



From Rights to Results in Rural Water Services - Evidence from Kyuso, Kenya

March 2014



Smith School Water Programme

The Smith School Water Programme aims to understand and address water-related risks to economic growth, human development and environmental stewardship. A problem-based and interdisciplinary approach focuses on designing, testing and implementing new tools, technologies and models. Current projects are making science, policy and practice advances in the areas of urban utility finance, rural water institutions, groundwater risk management, smart river management, and mobile-enabled water technologies.

The Water Programme works in partnership with the School of Geography and the Environment, Department of Engineering Science, Skoll Centre for Social Entrepreneurship and the Saïd Business School. The programme is a core member of the wider Oxford Water Network with over 70 faculty and researchers working globally on water science and policy challenges across biodiversity, climate systems, economics, ecosystems, energy, engineering, food systems, hydrology, law, politics and public health.

The programme is funded from competitive grants won from UK research councils (ESRC, NERC), DFID, John Fell Fund and the Skoll Foundation. Past donors include OECD, World Bank and the Gates Foundation. Enterprise partners in the programme include global leaders in the extractives industry, beverages/food sector, insurance, mobile network operators, and wireless technology and semi-conductor industries.

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Executive Summary

Institutional transformations are required if Africa is to deliver the universal Human Right to Water to 275 million rural people without improved water services. Improving the reliability of one million handpumps which should deliver drinking water to over 200 million rural Africans will be a major contribution to translating water rights into measurable results. This study tests a new maintenance service model over a one year period in rural Kenya using mobile-enabled data to improve operational and financial performance by reducing risks at scale.

Results have led to

- a) a ten-fold reduction in handpump downtime (days not working),
- b) a shift to 98 per cent of handpumps functioning,
- c) a fairer and more flexible payment model contingent on service delivery,
- d) new and objective metrics to guide water service regulatory reform,
- e) a revised financial architecture shaped by an output-based payment model.

The model outlines a new and replicable framework for policy and investment behaviour informed by rural water users' more expansive views of the design and delivery of rural water institutions than currently prescribed.

Is the Human Right to Water Achievable in Rural Africa?

275 million people without improved water in rural Africa

< 1 in 5 handpump users pre-pay for water

Only **70%** of handpumps are working at any one time in Africa

0.9 billion people will live in rural Africa by 2050

40 billion hours spent collecting water every year



From Rights to Results – Evidence from Kyuso

98% of handpumps
are now working in
Kyuso

4 in 5 users
willing to prepay
after the trial

Handpump downtime reduced **10-fold**
from 27 days to **<3 days**

People pay **fairer**
prices, based on actual
pump usage, for a
better service

5 times higher
revenue collection



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1. From Rights to Results

The Human Right to Water and Sanitation was recognised by the United Nations General Assembly in 2010 with the goal of the progressive realisation of sufficient, safe, close, affordable and reliable water services for everyone. In Africa water service reliability remains most elusive in rural areas where extreme poverty and water insecurity are often synonymous. One million handpumps supply water to over 200 million rural water users across the continent. Yet, one in three handpumps is thought not to be working at any one time. Major investments in infrastructure have not translated into reliable water services over time. Delivering long-term water maintenance services carries political and organisational risk but is the key to rural water supply sustainability. Without verifiable, comparable and regulated water service metrics ambitious political targets will continue to be set but are unlikely to be met, as historical evidence demonstrates. The systemic information deficit in rural water reliability over decades has insulated policy, institutional and investment decisions from scrutiny and reform. This is now changing as the confluence of a global water policy goal and mobile information architecture can promote and test universal delivery models. This report provides evidence from a 12-month ‘smart handpump’ trial in Kenya in 2013 which tests a new maintenance service model with the aim to support progress towards universal and reliable water services.

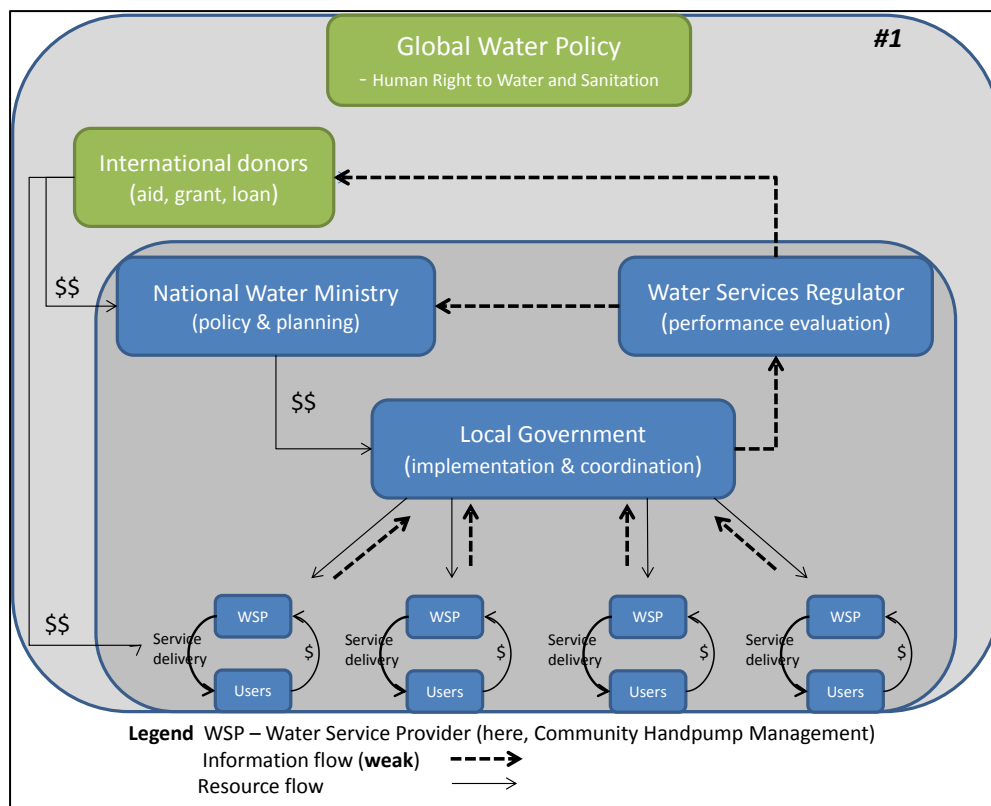
The study was funded under the UK Department for International Development’s (DFID) New and Emerging Technologies programme in response to the Government of Kenya’s demand for empirical evidence of new models to improve rural water service delivery.



