                                                                                                  | <input type="checkbox"/> Anasoma                                                                                         |
| <input type="checkbox"/> No income                                                                                              | <input type="checkbox"/> Hana kazi                                                                                       |
| <input type="checkbox"/> Other                                                                                                  | <input type="checkbox"/> Zinginezo                                                                                       |
| <b>How do you generate income?:</b>                                                                                             | <b>Mhusika anajipatia mapato kwa njia gani?</b>                                                                          |
| <input type="checkbox"/> Fishing                                                                                                | <input type="checkbox"/> Uvuvi                                                                                           |
| <input type="checkbox"/> Farming                                                                                                | <input type="checkbox"/> Ukulima                                                                                         |
| <input type="checkbox"/> Small business                                                                                         | <input type="checkbox"/> Biashara ndogo ndogo                                                                            |
| <input type="checkbox"/> Other                                                                                                  | <input type="checkbox"/> Nyenginezo                                                                                      |
| <b>What is the HIGHEST LEVEL of SCHOOL you have attended?:</b>                                                                  | <b>Umefikia kiwango gani cha elimu?</b>                                                                                  |
| <input type="checkbox"/> None                                                                                                   | <input type="checkbox"/> Hakuna                                                                                          |
| <input type="checkbox"/> Nursery/Kindergarten                                                                                   | <input type="checkbox"/> Chekechea                                                                                       |
| <input type="checkbox"/> Primary                                                                                                | <input type="checkbox"/> Shule ya msingi                                                                                 |
| <input type="checkbox"/> Post primary, vocational                                                                               | <input type="checkbox"/> Chuo cha Ufundi                                                                                 |
| <input type="checkbox"/> Secondary                                                                                              | <input type="checkbox"/> Shule ya upili                                                                                  |
| <input type="checkbox"/> College (middle level)                                                                                 | <input type="checkbox"/> Chuo cha mafunzo                                                                                |
| <input type="checkbox"/> University                                                                                             | <input type="checkbox"/> Chuo kikuu                                                                                      |
| <input type="checkbox"/> Don't know                                                                                             | <input type="checkbox"/> Hajui                                                                                           |
| <b>What is the highest class you completed?:</b>                                                                                | <b>Ulifikia darasa la ngapi?</b>                                                                                         |
| <b>What is the highest form you completed?:</b>                                                                                 | <b>Ulifikia kidato cha ngapi?</b>                                                                                        |
| <b>"Now I'm going to ask you about other members of your household":</b>                                                        | <b>Ningependa kukuuliza kuhusu watu wengine wanaoishi katika nyumba yako</b>                                             |
| <b>How many OTHER people live in your household?:</b>                                                                           | <b>Je, ni watu wengine wangapi wanaoishi katika nyumba yako?</b>                                                         |
| <i>Number should NOT include the respondent. Include all other people who eat or sleep in this household on a regular basis</i> | <i>Mhusika asiwe katika idadi ya wanaoishi katika hiyo nyumba. Jumlisha wote wanaokula ama wanaolala kwa hiyo nyumba</i> |
| <i>"Let's start with the oldest member of your household":</i>                                                                  | <i>Tuanze na yule mkubwa ki umri</i>                                                                                     |
| <b>First NAME of Person(1):</b>                                                                                                 | <b>Jina la kwanza</b>                                                                                                    |
| <b>Gender of [NAME](1):</b>                                                                                                     | <b>Jinsia</b>                                                                                                            |
| <b>Age of [NAME] in years(1):</b>                                                                                               | <b>Umri wake</b>                                                                                                         |
| <b>What is [NAME'S] job status(1):</b>                                                                                          | <b>Anafanya kazi gani?</b>                                                                                               |
| <b>How does [NAME] generate income?(1):</b>                                                                                     | <b>Anajipatia mapato kwa njia gani?</b>                                                                                  |
| <b>What is the highest level of education [NAME] has attended?(1):</b>                                                          | <b>Amefikia kiwango gani cha elimu?</b>                                                                                  |
| <b>What is the highest class completed?(1):</b>                                                                                 | <b>Alifikia darasa la ngapi?</b>                                                                                         |
| <b>What is the highest form completed?(1):</b>                                                                                  | <b>Alifika kidato cha ngapi?</b>                                                                                         |
| <b>Did [NAME] attend school at any time during the 2013 school year?(1):</b>                                                    | <b>Je amehudhuria shule mwaka huu wa 2013?</b>                                                                           |
| <b>Now I'm going to ask you about the health of [NAME](1):</b>                                                                  | <b>Sasa nitakuuliza kuhusu hali yake ya afya</b>                                                                         |
| <b>Has [NAME] had diarrhoea in the last 2 weeks?(1):</b>                                                                        | <b>Je, amewahi kuharisha ndani ya wiki mbili zilizopita?</b>                                                             |

|                                                                                                                                                  |                                                                                                               |
|--------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------|
| <input type="checkbox"/> Yes                                                                                                                     | <input type="checkbox"/> Ndio                                                                                 |
| <input type="checkbox"/> No                                                                                                                      | <input type="checkbox"/> La                                                                                   |
| <input type="checkbox"/> Don't know                                                                                                              | <input type="checkbox"/> Sijui                                                                                |
| <b>Was there blood in the stools?(1):</b>                                                                                                        | <b>Je, kulikuwa na damu kwenye kinyesi?</b>                                                                   |
| <input type="checkbox"/> Yes                                                                                                                     | <input type="checkbox"/> Ndio                                                                                 |
| <input type="checkbox"/> No                                                                                                                      | <input type="checkbox"/> La                                                                                   |
| <input type="checkbox"/> Don't know                                                                                                              | <input type="checkbox"/> Sijui                                                                                |
| <b>Was [NAME] taken anywhere for treating the diarrhoea, such as a health centre, dispensary, or hospital?(1):</b>                               | <b>Je, alipelekwa popote kupata matibabu ya kuhara?</b>                                                       |
| <input type="checkbox"/> No                                                                                                                      | <input type="checkbox"/> La                                                                                   |
| <input type="checkbox"/> Yes - Hospital                                                                                                          | <input type="checkbox"/> Ndio-hospitali,                                                                      |
| <input type="checkbox"/> Yes - Dispensary / Govt clinic                                                                                          | <input type="checkbox"/> Ndio-zahanati ya serikali                                                            |
| <input type="checkbox"/> Yes - Private clinic                                                                                                    | <input type="checkbox"/> Ndio-zahanati ya kibinafsi                                                           |
| <input type="checkbox"/> Yes - Herbalist                                                                                                         | <input type="checkbox"/> Ndio-matibabu ya miti shamba                                                         |
| <input type="checkbox"/> Yes - other                                                                                                             | <input type="checkbox"/> Ndio-nyenginezo                                                                      |
| <input type="checkbox"/> Don't know                                                                                                              | <input type="checkbox"/> Sijui                                                                                |
| <b>Did [NAME] have schistosomiasis or blood in their urine during the last month?(1):</b>                                                        | <b>Je, amewahi kuwa na ugonjwa wa kisonono/kichocho ndani ya mwezi uliopita?</b>                              |
| <input type="checkbox"/> Yes                                                                                                                     | <input type="checkbox"/> Ndio                                                                                 |
| <input type="checkbox"/> No                                                                                                                      | <input type="checkbox"/> La                                                                                   |
| <input type="checkbox"/> Don't know                                                                                                              | <input type="checkbox"/> Sijui                                                                                |
| <b>Was [NAME] taken anywhere for treating the schistosomiasis, such as a health centre, dispensary, or hospital?(1):</b>                         | <b>Je alipelekwa popote kwa matibabu ya kisonono/kichocho?</b>                                                |
| <input type="checkbox"/> No                                                                                                                      | <input type="checkbox"/> La                                                                                   |
| <input type="checkbox"/> Yes - Hospital                                                                                                          | <input type="checkbox"/> Ndio-hospitali,                                                                      |
| <input type="checkbox"/> Yes - Dispensary / Govt clinic                                                                                          | <input type="checkbox"/> Ndio-zahanati ya serikali                                                            |
| <input type="checkbox"/> Yes - Private clinic                                                                                                    | <input type="checkbox"/> Ndio-zahanati ya kibinafsi                                                           |
| <input type="checkbox"/> Yes - Herbalist                                                                                                         | <input type="checkbox"/> Ndio-matibabu ya miti shamba                                                         |
| <input type="checkbox"/> Yes - other                                                                                                             | <input type="checkbox"/> Ndio-nyenginezo                                                                      |
| <input type="checkbox"/> Don't know                                                                                                              | <input type="checkbox"/> Sijui                                                                                |
| <b>Has [NAME] had an illness with a cough at any time in the last 2 weeks?(1):</b>                                                               | <b>Je, amewahi kuwa na ugonjwa wa kukohoa ndani ya wiki mbili zilizopita?</b>                                 |
| <input type="checkbox"/> Yes                                                                                                                     | <input type="checkbox"/> Ndio                                                                                 |
| <input type="checkbox"/> No                                                                                                                      | <input type="checkbox"/> La                                                                                   |
| <input type="checkbox"/> Don't know                                                                                                              | <input type="checkbox"/> Sijui                                                                                |
| <b>When [NAME] had an illness with a cough, did he/she breathe faster than usual with short, rapid breaths or have difficulty breathing?(1):</b> | <b>Alipokuwa na ugonjwa wa kukohoa je, alikuwa akipumua haraka kuliko kawaida au kupata ugumu wa kupumua?</b> |
| <input type="checkbox"/> Yes                                                                                                                     | <input type="checkbox"/> Ndio                                                                                 |
| <input type="checkbox"/> No                                                                                                                      | <input type="checkbox"/> La                                                                                   |
| <input type="checkbox"/> Don't know                                                                                                              | <input type="checkbox"/> Sijui                                                                                |
| <b>Was the fast or difficult breathing due to a problem in the chest or to a blocked or runny nose?(1):</b>                                      | <b>Je, huo ugumu wa kupumua ulisababishwa na shida ya kifua ama kuziba kwa pua?</b>                           |

|                                                                                                                                        |                                                                                                                 |
|----------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------|
| <input type="checkbox"/> Chest only                                                                                                    | <input type="checkbox"/> Kifua pekee                                                                            |
| <input type="checkbox"/> Nose only                                                                                                     | <input type="checkbox"/> Pua pekee                                                                              |
| <input type="checkbox"/> Both (chest and nose)                                                                                         | <input type="checkbox"/> zote mbili (kifua na pua)                                                              |
| <input type="checkbox"/> Other                                                                                                         | <input type="checkbox"/> Nyenginezo                                                                             |
| <b>Was [NAME] taken anywhere for treating the cough, such as a health clinic, dispensary, or hospital?(1):</b>                         | <b>Je, alipelekwa popote kupata matibabu ya kukohoa?</b>                                                        |
| <input type="checkbox"/> No                                                                                                            | <input type="checkbox"/> La                                                                                     |
| <input type="checkbox"/> Yes - Hospital                                                                                                | <input type="checkbox"/> Ndio-hospitali,                                                                        |
| <input type="checkbox"/> Yes - Dispensary / Govt clinic                                                                                | <input type="checkbox"/> Ndio-zahanati ya serikali                                                              |
| <input type="checkbox"/> Yes - Private clinic                                                                                          | <input type="checkbox"/> Ndio-zahanati ya kibinafsi                                                             |
| <input type="checkbox"/> Yes - Herbalist                                                                                               | <input type="checkbox"/> Ndio-matibabu ya miti shamba                                                           |
| <input type="checkbox"/> Yes - other                                                                                                   | <input type="checkbox"/> Ndio-nyenginezo                                                                        |
| <input type="checkbox"/> Don't know                                                                                                    | <input type="checkbox"/> Sijui                                                                                  |
| <b>Does [NAME] currently have skin infections anywhere on their body?(1):</b>                                                          | <b>Je, ana ugonjwa wowote wa ngozi?</b>                                                                         |
| <input type="checkbox"/> Yes                                                                                                           | <input type="checkbox"/> Ndio                                                                                   |
| <input type="checkbox"/> No                                                                                                            | <input type="checkbox"/> La                                                                                     |
| <input type="checkbox"/> Don't know                                                                                                    | <input type="checkbox"/> Sijui                                                                                  |
| <b>Please specify name of health centre / dispensary / hospital that [NAME] has received treatment for any of these conditions(1):</b> | <b>Tafadhali, nieleze jina la hospitali au zahanati alipopata matibabu</b>                                      |
| <b>Are there other household members? If so, now ask about the next oldest person in the household.</b>                                | <b>Kuna watu wengine? Kama ndio, uliza kuhusu anayefuata</b>                                                    |
| <input type="checkbox"/> Yes                                                                                                           | <input type="checkbox"/> Ndio                                                                                   |
| <input type="checkbox"/> No                                                                                                            | <input type="checkbox"/> La                                                                                     |
| <b>Full-time or part time employment in last month:</b>                                                                                | <b>Kuajiriwa au kibarua kwa mwezi uliopita</b>                                                                  |
| <i>Please provide the details of all full-time and part-time employment that adults in this household have had in the last month</i>   | <i>Tafadhali nieleze kuhusu ajira na mapato ya mwezi uliopita kwa wale wanaofanya kazi katika nyumba hii</i>    |
| Adult                                                                                                                                  | Mtu mzima                                                                                                       |
| Employer                                                                                                                               | Muajiri                                                                                                         |
| Time                                                                                                                                   | Kiasi cha muda                                                                                                  |
| Unit                                                                                                                                   | Muda                                                                                                            |
| Pay                                                                                                                                    | Malipo                                                                                                          |
| Pay unit                                                                                                                               | Kiasi cha malipo                                                                                                |
| <b>"Suppose that the government could help your village with just THREE of these issues. Which would YOUR FAMILY choose?":</b>         | <b>Iwapo Serikali ingependa kusaidia kijiji hiki, ni mambo yapi matatu familia yako ingependekeza yafanywe?</b> |
| <i>Do NOT prompt. Tick only THREE</i>                                                                                                  | <i>Usimuelekeze mhusika. Chagua majibu 3</i>                                                                    |
| <input type="checkbox"/> Health                                                                                                        | <input type="checkbox"/> Afya na huduma za afya                                                                 |
| <input type="checkbox"/> Sanitation                                                                                                    | <input type="checkbox"/> Usafi (vyoo na upitishaji wa maji machafu)                                             |
| <input type="checkbox"/> Transport                                                                                                     | <input type="checkbox"/> Usafiri na barabara                                                                    |
| <input type="checkbox"/> Security                                                                                                      | <input type="checkbox"/> Usalama na uhalifu                                                                     |
| <input type="checkbox"/> Electricity                                                                                                   | <input type="checkbox"/> Huduma za umeme                                                                        |

|                                                                                                            |                                                                                                                   |
|------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------|
| <input type="checkbox"/> Jobs and unemployment                                                             | <input type="checkbox"/> Kazi na ukosefu wa ajira                                                                 |
| <input type="checkbox"/> Education                                                                         | <input type="checkbox"/> elimu                                                                                    |
| <input type="checkbox"/> Agriculture                                                                       | <input type="checkbox"/> Usaidizi wa kilimo                                                                       |
| <input type="checkbox"/> Water services                                                                    | <input type="checkbox"/> Huduma za usambazaji wa maji,                                                            |
| <input type="checkbox"/> Other                                                                             | <input type="checkbox"/> Nyenginezo                                                                               |
| <b>What are your concerns regarding the WATER SUPPLY?:</b>                                                 | Ni mambo gani yanakukera kuhusu hali ya usambazaji wa maji                                                        |
| <i>Do NOT prompt. Tick all mentioned</i>                                                                   | <i>Usimuelekeze mhusika. Chagua yote yatakayotajwa</i>                                                            |
| <input type="checkbox"/> Water source is too far away                                                      | <input type="checkbox"/> Maji yanasambaziwa mbali sana                                                            |
| <input type="checkbox"/> Insufficient water for domestic use                                               | <input type="checkbox"/> Maji hayatoshi kwa matumizi ya nyumbani                                                  |
| <input type="checkbox"/> Insufficient water for agricultural use                                           | <input type="checkbox"/> maji hayatoshi kwa kilimo                                                                |
| <input type="checkbox"/> Insufficient water for livestock                                                  | <input type="checkbox"/> maji hayatoshi kwa mifugo                                                                |
| <input type="checkbox"/> Water is too expensive                                                            | <input type="checkbox"/> Usambazaji wa maji ni ghali                                                              |
| <input type="checkbox"/> Water is not safe to drink                                                        | <input type="checkbox"/> Maji si salama kwa kunywa                                                                |
| <input type="checkbox"/> Insufficient water storage in the home                                            | <input type="checkbox"/> Hakuna mahali pa kuhifadhi maji nyumbani,                                                |
| <input type="checkbox"/> Water is unreliable                                                               | <input type="checkbox"/> Usambazaji wa maji haategemeeki                                                          |
| <input type="checkbox"/> Water is seasonal                                                                 | <input type="checkbox"/> Maji ni ya msimu                                                                         |
| <input type="checkbox"/> Queue for water is too long                                                       | <input type="checkbox"/> Mlolongo wa kupata maji ni mrefu sana                                                    |
| <input type="checkbox"/> Other                                                                             | <input type="checkbox"/> Nyenginezo                                                                               |
| <b>Other concern relating to water supply:</b>                                                             | <b>Mambo mengine yanayokera kuhusu usambazaji wa maji</b>                                                         |
| <b>Does your household have any of the following items</b>                                                 | <b>Je, nyumba yako ina vitu vifuatavyo?</b>                                                                       |
| <input type="checkbox"/> Household assets                                                                  | <input type="checkbox"/> Rasimali za nyumbani                                                                     |
| <input type="checkbox"/> Electricity connection                                                            | <input type="checkbox"/> Umeme                                                                                    |
| <input type="checkbox"/> Solar panel                                                                       | <input type="checkbox"/> Sola                                                                                     |
| <input type="checkbox"/> Television                                                                        | <input type="checkbox"/> Televisheni/ Runinga                                                                     |
| <input type="checkbox"/> Computer                                                                          | <input type="checkbox"/> Kompyuta / Tarakilishi                                                                   |
| <input type="checkbox"/> Radio                                                                             | <input type="checkbox"/> Redio                                                                                    |
| <input type="checkbox"/> Bicycle                                                                           | <input type="checkbox"/> Baiskeli                                                                                 |
| <input type="checkbox"/> Motorcycle                                                                        | <input type="checkbox"/> Pikipiki                                                                                 |
| <input type="checkbox"/> Dhow                                                                              | <input type="checkbox"/> Dhow                                                                                     |
| <input type="checkbox"/> Mobile phone                                                                      | <input type="checkbox"/> Simu ya mkononi/ rununu                                                                  |
| <b>Does your household currently have the following items and foodstuffs</b>                               | <b>Je, nyumba yako ina vitu na vyakula vifuatavyo?</b>                                                            |
| <input type="checkbox"/> Cooking oil                                                                       | <input type="checkbox"/> Mafuta ya kupikia                                                                        |
| <input type="checkbox"/> Sugar                                                                             | <input type="checkbox"/> Sukari                                                                                   |
| <input type="checkbox"/> Flour                                                                             | <input type="checkbox"/> Unga                                                                                     |
| <input type="checkbox"/> Tea leaves                                                                        | <input type="checkbox"/> Majani chai                                                                              |
| <input type="checkbox"/> Soap                                                                              | <input type="checkbox"/> Sabuni                                                                                   |
| <b>Have you or anyone in your household received or sent MONEY using a MOBILE PHONE in the last year?:</b> | <b>Je, kuna mtu yeyote wa nyumba hii amewahi tuma au kupokea pesa kutumia simu ya mkononi kwa mwaka uliopita?</b> |
| <input type="checkbox"/> Yes                                                                               | <input type="checkbox"/> Ndio                                                                                     |

|                                                                                                   |                                                                               |
|---------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------|
| <input type="checkbox"/> No                                                                       | <input type="checkbox"/> La                                                   |
| <b>Which MOBILE MONEY PROVIDER(S) have you or other household members used in the last year?:</b> | <b>Je, ni mtandao gani uliotumia?</b>                                         |
| <b>What type of fuel does your household mainly use for cooking?:</b>                             | <b>Unatumia nini kupikia?</b>                                                 |
| <input type="checkbox"/> Electricity                                                              | <input type="checkbox"/> Umeme                                                |
| <input type="checkbox"/> Natural gas                                                              | <input type="checkbox"/> Gesi                                                 |
| <input type="checkbox"/> Kerosene                                                                 | <input type="checkbox"/> Mafuta ya taa                                        |
| <input type="checkbox"/> Charcoal                                                                 | <input type="checkbox"/> Makaa                                                |
| <input type="checkbox"/> Wood                                                                     | <input type="checkbox"/> Kuni                                                 |
| <input type="checkbox"/> Straw/Shrubs/Grass                                                       | <input type="checkbox"/> Nyasi                                                |
| <input type="checkbox"/> Agricultural crop (e.g. maize)                                           | <input type="checkbox"/> Mahunzi (Maguguta)                                   |
| <input type="checkbox"/> Animal dung                                                              | <input type="checkbox"/> Mavi ya ngombe                                       |
| <input type="checkbox"/> No food cooked in household                                              | <input type="checkbox"/> Hatupiki                                             |
| <input type="checkbox"/> Other                                                                    | <input type="checkbox"/> Nyenginezo                                           |
| <b>What kind of toilet facility do members of your household usually use?:</b>                    | <b>Mnatumia choo cha aina gani?</b>                                           |
| <input type="checkbox"/> Flush to piped sewer system                                              | <input type="checkbox"/> Choo cha kusukuma kwa kupitia bomba                  |
| <input type="checkbox"/> Flush to septic tank                                                     | <input type="checkbox"/> Choo cha kusukuma kwa kupitia tangi                  |
| <input type="checkbox"/> Flush to pit latrine                                                     | <input type="checkbox"/> Choo cha kusukuma hadi kwenye shimo                  |
| <input type="checkbox"/> VIP latrine                                                              | <input type="checkbox"/> Shimo la choo lenye hewa nzuri                       |
| <input type="checkbox"/> Pit latrine with slab                                                    | <input type="checkbox"/> Choo cha shimo kilichojengewa                        |
| <input type="checkbox"/> Bucket toilet                                                            | <input type="checkbox"/> Choo cha ndoo                                        |
| <input type="checkbox"/> Composting toilet                                                        | <input type="checkbox"/> Choo cha kuhifadhi mbolea                            |
| <input type="checkbox"/> Hanging toilets/latrines                                                 | <input type="checkbox"/> Choo kando kando ya maji                             |
| <input type="checkbox"/> No facility/bush/field                                                   | <input type="checkbox"/> Hakuna choo/ Choo cha msituni/uwanjani               |
| <input type="checkbox"/> Other                                                                    | <input type="checkbox"/> Nyenginezo                                           |
| <b>If 'other' toilet facility, please specify::</b>                                               | <b>Kama ni nyenginezo, tafadhali fafania kwenye nafasi</b>                    |
| <b>Do you share this toilet facility with other households?:</b>                                  | <b>Je, mantumia hiki choo pamoja na watu wengine?</b>                         |
| <input type="checkbox"/> Yes                                                                      | <input type="checkbox"/> Ndio                                                 |
| <input type="checkbox"/> No                                                                       | <input type="checkbox"/> La                                                   |
| <b>How many households use this facility?:</b>                                                    | <b>Kama ndio, mbali na nyumba yako, ni ngapi zingine zinatumia choo hiki?</b> |
| <i>Type '-99' if not known, or '88' if no response</i>                                            | <i>Andika '-99' kama mhusika hajui au '-88' asipojibu</i>                     |
| <b>How many rooms in this household are used for sleeping?:</b>                                   | <b>Mna vyumba vingapi vya kulala?</b>                                         |
| <b>Does your household own the LAND on which the structure (house, flat, shack) sits?:</b>        | <b>Je, mnamiliki ardhi ya nyumba hii?</b>                                     |
| <input type="checkbox"/> Owns                                                                     | <input type="checkbox"/> Tunamiliki                                           |
| <input type="checkbox"/> Pays rent                                                                | <input type="checkbox"/> Tumekodi ardhi                                       |
| <input type="checkbox"/> Does not pay rent with consent of owner                                  | <input type="checkbox"/> Hatukukodi-tumepewa kwa ridhaa                       |
| <input type="checkbox"/> Does not pay rent – squatting                                            | <input type="checkbox"/> Hatukukodi-ni maskwata                               |
| <input type="checkbox"/> Don't know                                                               | <input type="checkbox"/> Sijui                                                |