2. Institutional Challenges and Opportunities

2.1. A Broken Loop Model

The current model of rural water service delivery is broken (figure below). Money flows down from donors and government to install infrastructure but little reliable information on performance flows back. Increased use of handpump mapping exercises by survey teams may usefully identify handpumps working one day of the year but this leaves the remaining 99.7 per cent of any year unknown. With a growing consensus on the Human Right to Water monitoring daily services is increasingly important. For governments and donors, knowing whether investments deliver verifiable impacts over time rather than simply that budgets were spent is transforming established thinking. Mobile networks provide an inclusive architecture to reduce the information asymmetry between investments and outcomes. Information alone is insufficient to make progress but information is necessary to track and improve accountable service delivery. Information can improve institutional performance and shape appropriate roles and responsibilities between communities, governments and donors to close the loop between well-meaning investments and quantifiable outcomes. Donors can demonstrate value-for-money, government and water service regulators can align performance with measureable outcomes, and communities can contribute to financial sustainability through user payments that are contingent upon service delivery.

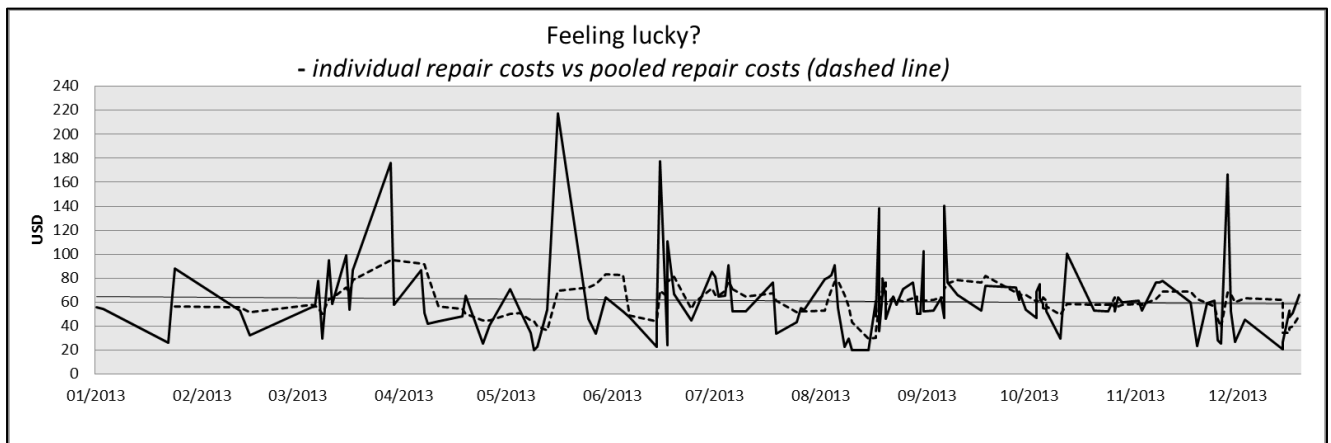


Regulation of water service delivery depends on reliable and regular information for government, the public and donors to know how investments translate into measureable and objective metrics of water services. Local government (County, District) are often responsible for implementation and coordination of activities at an operational level. Post-construction activities of operation and maintenance are the responsibility of the community. These activities commonly include creating user committees to determine access arrangements, water fees and maintenance arrangements. By transferring handpump ownership and operational

responsibility to a community of water users the state provides the technical means by which individuals can access water. In theory, handpump users have the right incentives to deliver effective services tailored to local requirements. However, over the last decade there has been increasing evidence that communities are not able to manage handpumps reliably, with implications for public health and poverty reduction.

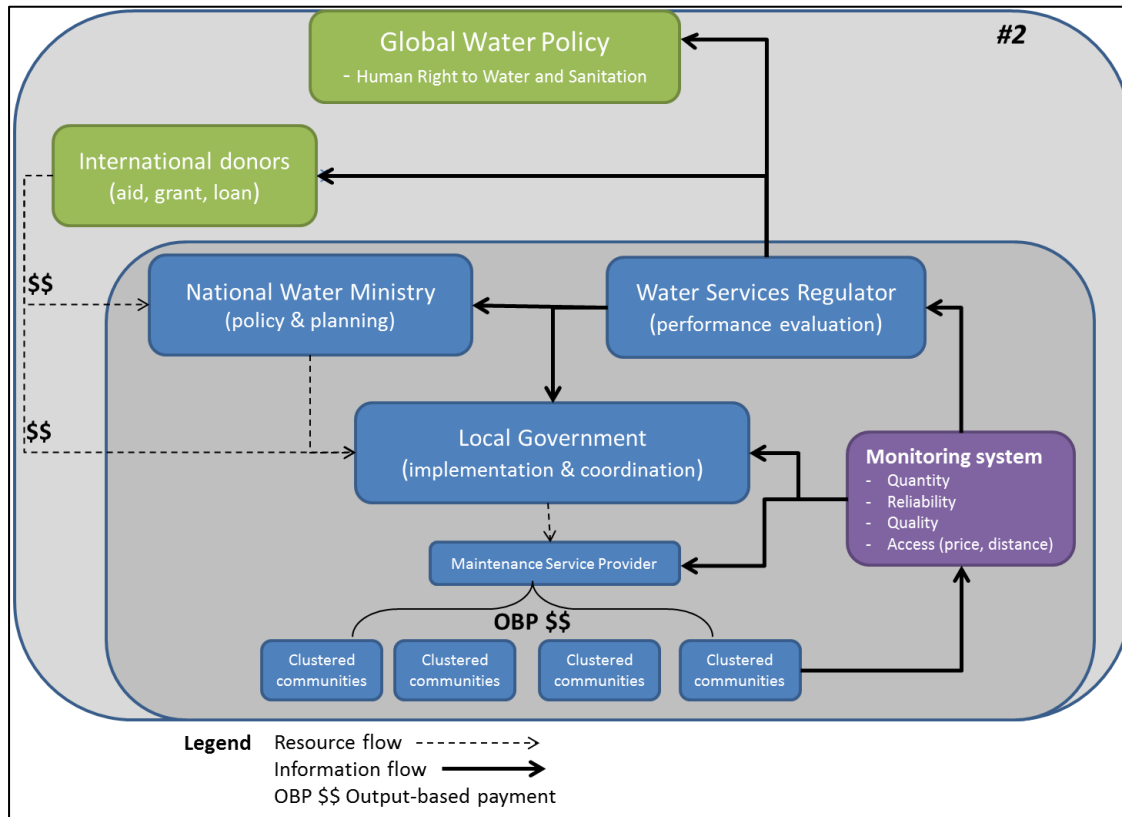
The decentralisation of rural water services to rural communities represents an almost unique model of the roles and responsibilities between the state and the community. In an all-Africa infrastructure assessment, the World Bank reports that central, regional or local governments play a dominant role in planning, implementation and finance. It is only in the area of providing and maintaining water services that local communities have a leading role, precisely where the authors identify most challenges occur. Analysis of over 25,000 handpumps in Liberia, Sierra Leone and Uganda provides data on the significant and wide-spread challenges with the only cross-country and significant determinants of handpump functionality being recently-installed handpumps, pre-payment of maintenance costs and less isolated communities; unfortunately, very few handpumps meet these conditions.

A key hypothesis of this study is that scale reduces risk. Currently communities take on all the risk associated with failure of their handpump. Comparing the baseline data to the one-year Kyuso trial, evidence – presented in the sections below – indicates that these operational and financial risks can be reduced by community incorporation into a larger system. This is the law of large numbers that drives insurance models around the world, including rural Africa (livestock, agriculture, health). Scale can smooth financial risk in comparison to going alone which compounds risk.



2.2. Maintenance Service Provider Model

Working with the District Water Office a new maintenance service was designed and powered by a mobile-enabled transmitter installed into 66 existing handpumps providing water to up to 20,000 people. The study set out to explore if reliable and timely information on handpump functionality could improve institutional, operational and financial performance.



The new Maintenance Service Provider model introduces modifications to the scale, monitoring and finance of water service delivery:

1. Communities are clustered to provide economies of scale and pool risk in the operation and financial delivery of maintenance services. We first tested to see if this was socially-acceptable using a stated preference method;
2. A single maintenance service provider was introduced, with accountability for service delivery to all communities that voluntarily participated in the study. The maintenance service provider was locally-appointed via the District Water Office;
3. There was spares parts' inventory system to ensure adequate stock was always available. Each repair event logged parts used and logistical data;
4. Information on handpump use was automatically transmitted to trigger maintenance visits. This was shared with the service provider, local government and the regulator using a bespoke user interface;
5. Communities were informed before the trial began that the free service would last one year after which they could return to their former maintenance arrangements or pay an external provider for the continuation of the maintenance service.

The objectives of the study can be separated under institutional, operational and financial headings:

Institutional:

- Design and test a new maintenance model based on the availability of timely handpump functionality information;
- Evaluate this model, identifying limitations, potential improvements and pathways to scale.

Operational:

- Reduce handpump down-times (days non-functioning) through a faster response to handpump breakdowns;
- Test the 'smart handpumps' hardware for a year under representative field conditions.

Financial:

- Accurately measure the cost of delivering this information-enabled maintenance service;
- Evaluate community acceptance of the model and willingness-to-pay in the future.