|                                                                                                                        |      |           |        |        |       |        |                                                                                              |         |         |               |       |      |                                        |
|------------------------------------------------------------------------------------------------------------------------|------|-----------|--------|--------|-------|--------|----------------------------------------------------------------------------------------------|---------|---------|---------------|-------|------|----------------------------------------|
| <b>How many acres of land (altogether) are owned by the members of this household?:</b>                                |      |           |        |        |       |        | <b>Mnamiliki hekari ngapi za shamba?</b>                                                     |         |         |               |       |      |                                        |
| <i>If unknown, enter '-99'</i>                                                                                         |      |           |        |        |       |        | <i>Andika '-99' kama haijulikani</i>                                                         |         |         |               |       |      |                                        |
| <b>Do any members of your household grow crops?:</b>                                                                   |      |           |        |        |       |        | <b>Kuna yeyote anaelima?</b>                                                                 |         |         |               |       |      |                                        |
| <input type="checkbox"/> Yes                                                                                           |      |           |        |        |       |        | <input type="checkbox"/> Ndio                                                                |         |         |               |       |      |                                        |
| <input type="checkbox"/> No                                                                                            |      |           |        |        |       |        | <input type="checkbox"/> La                                                                  |         |         |               |       |      |                                        |
| <b>Of the land you own, how many acres do you farm in the wet season?:</b>                                             |      |           |        |        |       |        | <b>Ni hekari ngapi mnazolima wakati wa masika?</b>                                           |         |         |               |       |      |                                        |
| <b>Does your household grow any sugarcane for KISCOL?:</b>                                                             |      |           |        |        |       |        | <b>Je mnakuza miwa kwa ajili ya KISCOL?</b>                                                  |         |         |               |       |      |                                        |
| <input type="checkbox"/> Yes                                                                                           |      |           |        |        |       |        | <input type="checkbox"/> Ndio                                                                |         |         |               |       |      |                                        |
| <input type="checkbox"/> No                                                                                            |      |           |        |        |       |        | <input type="checkbox"/> La                                                                  |         |         |               |       |      |                                        |
| <b>How many acres of your farming land are under sugarcane?:</b>                                                       |      |           |        |        |       |        | <b>Ni hekari ngapi zilizopandwa miwa?</b>                                                    |         |         |               |       |      |                                        |
| <i>If unknown, enter -99</i>                                                                                           |      |           |        |        |       |        | <i>Andika '-99' kama haijulikani</i>                                                         |         |         |               |       |      |                                        |
| <b>Does this household own any livestock, herds, other farm animals or poultry?:</b>                                   |      |           |        |        |       |        | <b>Je, mnamiliki mifugo wa aina yoyote?</b>                                                  |         |         |               |       |      |                                        |
| <input type="checkbox"/> Yes                                                                                           |      |           |        |        |       |        | <input type="checkbox"/> Ndio                                                                |         |         |               |       |      |                                        |
| <input type="checkbox"/> No                                                                                            |      |           |        |        |       |        | <input type="checkbox"/> La                                                                  |         |         |               |       |      |                                        |
| <b>How many indigenous cattle does your household own?:</b>                                                            |      |           |        |        |       |        | <b>Mna ng'ombe wa kienyeji wangapi?</b>                                                      |         |         |               |       |      |                                        |
| <b>How many dairy cows does your household own?:</b>                                                                   |      |           |        |        |       |        | <b>Mna ng'ombe wa maziwa wangapi?</b>                                                        |         |         |               |       |      |                                        |
| <b>How many oxen does your household own?:</b>                                                                         |      |           |        |        |       |        | <b>Mna ng'ombe wa kulima wangapi?</b>                                                        |         |         |               |       |      |                                        |
| <b>"Now I would like to know how much money you spend on different things":</b>                                        |      |           |        |        |       |        | <b>Sasa ningependa kukuuliza ni kiasi gani cha fedha unachotumia juu ya vitu tofauti</b>     |         |         |               |       |      |                                        |
| <b>Household expenditure in the last week or month - if no expenditure, enter '0':</b>                                 |      |           |        |        |       |        | <b>Matumizi ya nyumbani kwa wiki/mwezi uliopita. Kama hakuna matumizi, andika 0 (sufuri)</b> |         |         |               |       |      |                                        |
|                                                                                                                        | Food | Transport | Health | School | Water | Energy |                                                                                              | Chakula | Usafiri | Matibabu/Dawa | Shule | Maji | Matumizi kwa umeme na nguvu ya kupikia |
| <b>Item:</b>                                                                                                           |      |           |        |        |       |        | <b>Kitu:</b>                                                                                 |         |         |               |       |      |                                        |
| <b>Amount:</b>                                                                                                         |      |           |        |        |       |        | <b>Kiasi cha pesa:</b>                                                                       |         |         |               |       |      |                                        |
| <b>Unit:</b>                                                                                                           |      |           |        |        |       |        | <b>Kiasi cha muda:</b>                                                                       |         |         |               |       |      |                                        |
| <b>In general, would you say that your family is well-off, average or not well off in terms of income and assets?:</b> |      |           |        |        |       |        | <b>Kwa ujumla, utasema familia yako ni tajiri, inajiweza au ni maskini?</b>                  |         |         |               |       |      |                                        |
| <input type="checkbox"/> Well-off                                                                                      |      |           |        |        |       |        | <input type="checkbox"/> Tajiri                                                              |         |         |               |       |      |                                        |
| <input type="checkbox"/> Average                                                                                       |      |           |        |        |       |        | <input type="checkbox"/> Inajiweza                                                           |         |         |               |       |      |                                        |
| <input type="checkbox"/> Maskini                                                                                       |      |           |        |        |       |        | <input type="checkbox"/> Maskini                                                             |         |         |               |       |      |                                        |
| <input type="checkbox"/> Don't know                                                                                    |      |           |        |        |       |        | <input type="checkbox"/> Sijui                                                               |         |         |               |       |      |                                        |
| <i>"Now I'm going to ask you about which water source(s) you normally use for drinking":</i>                           |      |           |        |        |       |        | <i>Sasa nitakuuliza njia unazotumia kupata maji ya KUNYWA</i>                                |         |         |               |       |      |                                        |
| <b>In the DRY season, what is the MAIN source of water your household uses for DRINKING?:</b>                          |      |           |        |        |       |        | <b>Wakati wa kiangazi, mnapata maji ya kunywa wapi?</b>                                      |         |         |               |       |      |                                        |
| <input type="checkbox"/> Reference handpump                                                                            |      |           |        |        |       |        | <input type="checkbox"/> Reference handpump                                                  |         |         |               |       |      |                                        |
| <input type="checkbox"/> Other handpump                                                                                |      |           |        |        |       |        | <input type="checkbox"/> Handpump nyengine                                                   |         |         |               |       |      |                                        |
| <input type="checkbox"/> Submersible pump PUBLIC                                                                       |      |           |        |        |       |        | <input type="checkbox"/> Mashine ya kupamp maji (ya umma)                                    |         |         |               |       |      |                                        |

|                                                                                                             |                                                                                                   |             |  |                |                |              |
|-------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------|-------------|--|----------------|----------------|--------------|
| <input type="checkbox"/> Submersible pump PRIVATE                                                           | <input type="checkbox"/> Mashine ya kupamp maji (ya binafsi)                                      |             |  |                |                |              |
| <input type="checkbox"/> Protected well PUBLIC                                                              | <input type="checkbox"/> Kisima kilichofunikwa (cha umma)                                         |             |  |                |                |              |
| <input type="checkbox"/> Protected well PRIVATE                                                             | <input type="checkbox"/> Kisima kilichofunikwa (cha binafsi)                                      |             |  |                |                |              |
| <input type="checkbox"/> Unprotected well PUBLIC                                                            | <input type="checkbox"/> Kisima kilichowazi (cha umma)                                            |             |  |                |                |              |
| <input type="checkbox"/> Unprotected well PRIVATE                                                           | <input type="checkbox"/> Kisima kilichowazi (cha binafsi)                                         |             |  |                |                |              |
| <input type="checkbox"/> Surface water (river, stream, pond, dam, lake)                                     | <input type="checkbox"/> Maji ya ardhi (mito, ziwa, kidimbwi, mito midogo, kishimo)               |             |  |                |                |              |
| <input type="checkbox"/> Piped to yard dwelling                                                             | <input type="checkbox"/> Maji ya mfereji nyumbani                                                 |             |  |                |                |              |
| <input type="checkbox"/> Piped to neighbour's yard                                                          | <input type="checkbox"/> Maji ya mfereji kwa jirani                                               |             |  |                |                |              |
| <input type="checkbox"/> Public tap Kiosk                                                                   | <input type="checkbox"/> Mfereji wa umma                                                          |             |  |                |                |              |
| <input type="checkbox"/> Tanker truck                                                                       | <input type="checkbox"/> Gari la maji                                                             |             |  |                |                |              |
| <input type="checkbox"/> Cart bicycle with tanks drums jerricans                                            | <input type="checkbox"/> Mkokoteni/baiskeli iliyo na madebe/ mitungi                              |             |  |                |                |              |
| <input type="checkbox"/> Rainwater collection                                                               | <input type="checkbox"/> Maji ya mvua                                                             |             |  |                |                |              |
| <input type="checkbox"/> Bottled water                                                                      | <input type="checkbox"/> Maji ya chupa                                                            |             |  |                |                |              |
| <input type="checkbox"/> Other                                                                              | <input type="checkbox"/> Nyenginezo                                                               |             |  |                |                |              |
| <b>If 'other' chosen, please specify:</b>                                                                   | <b>Kama ni nyenginezo, tafadhali fafana kwenye nafasi</b>                                         |             |  |                |                |              |
| <b>What are the main reason(s) you choose this source as main DRINKING water source in the DRY season?:</b> | <b>Ni sababu gani zinazofanya uchague kupata maji ya kunywa kwa njia hiyo wakati wa kiangazi?</b> |             |  |                |                |              |
| <i>Do not prompt. Tick ALL that apply</i>                                                                   | <i>Usimuelekeze mhusika. Chagua yote yatakayotajwa</i>                                            |             |  |                |                |              |
| <input type="checkbox"/> Close_to_home                                                                      | <input type="checkbox"/> Iko karibu na nyumba                                                     |             |  |                |                |              |
| <input type="checkbox"/> Taste                                                                              | <input type="checkbox"/> Ladha ya maji                                                            |             |  |                |                |              |
| <input type="checkbox"/> Colour                                                                             | <input type="checkbox"/> Rangi ya maji                                                            |             |  |                |                |              |
| <input type="checkbox"/> Smell                                                                              | <input type="checkbox"/> Harufu ya maji                                                           |             |  |                |                |              |
| <input type="checkbox"/> Safe to drink                                                                      | <input type="checkbox"/> Usalama wa kunywa                                                        |             |  |                |                |              |
| <input type="checkbox"/> Affordable                                                                         | <input type="checkbox"/> Yananulika kwa bei nafuu                                                 |             |  |                |                |              |
| <input type="checkbox"/> Free                                                                               | <input type="checkbox"/> Ni bure                                                                  |             |  |                |                |              |
| <input type="checkbox"/> Reliable                                                                           | <input type="checkbox"/> Yanategemeeka                                                            |             |  |                |                |              |
| <input type="checkbox"/> Only source available                                                              | <input type="checkbox"/> Ndio njia ya pekee                                                       |             |  |                |                |              |
| <input type="checkbox"/> Nyenginezo                                                                         | <input type="checkbox"/> Nyenginezo                                                               |             |  |                |                |              |
| <b>If 'other' chosen, please specify:</b>                                                                   | <b>Kama ni nyenginezo, tafadhali fafana kwenye nafasi</b>                                         |             |  |                |                |              |
| <b>Do you think the water from this source in the DRY season is safe to drink?:</b>                         | <b>Wakati wa kiangazi, maji haya ni salama kwa kunywa?</b>                                        |             |  |                |                |              |
| <input type="checkbox"/> Yes                                                                                | <input type="checkbox"/> Ndio                                                                     |             |  |                |                |              |
| <input type="checkbox"/> No                                                                                 | <input type="checkbox"/> La                                                                       |             |  |                |                |              |
| <input type="checkbox"/> Don't know                                                                         | <input type="checkbox"/> Sijui                                                                    |             |  |                |                |              |
| <b>How would you rate the water quality from this source in the dry season?</b>                             | <b>Utasema vipi kuhusu hali ya maji wakati wa kiangazi?</b>                                       |             |  |                |                |              |
|                                                                                                             |                                                                                                   |             |  |                |                |              |
| <b>Good</b>                                                                                                 | <b>Average</b>                                                                                    | <b>Poor</b> |  | <b>Nzuri</b>   | <b>Wastani</b> | <b>Mbaya</b> |
| <b>Taste:</b>                                                                                               |                                                                                                   |             |  | <b>Ladha:</b>  |                |              |
| <b>Colour:</b>                                                                                              |                                                                                                   |             |  | <b>Rangi:</b>  |                |              |
| <b>Smell:</b>                                                                                               |                                                                                                   |             |  | <b>Harufu:</b> |                |              |
| <b>How much do you pay to use this main drinking water source in the DRY season?:</b>                       | <b>Unalipa pesa ngapi kutumia maji haya wakati wa kiangazi?</b>                                   |             |  |                |                |              |