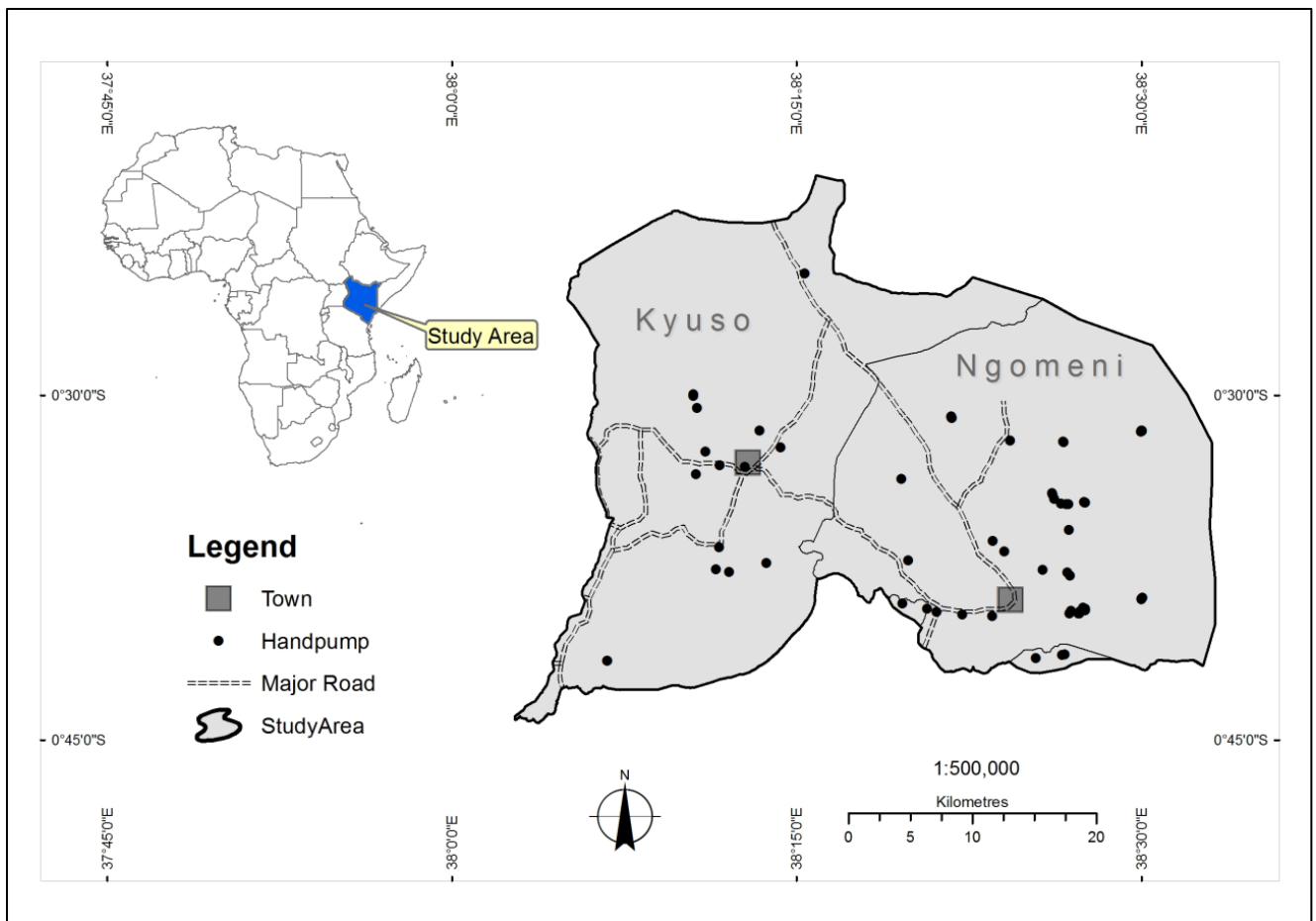


3. Study Site and Methodology

3.1. Study Site

The study site is situated in Kyuso District in Kitui County, Kenya, (38° 10' E, 0° 35' S; 660-880 m elevation; 2,446 km²) located 267 km east of Nairobi with a population of 26,848 households. The population is almost entirely rural (99%) with two out of three households classified as 'poor'. The two towns in the District are Kyuso and Ngomeni Town. Average rainfall in the period 1961 to 2006 is 774 mm with increasing variation in decadal rainfall patterns during both the long rains (mean=250 mm; March-May) and short rains (mean=426 mm; October-December). Temperatures range from 14° to 34° with February and September marking increasingly severe and extended dry periods. Livelihood systems are largely agro-pastoral with cattle and goat husbandry combined with low-value, rain-fed agriculture (maize, beans) on small plots (<1 hectare). Households rely on casual labour and remittances for most of their cash income. Over half the population (54%) use unimproved water sources (stream, pond, dam). Of the remainder, 39 per cent use wells or boreholes, which include 66 Afridev handpumps installed over the last 20 years to help improve drinking water services.

Study site, Kyuso District, Kenya

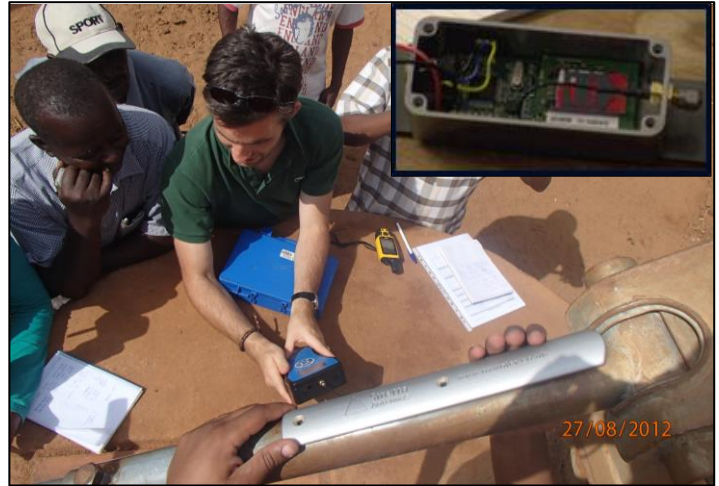




3.2. What is a 'Smart Handpump'?

3.2.1. Hardware

A smart handpump has a GSM transmitter securely fitted inside the handle of the pump. The transmitter automatically sends data on handpump use via SMS over the mobile phone network. The transmitter is small and robust with no moving parts with a specially designed antenna that fits discreetly to the handle. Installation is simple, enabling it to be retrofitted into existing pumps in the field or built into new pumps prior to deployment. The prototype smart handpump was tested in Lusaka in July 2011 with peer-reviewed results published early the following year. These trials demonstrated proof-of-concept, and the transmitter's ability, following calibration, to produce an estimate of the volume of water produced by the pump to which it was fitted, over



and above simply indicating whether the pump was being used or not. This led to the Kyuso study with the first installation in August 2012 preceding the full trial running from January through December 2013. Hardware and software improvements have been made progressively over time with a more efficient transmitter launched in a larger programme in January 2014.

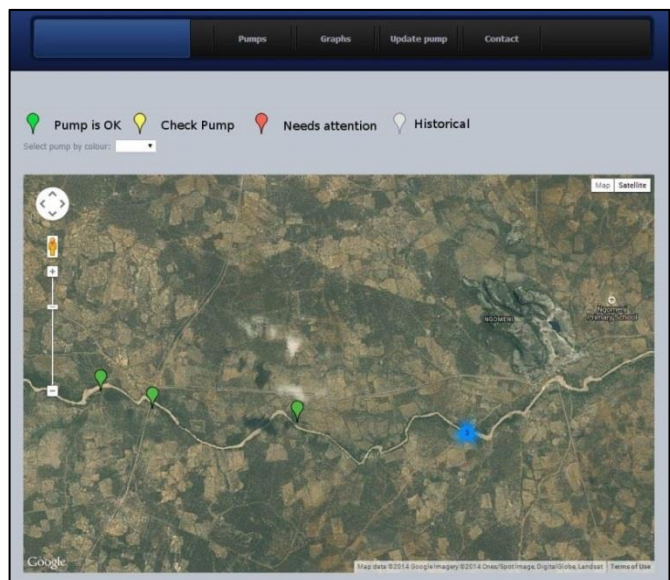
The transmitter offers three key benefits:

1. Measurement of handpump usage and associated volumetric water use to monitor service delivery;
2. Remote surveillance of maintenance service delivery and down-time to guide performance-based contracts;
3. Objective data that can improve infrastructure planning and investment, and promote sector accountability.

3.2.2. Database and User Interface

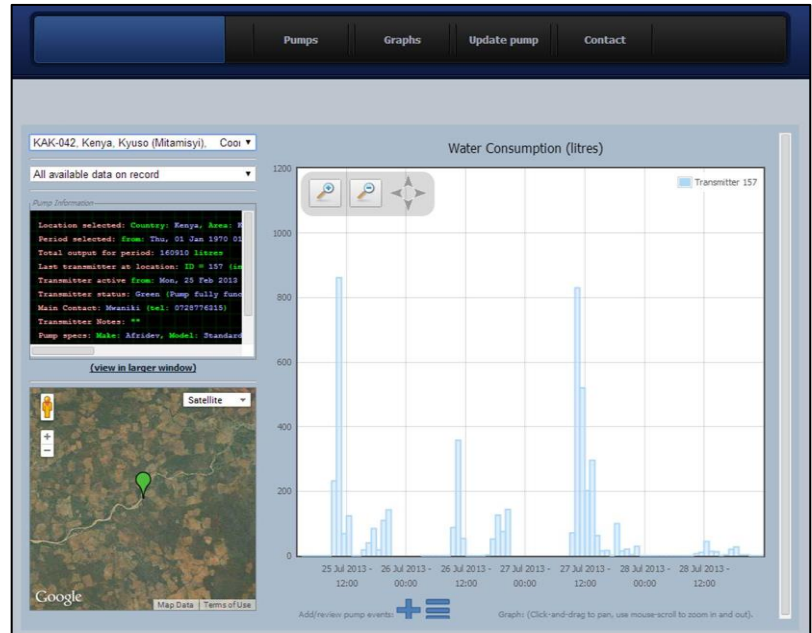
The data transmitted from the pumps are captured in a relational database and presented using a bespoke graphic user interface. The database was built in a modular fashion so that the system can easily be expanded to any scale. The user interface was developed with the support and input of the Ministry of Water and Irrigation, Water Services Regulatory Board and District Water Office. The system processes and presents data transmitted from each handpump.

During installation the latitude and longitude of each pump was recorded by Global Positioning System (GPS). An interactive map with markers representing the pumps was integrated into the website using the Google API. Each pump location is represented by a marker on the map, with the



status of the pump (fully operational, needing checking, broken, or historical) represented by the colour of the marker.

The graphs page is a convenient interface to monitor a pump's output and history, to see usage patterns and identify potential pump failures. The graph data are extracted directly from the MySQL database via a PHP interface based on the selection made (days, weeks, months, all), and a graph is generated dynamically, ensuring the data are always up-to-date. It is also a pure java script-based library, thereby avoiding the need for an online connection or resource-hungry plugins.



3.3. Sampling Frame and Methods

The study site was purposively selected following a waterpoint mapping exercise in 2011 that identified the location of the handpumps. It is an area where extreme poverty, increasing hydrological risk, uneven mobile network coverage and handpump dependency broadly reflect the conditions of the wider rural African context. Official support and guidance was sought and granted from the Ministry of Water and Irrigation, Water Services Regulatory Board, TanAthi Water Services Board, District Water Officer and local communities and traditional leaders. Ethical permissions for social research methods were reviewed and granted by Oxford University. Part of the ethical permission was based on the provision of a free, one-year maintenance service that would transition into a payment model if successful. Therefore no harm would come to any water user but it would provide experience of the new maintenance model while the research team gathered detailed information on the costs of service delivery, user preferences, and the institutional, operational and technical performance of the new technology.

The decision to work in an area of uneven mobile network coverage was made on three grounds: (1) to reflect the wider context of significant gaps in mobile coverage across rural Africa; (2) to assess the value of the data generated, even if it has gaps; and (3) to permit a stratified sample of handpumps split between 'actively-managed' handpumps and 'crowd-sourced' handpumps. Actively managed handpumps were the responsibility of the research team to track daily data on functionality to trigger maintenance cover. Crowd-sourced handpumps relied on the water users to trigger maintenance alerts; the users were informed of the free service and provided with contact details through a weather-proof sign attached to the handpump. The design would permit a quasi-experimental analysis of relative benefits and costs of installing the transmitter.

Iterative steps were taken in the technical and socio-economic components of the study which were co-designed by Oxford and RFL staff, and administered by trained staff in local languages:

1. July 2012 – baseline survey and choice experiment of user preferences;
2. August 2012 – re-survey of handpumps with GSM data and installation of first transmitter;
3. October 2012 – development and testing of Graphic User Interface (GUI);
4. November 2012 – design of and training for maintenance service model;
5. December 2012 – deployment of transmitters;



6. January 2013 – launch of the one year free maintenance trial and monitoring programme;
7. July 2013 – interim evaluation and focus group discussions with handpump users;
8. December 2013 – final evaluation and focus group discussions with handpump users; end of study period.

3.4. Baseline Survey

In order to test the model against the status-quo and understand the choices and preferences of water users, a baseline survey was conducted in July 2012. This involved interviewing 124 voluntary respondents who were collecting water at 21 handpumps. Sampled respondents were mainly female (64%) with an average age of 41 years with an average of 5.3 household members. Median adult equivalent expenditure is USD 313 per year which is two thirds (68%) of the global poverty line of USD 1.25 per person per day. Handpumps provide the majority of households with their main drinking water source (59%) and cooking, bathing and washing water (67%) throughout the year. However the dominant use of handpump water for households is for livestock watering (74%). Almost nine in ten households (86%) consider the water safe to drink though one in three claimed to treat the water by either boiling or chlorination.

3.4.1. Pump Breakdown Data

In the previous 12 months to the survey, 18 of the 21 handpumps (86%) had experienced a failure. The average failure rate was just over two failures per year (range 0-10) with a total of 48 failures. The median repair time to fix a pump was six days with an average of 27 days (7% of cases had a downtime of 365 days and over). To generate these data multiple informants were asked and the average of their responses taken as the downtime. There was wide variation in responses but the aggregated data were consistent with available estimates. For example, a mapping survey of 440 Afridev handpumps in Kwale County by the project team in September 2013, estimated the average downtime of handpumps per breakdown at 37 days for functional pumps and 85 days for non-functional pumps. Average downtime estimates at 'functioning' handpumps will under-estimate the aggregate downtime figure as illustrated by the longer downtime in non-functioning handpumps in Kwale. Given the likely recall bias in estimating downtime by respondents we chose to use the figure of 27 days downtime per handpump per year as our baseline figure as it will likely be a conservative estimate.