|                                                                                                             |                                                                                                 |
|-------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------|
| <b>Amount:</b>                                                                                              | <b>Kiasi cha pesa:</b>                                                                          |
| <b>Frequency:</b>                                                                                           | <b>Jinsi ya malipo:</b>                                                                         |
| <b>In the WET season, what is the MAIN source of water your household uses for DRINKING?:</b>               | <b>Wakati wa masika, mnapata maji ya kunywa wapi?</b>                                           |
| <input type="checkbox"/> Reference handpump                                                                 | <input type="checkbox"/> Reference handpump                                                     |
| <input type="checkbox"/> Other handpump                                                                     | <input type="checkbox"/> Handpump nyengine                                                      |
| <input type="checkbox"/> Submersible pump PUBLIC                                                            | <input type="checkbox"/> Mashine ya kupamp maji (ya umma)                                       |
| <input type="checkbox"/> Submersible pump PRIVATE                                                           | <input type="checkbox"/> Mashine ya kupamp maji (ya binafsi)                                    |
| <input type="checkbox"/> Protected well PUBLIC                                                              | <input type="checkbox"/> Kisima kilichofunikwa (cha umma)                                       |
| <input type="checkbox"/> Protected well PRIVATE                                                             | <input type="checkbox"/> Kisima kilichofunikwa (cha binafsi)                                    |
| <input type="checkbox"/> Unprotected well PUBLIC                                                            | <input type="checkbox"/> Kisima kilichowazi (cha umma)                                          |
| <input type="checkbox"/> Unprotected well PRIVATE                                                           | <input type="checkbox"/> Kisima kilichowazi (cha binafsi)                                       |
| <input type="checkbox"/> Surface water (river, stream, pond, dam, lake)                                     | <input type="checkbox"/> Maji ya ardhini (mito, ziwa, kidimbwi, mito midogo, kishimo)           |
| <input type="checkbox"/> Piped to yard dwelling                                                             | <input type="checkbox"/> Maji ya mfereji nyumbani                                               |
| <input type="checkbox"/> Piped to neighbour's yard                                                          | <input type="checkbox"/> Maji ya mfereji kwa jirani                                             |
| <input type="checkbox"/> Public tap Kiosk                                                                   | <input type="checkbox"/> Mfereji wa umma                                                        |
| <input type="checkbox"/> Tanker truck                                                                       | <input type="checkbox"/> Gari la maji                                                           |
| <input type="checkbox"/> Cart bicycle with tanks drums jerricans                                            | <input type="checkbox"/> Mkokoteni/baiskeli iliyo na madebe/ mitungi                            |
| <input type="checkbox"/> Rainwater collection                                                               | <input type="checkbox"/> Maji ya mvua                                                           |
| <input type="checkbox"/> Bottled water                                                                      | <input type="checkbox"/> Maji ya chupa                                                          |
| <input type="checkbox"/> Other                                                                              | <input type="checkbox"/> Nyenginezo                                                             |
| <b>If 'other' chosen, please specify:</b>                                                                   | <b>Kama ni nyenginezo, tafadhali fafania kwenye nafasi</b>                                      |
| <b>What are the main reason(s) you choose this source as main DRINKING water source in the WET season?:</b> | <b>Ni sababu gani zinazofanya uchague kupata maji ya kunywa kwa njia hiyo wakati wa masika?</b> |
| <i>Do not prompt. Tick ALL that apply</i>                                                                   | <i>Usimuelekeze mhusika. Chagua yote yatakayotajwa</i>                                          |
| <input type="checkbox"/> Close_to_home                                                                      | <input type="checkbox"/> Iko karibu na nyumba                                                   |
| <input type="checkbox"/> Taste                                                                              | <input type="checkbox"/> Ladha ya maji                                                          |
| <input type="checkbox"/> Colour                                                                             | <input type="checkbox"/> Rangi ya maji                                                          |
| <input type="checkbox"/> Smell                                                                              | <input type="checkbox"/> Harufu ya maji                                                         |
| <input type="checkbox"/> Safe to drink                                                                      | <input type="checkbox"/> Usalama wa kunywa                                                      |
| <input type="checkbox"/> Affordable                                                                         | <input type="checkbox"/> Yananulika kwa bei nafuu                                               |
| <input type="checkbox"/> Free                                                                               | <input type="checkbox"/> Ni bure                                                                |
| <input type="checkbox"/> Reliable                                                                           | <input type="checkbox"/> Yanategemeeka                                                          |
| <input type="checkbox"/> Only source available                                                              | <input type="checkbox"/> Ndio njia ya pekee                                                     |
| <input type="checkbox"/> Nyenginezo                                                                         | <input type="checkbox"/> Nyenginezo                                                             |
| <b>Do you think the water from this source in the WET season is safe to drink?:</b>                         | <b>Wakati wa masika, maji haya ni salama kwa kunywa?</b>                                        |
| <input type="checkbox"/> Yes                                                                                | <input type="checkbox"/> Ndio                                                                   |
| <input type="checkbox"/> No                                                                                 | <input type="checkbox"/> La                                                                     |
| <input type="checkbox"/> Don't know                                                                         | <input type="checkbox"/> Sijui                                                                  |
| <b>How would you rate the water quality from this source in the dry season?</b>                             | <b>Utasema vipi kuhusu hali ya maji wakati wa masika?</b>                                       |

|                                                                                                                        | Good | Average | Poor |                                                                                                                           | Nzuri | Wastani | Mbaya |
|------------------------------------------------------------------------------------------------------------------------|------|---------|------|---------------------------------------------------------------------------------------------------------------------------|-------|---------|-------|
| <b>Taste:</b>                                                                                                          |      |         |      | <b>Ladha:</b>                                                                                                             |       |         |       |
| <b>Colour:</b>                                                                                                         |      |         |      | <b>Rangi:</b>                                                                                                             |       |         |       |
| <b>Smell:</b>                                                                                                          |      |         |      | <b>Harufu:</b>                                                                                                            |       |         |       |
| <b>How much do you pay to use this main drinking water source in the WET season?:</b>                                  |      |         |      | <b>Unalipa pesa ngapi kutumia maji haya wakati wa masika?</b>                                                             |       |         |       |
| <b>Amount:</b>                                                                                                         |      |         |      | <b>Kiasi cha pesa</b>                                                                                                     |       |         |       |
| <b>Frequency:</b>                                                                                                      |      |         |      | <b>Jinsi ya malipo</b>                                                                                                    |       |         |       |
| <b>In the last 12 months, what other water sources, if any have you used for drinking in the dry and/or wet season</b> |      |         |      | <b>Kwa mwaka uliopita, ni njia gani mbadala munayotumia kupata maji ya kunywa wakati wa kiangazi na wakati wa masika?</b> |       |         |       |
| <input type="checkbox"/> REFERENCE HANDPUMP                                                                            |      |         |      | <input type="checkbox"/> Handpump iliyolengwa                                                                             |       |         |       |
| <input type="checkbox"/> Other handpump                                                                                |      |         |      | <input type="checkbox"/> Handpump nyengine                                                                                |       |         |       |
| <input type="checkbox"/> Submersible pump (PUBLIC)                                                                     |      |         |      | <input type="checkbox"/> Mashine ya kupamp maji (ya umma)                                                                 |       |         |       |
| <input type="checkbox"/> Submersible pump (PRIVATE)                                                                    |      |         |      | <input type="checkbox"/> Mashine ya kupamp maji (ya binafsi)                                                              |       |         |       |
| <input type="checkbox"/> Protected well (PUBLIC)                                                                       |      |         |      | <input type="checkbox"/> Kisima kilichofunikwa (cha umma)                                                                 |       |         |       |
| <input type="checkbox"/> Protected well (PRIVATE)                                                                      |      |         |      | <input type="checkbox"/> Kisima kilichofunikwa (cha binafsi)                                                              |       |         |       |
| <input type="checkbox"/> Unprotected well (PUBLIC)                                                                     |      |         |      | <input type="checkbox"/> Kisima kilichowazi (cha umma)                                                                    |       |         |       |
| <input type="checkbox"/> Unprotected well (PRIVATE)                                                                    |      |         |      | <input type="checkbox"/> Kisima kilichowazi (cha binafsi)                                                                 |       |         |       |
| <input type="checkbox"/> Surface water                                                                                 |      |         |      | <input type="checkbox"/> Maji ya ardhini (mito, ziwa, kidimbwi, mito midogo, kishimo)                                     |       |         |       |
| <input type="checkbox"/> Piped to yard/dwelling                                                                        |      |         |      | <input type="checkbox"/> Maji ya mfereji nyumbani                                                                         |       |         |       |
| <input type="checkbox"/> Piped to neighbour's yard/dwelling                                                            |      |         |      | <input type="checkbox"/> Maji ya mfereji kwa jirani                                                                       |       |         |       |
| <input type="checkbox"/> Public tap / kiosk                                                                            |      |         |      | <input type="checkbox"/> Mfereji wa umma                                                                                  |       |         |       |
| <input type="checkbox"/> Tanker truck                                                                                  |      |         |      | <input type="checkbox"/> Gari la maji                                                                                     |       |         |       |
| <input type="checkbox"/> Cart/bicycle with tanks/drums/jerricans                                                       |      |         |      | <input type="checkbox"/> Mkokoteni/baiskeli iliyo na madebe/ mitungi                                                      |       |         |       |
| <input type="checkbox"/> Rainwater collection                                                                          |      |         |      | <input type="checkbox"/> Maji ya mvua                                                                                     |       |         |       |
| <input type="checkbox"/> Bottled water                                                                                 |      |         |      | <input type="checkbox"/> Maji ya chupa                                                                                    |       |         |       |
| <input type="checkbox"/> Other                                                                                         |      |         |      | <input type="checkbox"/> Nyenginezo                                                                                       |       |         |       |
| <b>If 'other' chosen, please specify:</b>                                                                              |      |         |      | <b>Kama ni nyenginezo, tafadhali fafania kwenye nafasi</b>                                                                |       |         |       |
| <b>Does your household treat water before drinking?:</b>                                                               |      |         |      | <b>Je, huwa mnatibu maji kabla ya kunywa?</b>                                                                             |       |         |       |
| <input type="checkbox"/> No                                                                                            |      |         |      | <input type="checkbox"/> La                                                                                               |       |         |       |
| <input type="checkbox"/> Yes – Dry season only                                                                         |      |         |      | <input type="checkbox"/> Ndio-wakati wa masika                                                                            |       |         |       |
| <input type="checkbox"/> Yes – Wet season only                                                                         |      |         |      | <input type="checkbox"/> Ndio-wakati wa kiangazi                                                                          |       |         |       |
| <input type="checkbox"/> Yes – Both wet & dry season                                                                   |      |         |      | <input type="checkbox"/> Ndio-nyakati zote                                                                                |       |         |       |
| <input type="checkbox"/> Don't know                                                                                    |      |         |      | <input type="checkbox"/> Sijui                                                                                            |       |         |       |
| <b>What method(s) does your household use to treat water before drinking?:</b>                                         |      |         |      | <b>Ni njia gani mnayotumia kuyatibu maji ya kunywa?</b>                                                                   |       |         |       |
| <input type="checkbox"/> Boil                                                                                          |      |         |      | <input type="checkbox"/> Kuchemsha                                                                                        |       |         |       |
| <input type="checkbox"/> Add bleach or chlorine (e.g. Waterguard)                                                      |      |         |      | <input type="checkbox"/> Kuongeza dawa,                                                                                   |       |         |       |
| <input type="checkbox"/> Strain through cloth                                                                          |      |         |      | <input type="checkbox"/> Kuchuja na nguo                                                                                  |       |         |       |
| <input type="checkbox"/> Use water filter                                                                              |      |         |      | <input type="checkbox"/> Kutumia kichungio cha maji                                                                       |       |         |       |
| <input type="checkbox"/> Solar disinfection                                                                            |      |         |      | <input type="checkbox"/> Kutumia miale ya jua                                                                             |       |         |       |

|                                                                                                    |                    |                 |                        |                                                                                       |                                   |                                                      |                                |
|----------------------------------------------------------------------------------------------------|--------------------|-----------------|------------------------|---------------------------------------------------------------------------------------|-----------------------------------|------------------------------------------------------|--------------------------------|
| <input type="checkbox"/> Let it stand and settle                                                   |                    |                 |                        | <input type="checkbox"/> Kuyaacha yatulie                                             |                                   |                                                      |                                |
| <input type="checkbox"/> Other                                                                     |                    |                 |                        | <input type="checkbox"/> Nyenginezo                                                   |                                   |                                                      |                                |
| <input type="checkbox"/> Don't know                                                                |                    |                 |                        | <input type="checkbox"/> Sijui                                                        |                                   |                                                      |                                |
| <b>If 'Other', please specify:</b>                                                                 |                    |                 |                        | <b>Kama ni nyenginezo, tafadhali fafania kwenye nafasi</b>                            |                                   |                                                      |                                |
| <b>In the last month how much did you spend on bleach/chorine?:</b>                                |                    |                 |                        | <b>Kwa mwezi uliopita, ulitumia pesa ngapi kununulia dawa za kutibu maji?</b>         |                                   |                                                      |                                |
| <i>If 'Don't know', enter '-99'</i>                                                                |                    |                 |                        | <i>Andika '-99' kama mhusika hajui au '-88' asipojibu</i>                             |                                   |                                                      |                                |
| <b>How many times per week is water boiled for drinking?</b>                                       |                    |                 |                        | <b>Je, unachemsha maji ya kunywa mara ngapi kwa wiki?</b>                             |                                   |                                                      |                                |
| <b>What fuel do you use to boil water for drinking?</b>                                            |                    |                 |                        | <b>Je, unatumia njia gani kuchemsha maji ya kunywa?</b>                               |                                   |                                                      |                                |
| <input type="checkbox"/> Electricity                                                               |                    |                 |                        | <input type="checkbox"/> Umeme                                                        |                                   |                                                      |                                |
| <input type="checkbox"/> Natural gas                                                               |                    |                 |                        | <input type="checkbox"/> Gesi                                                         |                                   |                                                      |                                |
| <input type="checkbox"/> Kerosene                                                                  |                    |                 |                        | <input type="checkbox"/> Mafuta ya taa                                                |                                   |                                                      |                                |
| <input type="checkbox"/> Charcoal                                                                  |                    |                 |                        | <input type="checkbox"/> Makaa                                                        |                                   |                                                      |                                |
| <input type="checkbox"/> Wood                                                                      |                    |                 |                        | <input type="checkbox"/> Kuni                                                         |                                   |                                                      |                                |
| <input type="checkbox"/> Straw, shrubs, grass                                                      |                    |                 |                        | <input type="checkbox"/> Nyasi                                                        |                                   |                                                      |                                |
| <input type="checkbox"/> Agricultural crop (e.g. maize cob)                                        |                    |                 |                        | <input type="checkbox"/> Mahunzi (Maguguta)                                           |                                   |                                                      |                                |
| <input type="checkbox"/> Animal dung                                                               |                    |                 |                        | <input type="checkbox"/> Mavi ya ngombe                                               |                                   |                                                      |                                |
| <input type="checkbox"/> No food cooked in household                                               |                    |                 |                        | <input type="checkbox"/> Hatupiki                                                     |                                   |                                                      |                                |
| <input type="checkbox"/> Other                                                                     |                    |                 |                        | <input type="checkbox"/> Nyenginezo                                                   |                                   |                                                      |                                |
| <b>Who is the main person in the household who collects water?:</b>                                |                    |                 |                        | <b>Ni nani anayechota maji ya nyumbani?</b>                                           |                                   |                                                      |                                |
| <input type="checkbox"/> Adult female                                                              |                    |                 |                        | <input type="checkbox"/> Mwanamke-mtu mzima                                           |                                   |                                                      |                                |
| <input type="checkbox"/> Adult male                                                                |                    |                 |                        | <input type="checkbox"/> Mwanamume-mtu mzima                                          |                                   |                                                      |                                |
| <input type="checkbox"/> Female child (<15 years)                                                  |                    |                 |                        | <input type="checkbox"/> Mtoto wa kike (<miaka 15)                                    |                                   |                                                      |                                |
| <input type="checkbox"/> Male child (<15 years)                                                    |                    |                 |                        | <input type="checkbox"/> Mtoto wa kiume (<miaka 15)                                   |                                   |                                                      |                                |
| <input type="checkbox"/> Other                                                                     |                    |                 |                        | <input type="checkbox"/> Wengine                                                      |                                   |                                                      |                                |
| <input type="checkbox"/> N/A – Water source is located on premises                                 |                    |                 |                        | <input type="checkbox"/> Hakuna anayechota(maji yanaletwa mpaka nyumbani)             |                                   |                                                      |                                |
| <b>Who collects water at different times during a weekday</b>                                      |                    |                 |                        | <b>Ni nani huchota maji nyakati tofauti za wiki (Jumatatu hadi Ijumaa)</b>            |                                   |                                                      |                                |
|                                                                                                    | <b>Before 8am:</b> | <b>8am-4pm:</b> | <b>After 4pm:</b>      |                                                                                       | <b>Kabla ya saa mbili asubuhi</b> | <b>Kati ya saa mbili asubuhi hadi saa kumi jioni</b> | <b>Baada ya saa kumi jioni</b> |
| Adult female                                                                                       |                    |                 |                        | Mwanamke-mtu mzima                                                                    |                                   |                                                      |                                |
| Adult male                                                                                         |                    |                 |                        | Mwanamume-mtu mzima                                                                   |                                   |                                                      |                                |
| Female child (<15 years)                                                                           |                    |                 |                        | Mtoto wa kike (<miaka 15)                                                             |                                   |                                                      |                                |
| Male child (<15 years)                                                                             |                    |                 |                        | Mtoto wa kiume (<miaka 15)                                                            |                                   |                                                      |                                |
| <b>Do you use water from the reference handpump for non drinking purposes? Tick all that apply</b> |                    |                 |                        | <b>Je, mbali na kunywa, una matumizi yapi mengine ya maji kutoka kwenye handpump?</b> |                                   |                                                      |                                |
|                                                                                                    | <b>Dry</b>         | <b>Wet</b>      |                        | <b>Kiangazi</b>                                                                       | <b>Masika</b>                     |                                                      |                                |
| Cooking, washing, bathing:                                                                         |                    |                 | Kupika, Kufua na kuoga |                                                                                       |                                   |                                                      |                                |

|                                                                                                        |  |  |                                                                                                    |  |  |
|--------------------------------------------------------------------------------------------------------|--|--|----------------------------------------------------------------------------------------------------|--|--|
| Irrigation:                                                                                            |  |  | Kunyunyizia mimea                                                                                  |  |  |
| Livestock watering:                                                                                    |  |  | Kunywesha                                                                                          |  |  |
| "Now I'm going to ask you about the water sources you use for drinking when the handpump BREAKS DOWN": |  |  | Sasa, nitakuuliza njia zingine unazotumia kupata maji ya kunywa handpump inapoharibika             |  |  |
| <b>When handpump breaks, what becomes your main source for DRINKING WATER in the DRY SEASON:</b>       |  |  | <b>Handpump ikiharibika, ni njia gani kuu unayotumia kupata maji ya kunywa wakati wa kiangazi?</b> |  |  |
| <input type="checkbox"/> REFERENCE HANDPUMP                                                            |  |  | <input type="checkbox"/> Handpump iliyolengwa                                                      |  |  |
| <input type="checkbox"/> Other handpump                                                                |  |  | <input type="checkbox"/> Handpump nyengine                                                         |  |  |
| <input type="checkbox"/> Submersible pump (PUBLIC)                                                     |  |  | <input type="checkbox"/> Mashine ya kupamp maji (ya umma)                                          |  |  |
| <input type="checkbox"/> Submersible pump (PRIVATE)                                                    |  |  | <input type="checkbox"/> Mashine ya kupamp maji (ya binafsi)                                       |  |  |
| <input type="checkbox"/> Protected well (PUBLIC)                                                       |  |  | <input type="checkbox"/> Kisima kilichofunikwa (cha umma)                                          |  |  |
| <input type="checkbox"/> Protected well (PRIVATE)                                                      |  |  | <input type="checkbox"/> Kisima kilichofunikwa (cha binafsi)                                       |  |  |
| <input type="checkbox"/> Unprotected well (PUBLIC)                                                     |  |  | <input type="checkbox"/> Kisima kilichowazi (cha umma)                                             |  |  |
| <input type="checkbox"/> Unprotected well (PRIVATE)                                                    |  |  | <input type="checkbox"/> Kisima kilichowazi (cha binafsi)                                          |  |  |
| <input type="checkbox"/> Surface water                                                                 |  |  | <input type="checkbox"/> Maji ya ardhini (mito, ziwa, kidimbwi, mito midogo, kishimo)              |  |  |
| <input type="checkbox"/> Piped to yard/dwelling                                                        |  |  | <input type="checkbox"/> Maji ya mfereji nyumbani                                                  |  |  |
| <input type="checkbox"/> Piped to neighbour's yard/dwelling                                            |  |  | <input type="checkbox"/> Maji ya mfereji kwa jirani                                                |  |  |
| <input type="checkbox"/> Public tap / kiosk                                                            |  |  | <input type="checkbox"/> Mfereji wa umma                                                           |  |  |
| <input type="checkbox"/> Tanker truck                                                                  |  |  | <input type="checkbox"/> Gari la maji                                                              |  |  |
| <input type="checkbox"/> Cart/bicycle with tanks/drums/jerricans                                       |  |  | <input type="checkbox"/> Mkokoteni/baiskeli iliyo na madebe/ mitungi                               |  |  |
| <input type="checkbox"/> Rainwater collection                                                          |  |  | <input type="checkbox"/> Maji ya mvua                                                              |  |  |
| <input type="checkbox"/> Bottled water                                                                 |  |  | <input type="checkbox"/> Maji ya chupa                                                             |  |  |
| <input type="checkbox"/> Other                                                                         |  |  | <input type="checkbox"/> Nyenginezo                                                                |  |  |
| <b>If 'other', please specify:</b>                                                                     |  |  | Kama ni nyenginezo, tafadhali fafania kwenye nafasi                                                |  |  |
| <b>When handpump breaks, what becomes your main source for DRINKING WATER in the WET SEASON:</b>       |  |  | <b>Handpump ikiharibika, ni njia gani kuu unayotumia kupata maji ya kunywa wakati wa masika?</b>   |  |  |
| <input type="checkbox"/> REFERENCE HANDPUMP                                                            |  |  | <input type="checkbox"/> Handpump iliyolengwa                                                      |  |  |
| <input type="checkbox"/> Other handpump                                                                |  |  | <input type="checkbox"/> Handpump nyengine                                                         |  |  |
| <input type="checkbox"/> Submersible pump (PUBLIC)                                                     |  |  | <input type="checkbox"/> Mashine ya kupamp maji (ya umma)                                          |  |  |
| <input type="checkbox"/> Submersible pump (PRIVATE)                                                    |  |  | <input type="checkbox"/> Mashine ya kupamp maji (ya binafsi)                                       |  |  |
| <input type="checkbox"/> Protected well (PUBLIC)                                                       |  |  | <input type="checkbox"/> Kisima kilichofunikwa (cha umma)                                          |  |  |
| <input type="checkbox"/> Protected well (PRIVATE)                                                      |  |  | <input type="checkbox"/> Kisima kilichofunikwa (cha binafsi)                                       |  |  |
| <input type="checkbox"/> Unprotected well (PUBLIC)                                                     |  |  | <input type="checkbox"/> Kisima kilichowazi (cha umma)                                             |  |  |
| <input type="checkbox"/> Unprotected well (PRIVATE)                                                    |  |  | <input type="checkbox"/> Kisima kilichowazi (cha binafsi)                                          |  |  |
| <input type="checkbox"/> Surface water                                                                 |  |  | <input type="checkbox"/> Maji ya ardhini (mito, ziwa, kidimbwi, mito midogo, kishimo)              |  |  |
| <input type="checkbox"/> Piped to yard/dwelling                                                        |  |  | <input type="checkbox"/> Maji ya mfereji nyumbani                                                  |  |  |
| <input type="checkbox"/> Piped to neighbour's yard/dwelling                                            |  |  | <input type="checkbox"/> Maji ya mfereji kwa jirani                                                |  |  |
| <input type="checkbox"/> Public tap / kiosk                                                            |  |  | <input type="checkbox"/> Mfereji wa umma                                                           |  |  |
| <input type="checkbox"/> Tanker truck                                                                  |  |  | <input type="checkbox"/> Gari la maji                                                              |  |  |
| <input type="checkbox"/> Cart/bicycle with tanks/drums/jerricans                                       |  |  | <input type="checkbox"/> Mkokoteni/baiskeli iliyo na madebe/ mitungi                               |  |  |