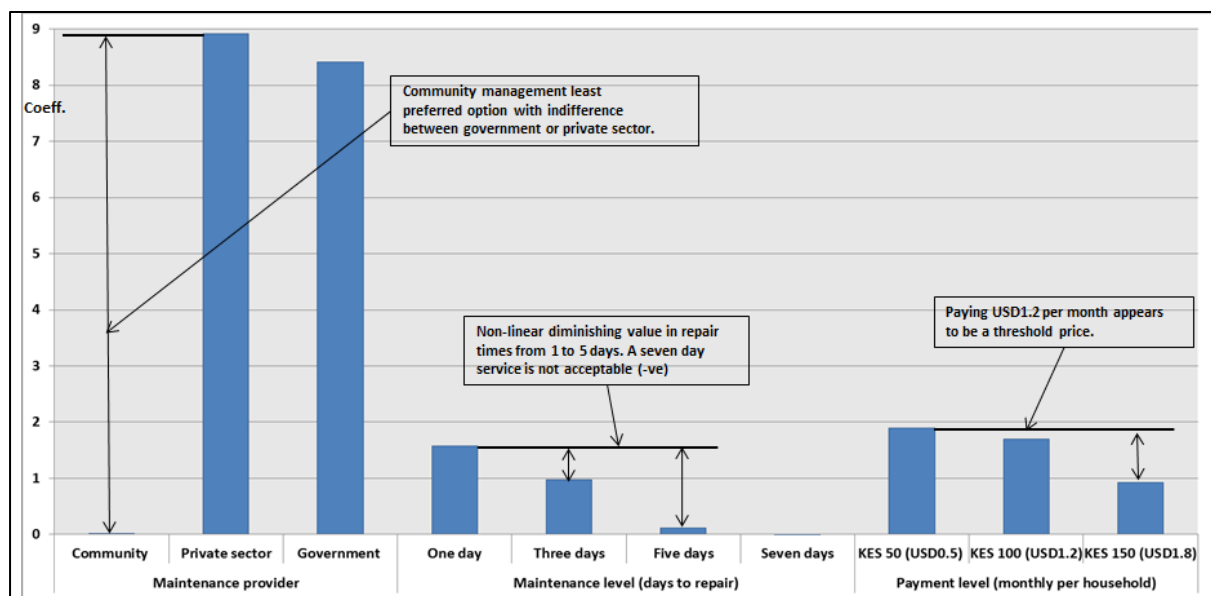
Over two in five households (44%) indicated they did not pay for water from their handpump. Among the majority that did pay a portfolio of overlapping payment approaches existed including a one-off membership fee, a monthly user fee and pay-as-you-go fees for drinking water containers or head of livestock. The most common payment modes were monthly fees which were generally USD 0.56 per month (30% of all paying households) or USD 1.1 per m³ water (Ksh2 per 20 litre container; 28% of all paying households). The opaque approach to fee collection is reflected in the financial challenges when a handpump breaks and needs repairing. It was reported that there are sometimes sufficient funds (24%), but more often there are not (36%), or funds which only cover minor repairs (18%).

Handpump failures are aggravated by delays in raising money in 40 per cent of cases with an average of 18 days to raise sufficient funds (median = 7 days; range 1-180 days). Unprompted concerns about handpump management showed maintenance to be a key priority across a range of overlapping factors:

1. Repairs are too expensive (19%)
2. Repairs take too long (17%)
3. Handpump breaks too often (17%)
4. Too many users (10%)
5. Pump too far (8%)
6. Water unsafe to drink (6%)
7. Water fee too high (1%)

3.4.2. User Preferences for Maintenance Service

As part of the survey a choice experiment tested handpump user preferences for alternative maintenance models. The experiment was orthogonally-designed with ten pictorial cards that required choices across competing attributes of maintenance provider, maintenance level, payment mode, and payment level. A sample of 3,540 observations was produced from usable data from 118 handpump users. Results identify community management of maintenance services as the least preferred option (see figure below).



The baseline data illustrate that rural water users have a more expansive view of alternative maintenance systems than currently prescribed. Without financial sustainability through full or partial cost recovery from water users no sustainable services will be maintained. Rural water users express a positive preference to pay for external maintenance services though payment behaviours are not uniform within communities. These findings have been further explored after the new maintenance service was introduced to understand user preferences for a pre-payment service.



3.5. Study Limitations

We are aware of a number of limitations in the wider implications of the study:

1. The sampling frame was not random and there was no control group against which to compare the treatment (see appendix);
2. No detailed information was available on the environmental conditions (e.g. geology, recharge, geochemistry), the quality of installations across the sample handpumps, or the historical quality of maintenance services;
3. The study did not have resources to evaluate health and wider poverty impacts on the study communities over time, or specifically related to failure events when alternative water sources were used for a number of days;
4. The future financial behaviour of the study communities has yet to be tested and is probably the single most important barrier and opportunity to wider adoption and sustainability of the model.