|                                                                                                                                                                                            |                                                                                                                                                                                            |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <input type="checkbox"/> Rainwater collection                                                                                                                                              | <input type="checkbox"/> Maji ya mvua                                                                                                                                                      |
| <input type="checkbox"/> Bottled water                                                                                                                                                     | <input type="checkbox"/> Maji ya chupa                                                                                                                                                     |
| <input type="checkbox"/> Other                                                                                                                                                             | <input type="checkbox"/> Nyenginezo                                                                                                                                                        |
| <b>If 'other', please specify:</b>                                                                                                                                                         | <b>Kama ni nyenginezo, tafadhali fafania kwenye nafasi</b>                                                                                                                                 |
| <b>In DRY season, how many times per day does your household collect water from the handpump?:</b>                                                                                         | <b>Wakati wa kiangazi, mnachota maji mara ngapi kwa siku kutoka kwenye handpump?</b>                                                                                                       |
| <b>In the DRY season, how many jerricans/buckets of water does your household collect from the handpump EACH DAY?:</b>                                                                     | <b>Mnachota mitungi mingapi kwa siku(wakati wa kiangazi)?</b>                                                                                                                              |
| <b>In WET season, how many times per day does your household collect water from the handpump?:</b>                                                                                         | <b>Wakati wa masika, mnachota maji mara ngapi kwa siku kutoka kwenye handpump?</b>                                                                                                         |
| <b>In the WET season, how many jerricans/buckets of water does your household collect from the handpump EACH DAY?:</b>                                                                     | <b>Mnachota mitungi mingapi kwa siku(wakati wa masika)?</b>                                                                                                                                |
| <b>Do you think the water from the handpump is safe to drink in the DRY season?:</b>                                                                                                       | <b>Je, unadhani maji kutoka kwa handpump ni salama kwa kunywa wakati wa kiangazi?</b>                                                                                                      |
| <input type="checkbox"/> Yes                                                                                                                                                               | <input type="checkbox"/> Ndio                                                                                                                                                              |
| <input type="checkbox"/> No                                                                                                                                                                | <input type="checkbox"/> La                                                                                                                                                                |
| <input type="checkbox"/> Don't know                                                                                                                                                        | <input type="checkbox"/> Sijui                                                                                                                                                             |
| <b>Do you think the water from the handpump is safe to drink in the WET season?:</b>                                                                                                       | <b>Je, unadhani maji kutoka kwa handpump ni salama kwa kunywa wakati wa masika?</b>                                                                                                        |
| <input type="checkbox"/> Yes                                                                                                                                                               | <input type="checkbox"/> Ndio                                                                                                                                                              |
| <input type="checkbox"/> No                                                                                                                                                                | <input type="checkbox"/> La                                                                                                                                                                |
| <input type="checkbox"/> Don't know                                                                                                                                                        | <input type="checkbox"/> Sijui                                                                                                                                                             |
| <b>Does your household have to pay fees to use the handpump?:</b>                                                                                                                          | <b>Mnalipa ada yoyote kwa huduma ya handpump?</b>                                                                                                                                          |
| <input type="checkbox"/> Yes – Regular payments                                                                                                                                            | <input type="checkbox"/> Ndio - Malipo ya kila mara                                                                                                                                        |
| <input type="checkbox"/> Yes – Only when handpump breaks                                                                                                                                   | <input type="checkbox"/> Ndio - Malipo handpump ikiharibika                                                                                                                                |
| <input type="checkbox"/> La                                                                                                                                                                | <input type="checkbox"/> No                                                                                                                                                                |
| <input type="checkbox"/> Don't know                                                                                                                                                        | <input type="checkbox"/> Sijui                                                                                                                                                             |
| <b>How much do you pay to use water from the handpump:</b>                                                                                                                                 | <b>Mnalipa pesa ngapi kwa huduma ya handpump?</b>                                                                                                                                          |
|                                                                                                                                                                                            |                                                                                                                                                                                            |
| <b>Dry</b>                                                                                                                                                                                 | <b>Wet</b>                                                                                                                                                                                 |
| <b>Amount</b>                                                                                                                                                                              | <b>Amount</b>                                                                                                                                                                              |
| <b>Frequency</b>                                                                                                                                                                           | <b>Frequency</b>                                                                                                                                                                           |
| <input type="checkbox"/> Per bucket<br><input type="checkbox"/> Per week<br><input type="checkbox"/> Per month<br><input type="checkbox"/> Per year<br><input type="checkbox"/> Other_____ | <input type="checkbox"/> Per bucket<br><input type="checkbox"/> Per week<br><input type="checkbox"/> Per month<br><input type="checkbox"/> Per year<br><input type="checkbox"/> Other_____ |
| <b>Who in your household is usually responsible for paying handpump user fees:</b>                                                                                                         | <b>Ni nani katika nyumba hii anayehusika na kulipia huduma ya handpump?</b>                                                                                                                |
| <input type="checkbox"/> Male adult                                                                                                                                                        | <input type="checkbox"/> Mwekahazina wa kamati ya maji                                                                                                                                     |
| <input type="checkbox"/> Female adult                                                                                                                                                      | <input type="checkbox"/> Mhudumu wa handpump                                                                                                                                               |
| <input type="checkbox"/> Male child (<15 years)                                                                                                                                            | <input type="checkbox"/> Mwanakamati mwingine                                                                                                                                              |
| <input type="checkbox"/> Female child (<15 years)                                                                                                                                          | <input type="checkbox"/> Mmiliki wa handpump                                                                                                                                               |
| <input type="checkbox"/> Other                                                                                                                                                             | <input type="checkbox"/> Wengine                                                                                                                                                           |
| <input type="checkbox"/> Don't know                                                                                                                                                        | <input type="checkbox"/> Sijui                                                                                                                                                             |

|                                                                                        |                                                                                    |
|----------------------------------------------------------------------------------------|------------------------------------------------------------------------------------|
| <b>Who usually collects the handpump user fees from your household?:</b>               | <b>Ni nani anayechukua malipo ya huduma ya handpump?</b>                           |
| <input type="checkbox"/> Water committee treasurer                                     | <input type="checkbox"/> Mwekahazina wa kamati ya maji                             |
| <input type="checkbox"/> Handpump attendant/caretaker                                  | <input type="checkbox"/> Mhudumu wa handpump                                       |
| <input type="checkbox"/> Other water committee member                                  | <input type="checkbox"/> Mwanakamati mwengine                                      |
| <input type="checkbox"/> Owner of the handpump                                         | <input type="checkbox"/> Mmiliki wa handpump                                       |
| <input type="checkbox"/> Other                                                         | <input type="checkbox"/> Wengine                                                   |
| <input type="checkbox"/> Don't know                                                    | <input type="checkbox"/> Sijui                                                     |
| <b>Where are the funds for repairs usually stored?:</b>                                | <b>Malipo ya huduma ya handpump yanahifadhiwa wapi?</b>                            |
| <input type="checkbox"/> Home of the treasurer                                         | <input type="checkbox"/> Nyumbani kwa mwekahazina                                  |
| <input type="checkbox"/> Home of other water committee member                          | <input type="checkbox"/> Nyumbani kwa mwanakamati mwengine                         |
| <input type="checkbox"/> Home of handpump attendant caretaker                          | <input type="checkbox"/> Nyumbani kwa mhudumu                                      |
| <input type="checkbox"/> Home of handpump owner                                        | <input type="checkbox"/> Nyumbani kwa mmiliki wa handpump                          |
| <input type="checkbox"/> Bank account                                                  | <input type="checkbox"/> Kwa akaunti ya benki                                      |
| <input type="checkbox"/> Rotating savings and credit association                       | <input type="checkbox"/> Kwa chama cha hazina                                      |
| <input type="checkbox"/> Other                                                         | <input type="checkbox"/> Nyenginezo                                                |
| <input type="checkbox"/> Don't know                                                    | <input type="checkbox"/> Sijui                                                     |
| <b>If 'other', please specify:</b>                                                     | <b>Kama ni nyenginezo, tafadhali fafania kwenye nafasi</b>                         |
| <b>When requested, how often do you contribute user fees for handpump repairs?:</b>    | <b>Je, wakati umeitishwa pesa kwa ajili ya handpump, huwa unalipa?</b>             |
| <input type="checkbox"/> Always                                                        | <input type="checkbox"/> Kila wakati                                               |
| <input type="checkbox"/> Often                                                         | <input type="checkbox"/> Mara kwa mara                                             |
| <input type="checkbox"/> Sometimes                                                     | <input type="checkbox"/> Mara moja moja                                            |
| <input type="checkbox"/> Rarely                                                        | <input type="checkbox"/> Kwa nadra                                                 |
| <input type="checkbox"/> Never                                                         | <input type="checkbox"/> Silipi                                                    |
| <input type="checkbox"/> Don't know                                                    | <input type="checkbox"/> Sijui                                                     |
| <b>Why do you do NOT always contribute funds?:</b>                                     | <b>Ni kwa nini haulipi kila wakati?</b>                                            |
| <input type="checkbox"/> Do NOT prompt. Tick ALL that apply                            | <input type="checkbox"/> Usimuelekeze mhusika. Chagua yote yatakayotajwa           |
| <input type="checkbox"/> Don't trust that money will be used for repairs               | <input type="checkbox"/> Siamini kuwa pesa zitatumika kwa marekebisho              |
| <input type="checkbox"/> Do not have enough money                                      | <input type="checkbox"/> Sina pesa za kutosha                                      |
| <input type="checkbox"/> Can get away with not paying and still access the handpump    | <input type="checkbox"/> Naweza kosa kulipa na bado nitatumia maji kutoka handpump |
| <input type="checkbox"/> Other users do not pay                                        | <input type="checkbox"/> Watu wengine hawalipi                                     |
| <input type="checkbox"/> Other                                                         | <input type="checkbox"/> Nyenginezo                                                |
| <input type="checkbox"/> Don't know                                                    | <input type="checkbox"/> Sijui                                                     |
| <b>If 'other', please specify:</b>                                                     | <b>Kama ni nyenginezo, tafadhali fafania kwenye nafasi</b>                         |
| <b>Has the handpump been repaired in the last 12 months?:</b>                          | <b>Je, handpump imerekebishwa kwa mwaka mmoja uliopita?</b>                        |
| <input type="checkbox"/> Yes                                                           | <input type="checkbox"/> Ndio                                                      |
| <input type="checkbox"/> No                                                            | <input type="checkbox"/> La                                                        |
| <input type="checkbox"/> Don't know                                                    | <input type="checkbox"/> Sijui                                                     |
| <b>The last time the handpump was repaired, for how many DAYS was it broken down?:</b> | <b>Mara ya mwisho iliporekebishwa, ilikaa siku ngapi bila kuhudumu?</b>            |

|                                                                                                |                                                                                             |
|------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------|
| <b>How much money did your household contribute to have the handpump repaired? (Kshs):</b>     | <b>Mlichanga pesa ngapi kwa ajili ya urekebishaji wa handpump?</b>                          |
| <b>How satisfied are you with the current handpump repair arrangements?:</b>                   | <b>Je, umeridhika na mpangilio unaotumika kwa urekebishaji wa handpump?</b>                 |
| <input type="checkbox"/> Very satisfied                                                        | <input type="checkbox"/> Nimeridhika sana                                                   |
| <input type="checkbox"/> Satisfied                                                             | <input type="checkbox"/> Nimeridhika                                                        |
| <input type="checkbox"/> Neither satisfied nor dissatisfied                                    | <input type="checkbox"/> Naona kawaida                                                      |
| <input type="checkbox"/> Dissatisfied                                                          | <input type="checkbox"/> Sijaridhika                                                        |
| <input type="checkbox"/> Very dissatisfied                                                     | <input type="checkbox"/> Sijaridhika kabisa                                                 |
| <input type="checkbox"/> Don't know                                                            | <input type="checkbox"/> Sijui                                                              |
| <b>If non-functional, for how long has the handpump been broken down?:</b>                     | <b>Handpump imeharibika kwa muda gani?</b>                                                  |
| <b>What is the main reason the HANDPUMP has not been repaired?:</b>                            | <b>Ni sababu gani kuu iliyofanya handpump isirekebishwe?</b>                                |
| <input type="checkbox"/> No money raised                                                       | <input type="checkbox"/> Hakuna pesa iliyochangwa                                           |
| <input type="checkbox"/> There is an acceptable alternative water source                       | <input type="checkbox"/> Kuna njia nyingine ya kupata maji                                  |
| <input type="checkbox"/> There is now a better water source available                          | <input type="checkbox"/> Kuna njia nzuri zaidi ya kupata maji                               |
| <input type="checkbox"/> The water committee is inactive                                       | <input type="checkbox"/> Kamati ya maji haiwajibiki                                         |
| <input type="checkbox"/> Fundi charges too much                                                | <input type="checkbox"/> Gharama ya ufundi ni ghali                                         |
| <input type="checkbox"/> Not possible to repair                                                | <input type="checkbox"/> Haiwezi rekebisha                                                  |
| <input type="checkbox"/> Use a rope and bucket instead                                         | <input type="checkbox"/> Tunatumia ndoo na kamba badala ya handpump                         |
| <input type="checkbox"/> Water quality is poor                                                 | <input type="checkbox"/> Hali ya maji ni mbaya                                              |
| <input type="checkbox"/> Other                                                                 | <input type="checkbox"/> Nyenginezo                                                         |
| <input type="checkbox"/> Don't know                                                            | <input type="checkbox"/> Sijui                                                              |
| <b>If 'Other', please specify:</b>                                                             | <b>Kama ni nyenginezo, tafadhali fafana kwenye nafasi</b>                                   |
| <b>Would you like the handpump repaired?:</b>                                                  | <b>Je, ungependa handpump irekebishwe?</b>                                                  |
| <input type="checkbox"/> Yes                                                                   | <input type="checkbox"/> Ndio                                                               |
| <input type="checkbox"/> No                                                                    | <input type="checkbox"/> La                                                                 |
| <input type="checkbox"/> Don't know                                                            | <input type="checkbox"/> Sijui                                                              |
| <b>How much would your household be willing to pay for the handpump to be repaired (Kshs):</b> | <b>Nyumba yako iko tayari kulipia pesa kiasi gani kwa ajili ya marekebisho ya handpump?</b> |
| <b>If the HANDPUMP was repaired, would it be your main DRINKING water source?:</b>             | <b>Handpump ikirekebisha, je itakuwa ndio njia yako kuu ya kupata maji ya kunywa?</b>       |
| <input type="checkbox"/> No                                                                    | <input type="checkbox"/> La                                                                 |
| <input type="checkbox"/> Yes – wet season only                                                 | <input type="checkbox"/> Ndio – wakati wa masika                                            |
| <input type="checkbox"/> Yes – dry season only                                                 | <input type="checkbox"/> Ndio – wakati wa kiangazi                                          |
| <input type="checkbox"/> Yes – both wet and dry season                                         | <input type="checkbox"/> Ndio – nyakati zote                                                |
| <input type="checkbox"/> Don't know                                                            | <input type="checkbox"/> Sijui                                                              |
| <b>If the handpump was repaired, would you use it for any of the following purposes</b>        | <b>Ikiwa handpump itarekebisha, utatumia maji kwa matumizi yafuatayo?</b>                   |
| <input type="checkbox"/> Cooking, Bathing, Washing:                                            | <input type="checkbox"/> Kupika, Kufua na kuoga                                             |
| <input type="checkbox"/> Irrigation:                                                           | <input type="checkbox"/> Kunyunyizia mimea                                                  |
| <input type="checkbox"/> Livestock watering:                                                   | <input type="checkbox"/> Kunywesha mifugo                                                   |
| <b>In the last 12 months have you been involved in managing the handpump?:</b>                 | <b>Kwa mwaka uliopita, umehusika kwa usimamizi wa handpump?</b>                             |
| <i>Tick ALL that apply</i>                                                                     | <i>Chagua yote yatakayotajwa</i>                                                            |