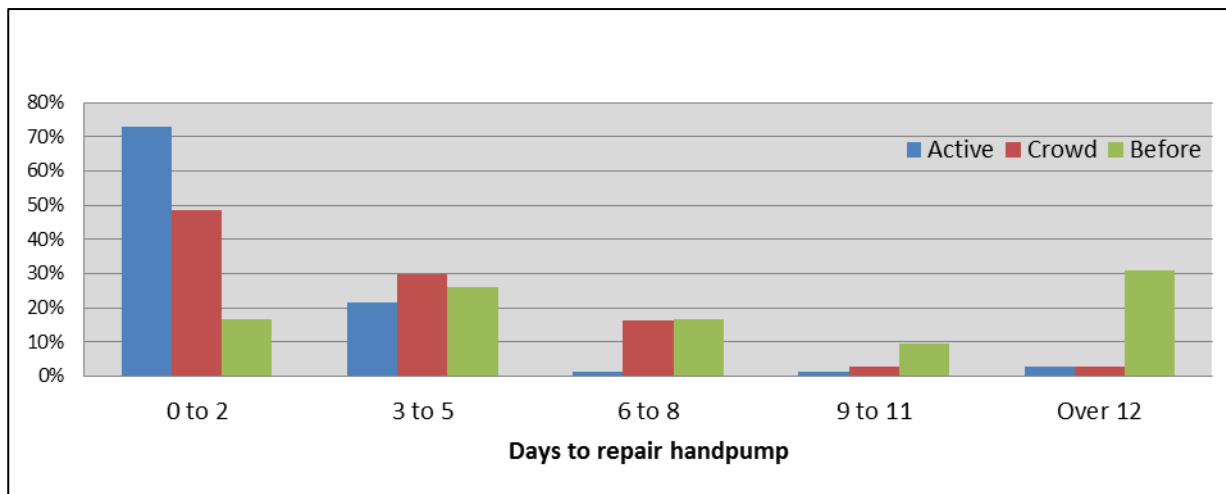


4. Evidence for Institutional Reform

4.1. Operational Sustainability

4.1.1. Operational Effectiveness

The primary research question is whether timely information of handpump failures can drive a maintenance model that leads to faster repairs. To this end we recorded when a maintenance alert was first raised and when the repair was actually completed, using the difference to indicate the time the handpump was not working and hence the effectiveness of the new maintenance model. The following figures show the range of downtimes for the two treatments (active, crowd) in the trial and the baseline.



Group		Mean days to repair	Median days to repair	Increase in chance of repair within two days vs. baseline ²	Repairs
Baseline Survey ¹		27	6	-	48
Study	All repairs	2.6	1	4.3	111 ³
	Actively Managed	2.0	1	4.8	74
	Crowd Sourced	3.7	3	3.2	37

1. See methodology appendix for further detail.

2. Risk Ratio or Relative Risk calculated with respect to the baseline case. All p-values are <0.001.

3. This figure excludes instances when the repair time was not related to the maintenance service (e.g. the local community had to deepen the well before additional pipes and rods could be added by the mechanic).



The results provide evidence of significant improvements under the new maintenance model:

- Pump outage times drop by *an order of magnitude* from a mean of 27 days to under three.
- 89 per cent of repairs were completed within five days, rising to 95 per cent for the actively managed group.
- A handpump is over *four times more likely* to have been repaired *within two days* than under the existing system.
- The actively-managed handpumps were 50 per cent more likely to have been fixed within two days than the crowd-sourced handpumps.

Durable but non-riveted stickers, with the maintenance number to call or text, were attached to the crowd-sourced handpumps to evaluate how communities would react both in terms of any change in calling in repairs and the risks of petty vandalism. The focus group discussions conducted after the trial showed that at least eight of these stickers had been removed.

Despite no clear geographical, usage or socio-cultural differences between the two treatments, crowd-sourced handpumps were less likely to have had a repair: there were twice as many repairs conducted on the actively-managed pumps than the crowd-sourced pumps. Without information on the timings of sticker removals it is impossible to unpack when and why stickers were removed and their impact on downtimes, and how this might have contributed to there being fewer repairs. In the new and larger trial in Kwale, riveted plates have been attached to crowd-sourced handpumps to better quantify differences (see photo).



In contrast to this, and more optimistically, when repair dates were compared to the usage of pumps, it was clear that in a significant number of cases the pump was still working to a certain extent when the repair was undertaken. These cases suggest that pump users were calling in a pre-emptive repair and therefore, even though there may have been a response lag, there was no actual pump down time, with users having access to water throughout this period.

All the pumps with a downtime of over 12 days during the trial were due to them requiring major repairs, e.g. new rising main sections, the spares for which were not held in Kyuso, as per the original study design. Given the demand for these larger spare parts, the larger trial in Kwale will include these in its spare parts inventory.

4.1.2. Operational Scale

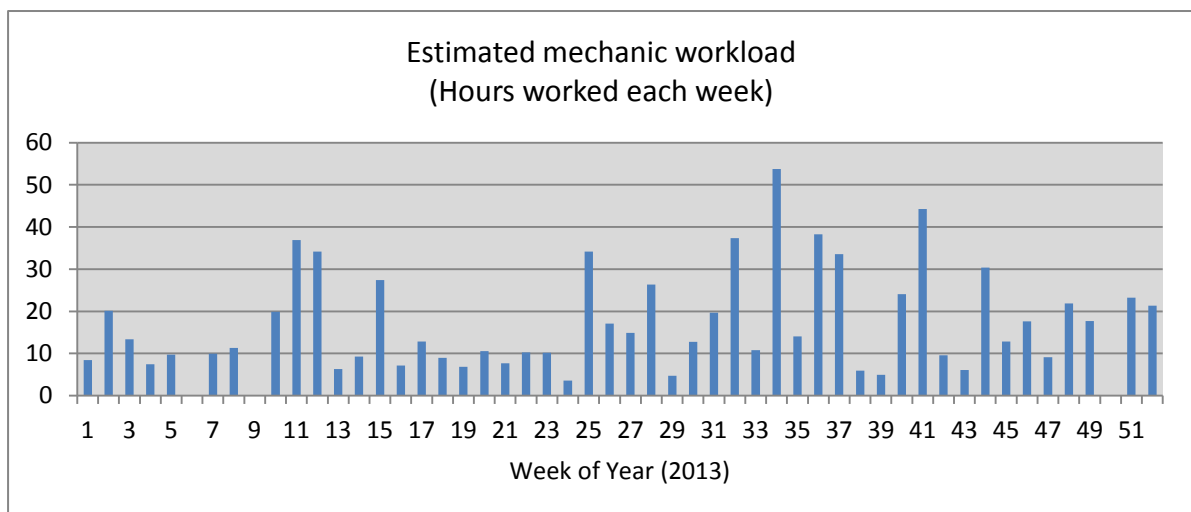
For a maintenance service to be both effective and sustainable, the speed of response must be balanced with the resources required to deliver the service. Given that failures happen in an unpredictable fashion, with some peak times throughout the year, there must be excess capacity to cope with the variation. In our case, this translated to the workload of the mechanic undertaking the repairs: if he has too much work, repair jobs will queue and downtimes will increase at peak times; too little work and it will be harder to make this an attractive and sustainable employment opportunity.