|                                                                                                                                                                   |                                                                                                 |                     |                                                                        |              |              |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------|---------------------|------------------------------------------------------------------------|--------------|--------------|
| <input type="checkbox"/> No, not at all                                                                                                                           | <input type="checkbox"/> La hapana                                                              |                     |                                                                        |              |              |
| <input type="checkbox"/> Member of water committee                                                                                                                | <input type="checkbox"/> Mimi ni mwanakamati                                                    |                     |                                                                        |              |              |
| <input type="checkbox"/> Helped carry out repairs                                                                                                                 | <input type="checkbox"/> Nilisaidia kwa urekebishaji                                            |                     |                                                                        |              |              |
| <input type="checkbox"/> Helped collect funds from other users                                                                                                    | <input type="checkbox"/> Nilisaidia kukusanya pesa                                              |                     |                                                                        |              |              |
| <input type="checkbox"/> Helped buy spare parts                                                                                                                   | <input type="checkbox"/> Nilinunua spare za handpump                                            |                     |                                                                        |              |              |
| <input type="checkbox"/> Helped enforce the rules of usage                                                                                                        | <input type="checkbox"/> Nilihimiza sheria za kutumia handpump                                  |                     |                                                                        |              |              |
| <input type="checkbox"/> Held the key to the handpump                                                                                                             | <input type="checkbox"/> Niliweka ufunguo wa handpump                                           |                     |                                                                        |              |              |
| <input type="checkbox"/> Other                                                                                                                                    | <input type="checkbox"/> Nyenginezo                                                             |                     |                                                                        |              |              |
| <input type="checkbox"/> Don't know                                                                                                                               | <input type="checkbox"/> Sijui                                                                  |                     |                                                                        |              |              |
| <b>If 'other', please specify:</b>                                                                                                                                | <b>Kama ni nyenginezo, tafadhali fafania kwenye nafasi</b>                                      |                     |                                                                        |              |              |
| <b>When the handpump was originally installed, did someone from your household participate in the planning or construction? If so, how did they participate?:</b> | <b>Wakati handpump iliwekwa, kuna yeyote wa nyumba yako alihusika? Alihusika kwa njia gani?</b> |                     |                                                                        |              |              |
| <i>Tick ALL that apply</i>                                                                                                                                        | <i>Chagua yote yatakayotajwa</i>                                                                |                     |                                                                        |              |              |
| <input type="checkbox"/> No participation                                                                                                                         | <input type="checkbox"/> Hakuna aliyehusika                                                     |                     |                                                                        |              |              |
| <input type="checkbox"/> Contributed labour                                                                                                                       | <input type="checkbox"/> Alichangia nguvu kazi                                                  |                     |                                                                        |              |              |
| <input type="checkbox"/> Financial contribution                                                                                                                   | <input type="checkbox"/> Alichangia fedha                                                       |                     |                                                                        |              |              |
| <input type="checkbox"/> Contributed materials                                                                                                                    | <input type="checkbox"/> Alichangia vifaa                                                       |                     |                                                                        |              |              |
| <input type="checkbox"/> Helped choose the technology                                                                                                             | <input type="checkbox"/> Alisaidia kuchagua ujuzi wa handpump                                   |                     |                                                                        |              |              |
| <input type="checkbox"/> Help decide on the payment rate                                                                                                          | <input type="checkbox"/> Alisaidia kuchagua eneo la kujengea handpump                           |                     |                                                                        |              |              |
| <input type="checkbox"/> Help decide the location of the handpump                                                                                                 | <input type="checkbox"/> Alisaidia kuchagua ada ya malipo                                       |                     |                                                                        |              |              |
| <input type="checkbox"/> Contributed land                                                                                                                         | <input type="checkbox"/> Alipeana ardhi                                                         |                     |                                                                        |              |              |
| <input type="checkbox"/> Other                                                                                                                                    | <input type="checkbox"/> Nyinginezo                                                             |                     |                                                                        |              |              |
| <input type="checkbox"/> Don't know                                                                                                                               | <input type="checkbox"/> Sijui                                                                  |                     |                                                                        |              |              |
| <b>If 'other', please specify:</b>                                                                                                                                | <b>Kama ni nyenginezo, tafadhali fafania kwenye nafasi:</b>                                     |                     |                                                                        |              |              |
| <b>Does your family store drinking water in the house?:</b>                                                                                                       | <b>Familia yako inahifadhi maji ya kunywa?:</b>                                                 |                     |                                                                        |              |              |
| <input type="checkbox"/> Yes                                                                                                                                      | <input type="checkbox"/> Ndio                                                                   |                     |                                                                        |              |              |
| <input type="checkbox"/> No                                                                                                                                       | <input type="checkbox"/> La                                                                     |                     |                                                                        |              |              |
| <b>Containers used for used for storing DRINKING WATER in the house:</b>                                                                                          | <b>Chombo kinachohifadhi maji ya kunywa:</b>                                                    |                     |                                                                        |              |              |
| <b>Container</b>                                                                                                                                                  | <b>Volume</b>                                                                                   | <b>Number owned</b> | <b>Container</b>                                                       | <b>Kiasi</b> | <b>Idadi</b> |
| 1                                                                                                                                                                 |                                                                                                 |                     | 1                                                                      |              |              |
| 2                                                                                                                                                                 |                                                                                                 |                     | 2                                                                      |              |              |
| 3                                                                                                                                                                 |                                                                                                 |                     | 3                                                                      |              |              |
| 4                                                                                                                                                                 |                                                                                                 |                     | 4                                                                      |              |              |
| 5                                                                                                                                                                 |                                                                                                 |                     | 5                                                                      |              |              |
| <b>Are you aware of insurance products sold in this area?</b>                                                                                                     |                                                                                                 |                     | <b>Je, unajua aina yoyote ya bima?</b>                                 |              |              |
| <input type="checkbox"/> Yes                                                                                                                                      |                                                                                                 |                     | <input type="checkbox"/> Ndio                                          |              |              |
| <input type="checkbox"/> No                                                                                                                                       |                                                                                                 |                     | <input type="checkbox"/> La                                            |              |              |
| <b>Which insurance products are you aware of?</b>                                                                                                                 |                                                                                                 |                     | <b>Kama ndio, muulize mhusika akueleze zile aina ya bima anazojua?</b> |              |              |

|                                                                                                                       |                                                                                          |
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| <i>Tick ALL that apply. Do NOT prompt.</i>                                                                            | <i>Usimuelekeze mhusika. Chagua yote yatakayotajwa</i>                                   |
| <input type="checkbox"/> Health insurance                                                                             | <input type="checkbox"/> Bima ya afya                                                    |
| <input type="checkbox"/> Life insurance                                                                               | <input type="checkbox"/> Bima ya maisha                                                  |
| <input type="checkbox"/> School fee insurance                                                                         | <input type="checkbox"/> Bima ya elimu                                                   |
| <input type="checkbox"/> Employment insurance                                                                         | <input type="checkbox"/> Bima ya ajira                                                   |
| <input type="checkbox"/> Property insurance                                                                           | <input type="checkbox"/> Bima ya raslimali                                               |
| <input type="checkbox"/> Vehicle insurance                                                                            | <input type="checkbox"/> Bima ya gari                                                    |
| <input type="checkbox"/> Other                                                                                        | <input type="checkbox"/> Nyenginezo                                                      |
| <b>In the last 12 months have you or any other member of your household purchased any type of insurance product?:</b> | <b>Kwa mwaka uliopita, kuna yeyote wa familia yako aliyenunua aina yoyote ya BIMA?</b>   |
| <input type="checkbox"/> Yes                                                                                          | <input type="checkbox"/> Ndio                                                            |
| <input type="checkbox"/> No                                                                                           | <input type="checkbox"/> La                                                              |
| <input type="checkbox"/> Don't know                                                                                   | <input type="checkbox"/> Sijui                                                           |
| <b>Why has your household not purchased any insurance product in the last 12 months?:</b>                             | <b>Ni kwa nini hamjanunua bima yoyote?</b>                                               |
| <i>Do not prompt. Tick ALL that apply</i>                                                                             | <i>Usimuelekeze mhusika. Chagua yote yatakayotajwa</i>                                   |
| <input type="checkbox"/> Too expensive                                                                                | <input type="checkbox"/> Ni ghali                                                        |
| <input type="checkbox"/> Don't need it                                                                                | <input type="checkbox"/> Hatuihitaji                                                     |
| <input type="checkbox"/> Don't trust insurance companies                                                              | <input type="checkbox"/> Hatuamini kampuni za bima                                       |
| <input type="checkbox"/> Don't understand the products                                                                | <input type="checkbox"/> Hatuelewi bima inafanya kazi vipi                               |
| <input type="checkbox"/> Contract period too long                                                                     | <input type="checkbox"/> Bima inahiyataji malipo kwa muda mrefu sana                     |
| <input type="checkbox"/> Poor value for money                                                                         | <input type="checkbox"/> Bima haitoshelezi                                               |
| <input type="checkbox"/> Friend_had_a_bad_experience                                                                  | <input type="checkbox"/> Jirani alipitia mdua mveya alipokuwa akilipia bima              |
| <input type="checkbox"/> Ni afadhali kutumia njia nyengine ya kuweka hazina                                           | <input type="checkbox"/> Ni afadhali kutumia njia nyengine ya kuweka hazina              |
| <input type="checkbox"/> Other                                                                                        | <input type="checkbox"/> Nyenginezo                                                      |
| <input type="checkbox"/> Don't know                                                                                   | <input type="checkbox"/> Sijui                                                           |
| <b>Which type(s) of insurance product have other household members purchased in the last 12 months?:</b>              | <b>Ni aina gani ya BIMA?</b>                                                             |
| <i>Do not prompt. Tick ALL that apply</i>                                                                             | <i>Usimuelekeze mhusika. Chagua yote yatakayotajwa</i>                                   |
| <input type="checkbox"/> Health insurance                                                                             | <input type="checkbox"/> Bima ya afya                                                    |
| <input type="checkbox"/> Life insurance                                                                               | <input type="checkbox"/> Bima ya maisha                                                  |
| <input type="checkbox"/> School fee insurance                                                                         | <input type="checkbox"/> Bima ya elimu                                                   |
| <input type="checkbox"/> Employment insurance                                                                         | <input type="checkbox"/> Bima ya ajira                                                   |
| <input type="checkbox"/> Property insurance                                                                           | <input type="checkbox"/> Bima ya raslimali                                               |
| <input type="checkbox"/> Vehicle insurance                                                                            | <input type="checkbox"/> Bima ya gari                                                    |
| <input type="checkbox"/> Other                                                                                        | <input type="checkbox"/> Nyinginezo                                                      |
| <input type="checkbox"/> Health insurance                                                                             | <input type="checkbox"/> Sijui                                                           |
| <b>If 'other', please specify:</b>                                                                                    | <b>Kama ni nyenginezo, tafadhali fafana kwenye nafasi</b>                                |
| <b>Who do you think is responsible for managing the water in the rivers, wells and springs?:</b>                      | <b>Ni nani ana jukumu la kutunza na kusimamia maji kwenye mito, visima na chemchemi?</b> |
| <i>Do NOT prompt</i>                                                                                                  | <i>Usimuelekeze mhusika.</i>                                                             |

|                                                                                    |                                                                      |
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| <input type="checkbox"/> Village_chairman                                          | <input type="checkbox"/> Mzee wa kijiji                              |
| <input type="checkbox"/> Water_user_committee                                      | <input type="checkbox"/> Kamati ya maji                              |
| <input type="checkbox"/> Water Resources Management Authority (WRMA)               | <input type="checkbox"/> Water Resources Management Authority (WRMA) |
| <input type="checkbox"/> Water Resources Users Association (WRUA)                  | <input type="checkbox"/> Water Resources Users Association (WRUA)    |
| <input type="checkbox"/> County government                                         | <input type="checkbox"/> Serikali ya kaunti                          |
| <input type="checkbox"/> Village chief                                             | <input type="checkbox"/> Chifu                                       |
| <input type="checkbox"/> KWAJASCO                                                  | <input type="checkbox"/> KWAJASCO                                    |
| <input type="checkbox"/> Other                                                     | <input type="checkbox"/> Nyenginezo                                  |
| <input type="checkbox"/> Don't know                                                | <input type="checkbox"/> Sijui                                       |
| <b>If 'other', please specify:</b>                                                 | <b>Kama ni nyenginezo, tafadhali fafana kwenye nafasi</b>            |
| <b>Do you know what the local WRUA does?:</b>                                      | <b>Je, unajua WRUA inafanya nini?</b>                                |
| <i>To confirm, ask respondent to explain what they believe the local WRUA does</i> |                                                                      |
| <input type="checkbox"/> Yes                                                       | <input type="checkbox"/> Ndio                                        |
| <input type="checkbox"/> No                                                        | <input type="checkbox"/> La                                          |
| <b>Do you know any members of your WRUA?:</b>                                      | <b>Je, unajua mwanachama yeyote wa WRUA?</b>                         |
| <input type="checkbox"/> Yes                                                       | <input type="checkbox"/> Ndio                                        |
| <input type="checkbox"/> No                                                        | <input type="checkbox"/> La                                          |
| <b>Have you ever attended a WRUA meeting?:</b>                                     | <b>Umewahi kuhudhuria mkutano wa WRUA?</b>                           |
| <input type="checkbox"/> Yes                                                       | <input type="checkbox"/> Ndio                                        |
| <input type="checkbox"/> No                                                        | <input type="checkbox"/> La                                          |
| <b>Are you satisfied with the performance of your WRUA?:</b>                       | <b>Umeridhika na utendakazi wa WRUA?</b>                             |
| <input type="checkbox"/> Very satisfied                                            | <input type="checkbox"/> Nimeridhika sana                            |
| <input type="checkbox"/> Satisfied                                                 | <input type="checkbox"/> Nimeridhika                                 |
| <input type="checkbox"/> Neither satisfied nor dissatisfied                        | <input type="checkbox"/> Naona kawaida                               |
| <input type="checkbox"/> Dissatisfied                                              | <input type="checkbox"/> Sijaridhika                                 |
| <input type="checkbox"/> Very dissatisfied                                         | <input type="checkbox"/> Sijaridhika kabisa                          |
| <input type="checkbox"/> Don't know                                                | <input type="checkbox"/> Sijui                                       |
| <b>Main material of the floor:</b>                                                 | <b>Vifaa husika kwa ajili ya sakafu</b>                              |
| <i>Record observation</i>                                                          |                                                                      |
| <input type="checkbox"/> Earth, sand                                               | <input type="checkbox"/> Mchanga                                     |
| <input type="checkbox"/> Dung                                                      | <input type="checkbox"/> Mavi ya ng'ombe                             |
| <input type="checkbox"/> Wood planks                                               | <input type="checkbox"/> Mbao                                        |
| <input type="checkbox"/> Palm, bamboo                                              | <input type="checkbox"/> Bambo                                       |
| <input type="checkbox"/> Polished wood                                             | <input type="checkbox"/> Mbao zilizopakwa rangi                      |
| <input type="checkbox"/> Vinyl or asphalt strips                                   | <input type="checkbox"/> Vinyl or asphalt strips                     |
| <input type="checkbox"/> Ceramic tiles                                             | <input type="checkbox"/> Vigae                                       |
| <input type="checkbox"/> Cement                                                    | <input type="checkbox"/> Simiti                                      |
| <input type="checkbox"/> Carpet                                                    | <input type="checkbox"/> Mpira                                       |
| <input type="checkbox"/> Other                                                     | <input type="checkbox"/> Nyenginezo                                  |
| <b>If 'other', please specify:</b>                                                 | <b>Kama ni nyenginezo, tafadhali fafana kwenye nafasi</b>            |

|                                                                                                                                                                                                                    |                                                                                                                                                                             |
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| <b>Main material of the roof:</b>                                                                                                                                                                                  | <b>Vifaa husika vya paa</b>                                                                                                                                                 |
| <i>Record observation</i>                                                                                                                                                                                          |                                                                                                                                                                             |
| <input type="checkbox"/> Thatch, grass                                                                                                                                                                             | <input type="checkbox"/> Makuti                                                                                                                                             |
| <input type="checkbox"/> Corrugated iron                                                                                                                                                                           | <input type="checkbox"/> Mabati                                                                                                                                             |
| <input type="checkbox"/> Tin cans                                                                                                                                                                                  | <input type="checkbox"/> Vikebe, Matope                                                                                                                                     |
| <input type="checkbox"/> Dung, mud                                                                                                                                                                                 | <input type="checkbox"/> Mavi ya ng'ombe                                                                                                                                    |
| <input type="checkbox"/> Asbestos sheet                                                                                                                                                                            | <input type="checkbox"/> Asbestos                                                                                                                                           |
| <input type="checkbox"/> Concrete                                                                                                                                                                                  | <input type="checkbox"/> Zege                                                                                                                                               |
| <input type="checkbox"/> Tiles                                                                                                                                                                                     | <input type="checkbox"/> Vigae                                                                                                                                              |
| <input type="checkbox"/> Other                                                                                                                                                                                     | <input type="checkbox"/> Nyenginezo                                                                                                                                         |
| <b>If 'other, please specify:</b>                                                                                                                                                                                  | <b>Kama ni nyenginezo, tafadhali fafania kwenye nafasi</b>                                                                                                                  |
| <b>Main materials of the walls:</b>                                                                                                                                                                                | <b>Vifaa husika vya ukuta</b>                                                                                                                                               |
| <input type="checkbox"/> Stone with mud                                                                                                                                                                            | <input type="checkbox"/> Mawe na udongo                                                                                                                                     |
| <input type="checkbox"/> Stone with lime cement                                                                                                                                                                    | <input type="checkbox"/> Mawe na simiti                                                                                                                                     |
| <input type="checkbox"/> Concrete blocks                                                                                                                                                                           | <input type="checkbox"/> Matofali ya zege                                                                                                                                   |
| <input type="checkbox"/> Wood with mud                                                                                                                                                                             | <input type="checkbox"/> Mbao na udongo                                                                                                                                     |
| <input type="checkbox"/> Corrugated iron                                                                                                                                                                           | <input type="checkbox"/> Mabati                                                                                                                                             |
| <input type="checkbox"/> Reused wood                                                                                                                                                                               | <input type="checkbox"/> Mbao za mtumba                                                                                                                                     |
| <input type="checkbox"/> Thatch, grass                                                                                                                                                                             | <input type="checkbox"/> Makuti                                                                                                                                             |
| <input type="checkbox"/> Cement                                                                                                                                                                                    | <input type="checkbox"/> Simiti                                                                                                                                             |
| <input type="checkbox"/> Cane, palm trunks                                                                                                                                                                         | <input type="checkbox"/> Vipande vya miti                                                                                                                                   |
| <input type="checkbox"/> Bricks                                                                                                                                                                                    | <input type="checkbox"/> Matofali                                                                                                                                           |
| <input type="checkbox"/> Adobe mud bricks                                                                                                                                                                          | <input type="checkbox"/> Matofali ya udongo                                                                                                                                 |
| <input type="checkbox"/> Plywood                                                                                                                                                                                   | <input type="checkbox"/> Plaiwudi                                                                                                                                           |
| <input type="checkbox"/> Cardboard                                                                                                                                                                                 | <input type="checkbox"/> Card board                                                                                                                                         |
| <input type="checkbox"/> Wood planks, shingles                                                                                                                                                                     | <input type="checkbox"/> Fito                                                                                                                                               |
| <input type="checkbox"/> Dirt                                                                                                                                                                                      | <input type="checkbox"/> Takataka                                                                                                                                           |
| <input type="checkbox"/> No walls                                                                                                                                                                                  | <input type="checkbox"/> Hakuna kuta                                                                                                                                        |
| <input type="checkbox"/> Other                                                                                                                                                                                     | <input type="checkbox"/> Nyenginezo                                                                                                                                         |
| <b>Are the walls rendered?:</b>                                                                                                                                                                                    |                                                                                                                                                                             |
| <input type="checkbox"/> Yes                                                                                                                                                                                       | <input type="checkbox"/> Ndio                                                                                                                                               |
| <input type="checkbox"/> No                                                                                                                                                                                        | <input type="checkbox"/> La                                                                                                                                                 |
| <b>If 'other, please specify:</b>                                                                                                                                                                                  | <b>Kama ni nyenginezo, tafadhali fafania kwenye nafasi</b>                                                                                                                  |
| <b>Take a photo of the dwelling:</b>                                                                                                                                                                               | <b>Chukua picha ya nyumba</b>                                                                                                                                               |
| <i>Explain that this will be needed in order to return to the dwelling in 12 months' time</i>                                                                                                                      |                                                                                                                                                                             |
| <b>GPS of Dwelling:</b>                                                                                                                                                                                            | <b>GPS ya nyumba</b>                                                                                                                                                        |
| <i>Will automatically save when within 5m accuracy. To override accuracy threshold, press 'OK'</i>                                                                                                                 |                                                                                                                                                                             |
| <i>This is the END of our interview. THANK YOU very much for your time. ***SMILE, answer any questions the respondent has, and MOVE AWAY from the household to complete a few additional questions. Great job!</i> | <i>Huu ni mwisho wa mahojiano, asante sana kwa kunipa muda wako, tabasamu, jibu maswali yoyote utakayoulizwa ni mhusika na uondoke ili kukamilisha maswali. Kazi nzuri!</i> |

|                                                                                      |                                                                                                   |
|--------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------|
| <b>Indicate how well you think the respondent(s) understood the questions asked:</b> | <b>Onyesha jinsi mhusika alivyoelewa maswali</b>                                                  |
| <input type="checkbox"/> Good understanding                                          | <input type="checkbox"/> Ufahamu mzuri                                                            |
| <input type="checkbox"/> Fair understanding                                          | <input type="checkbox"/> Ufahamu wastani                                                          |
| <input type="checkbox"/> Poor understanding                                          | <input type="checkbox"/> Ufahamu mbaya                                                            |
| <b>Do you think the majority of responses were accurate and truthful?</b>            | <b>Kwa maoni ya mwandishi, unadhani kwamba majibu uliyopewa na mhusika ni ya kweli na hakika?</b> |
| <input type="checkbox"/> Strongly agree                                              | <input type="checkbox"/> Nakubali sana                                                            |
| <input type="checkbox"/> Agree                                                       | <input type="checkbox"/> Nakubali                                                                 |
| <input type="checkbox"/> Concerns                                                    | <input type="checkbox"/> Tashwishi juu ya baadhi ya maswali - (ELEZEA kupitia njia ya sauti)      |
| <b>What was the main language that the interview was conducted in?:</b>              | <b>Je, mahojiano yalikuwa kwa lugha gani?</b>                                                     |
| <input type="checkbox"/> Swahili                                                     | <input type="checkbox"/> Swahili                                                                  |
| <input type="checkbox"/> Digo                                                        | <input type="checkbox"/> Digo                                                                     |
| <input type="checkbox"/> Duruma                                                      | <input type="checkbox"/> Duruma                                                                   |
| <input type="checkbox"/> Kamba                                                       | <input type="checkbox"/> Kamba                                                                    |
| <input type="checkbox"/> Kingereza                                                   | <input type="checkbox"/> Kingereza                                                                |
| <input type="checkbox"/> Lugha nyenginezo                                            | <input type="checkbox"/> Lugha nyenginezo                                                         |
| <b>If 'other', please specify:</b>                                                   | <b>Kama ni nyenginezo, tafadhali fafana kwenye nafasi</b>                                         |