The average time on site for a repair was three hours, and the average travel return time at two hours forty minutes. Therefore, unless two repairs happened to be at pumps close together, or one en-route to the other, the mechanic could only be expected to make one repair on any given day. The chart below shows how workload



varied from week to week, based on recorded time spent at each pump and calculated travel time based on kilometres. This does not include an estimate for administrative time, which would have taken around an hour or so each week. For travel time a uniform estimate of average speed was used. This is clearly a simplification as certain routes within Kyuso are faster than others and there would have been significant seasonal variations as roads became more difficult to pass during the rains.

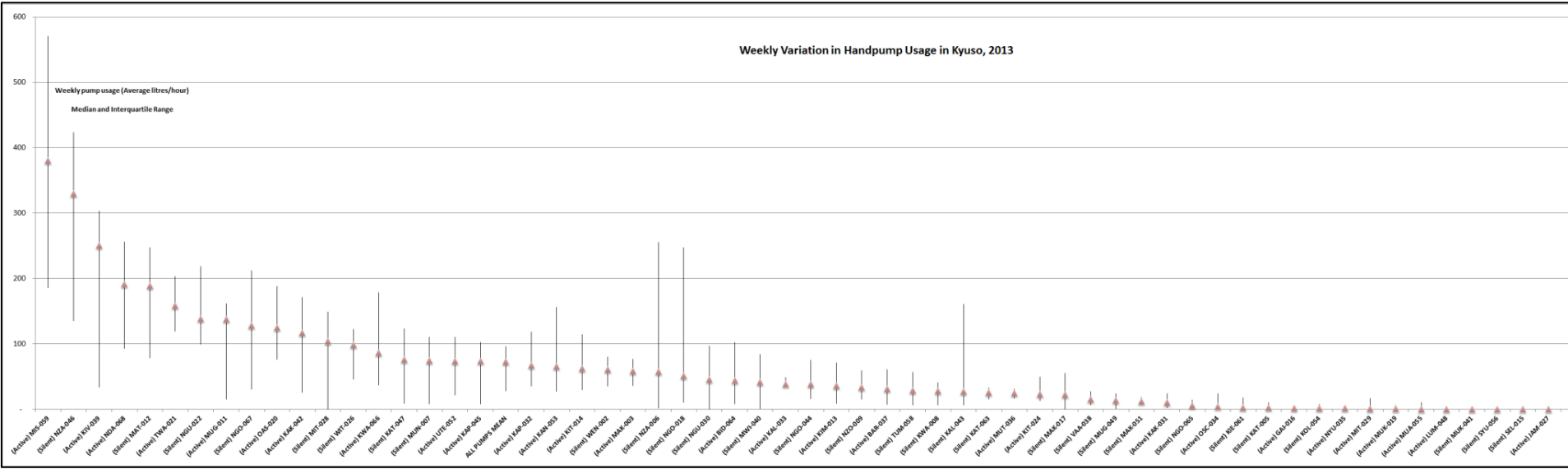
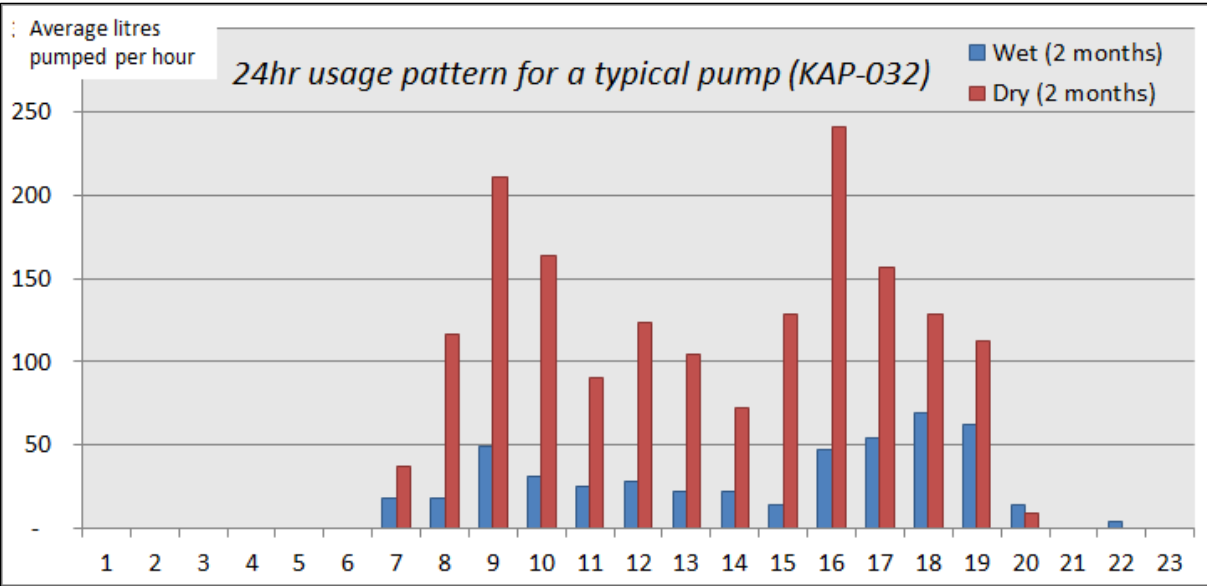
The average working hours on a repair day was five hours forty minutes. With 136 repairs, and only a handful of repairs undertaken on the same day, this corresponds to about a 50 per cent workload. However the workload is uneven with peaks during the year (see figure below). Therefore, taken on aggregate, the mechanic would have been able to maintain more handpumps, say up to 100. However such an increase in work would almost inevitably lead to there being weeks where jobs were delayed or queued, which would cause downtimes to rise.

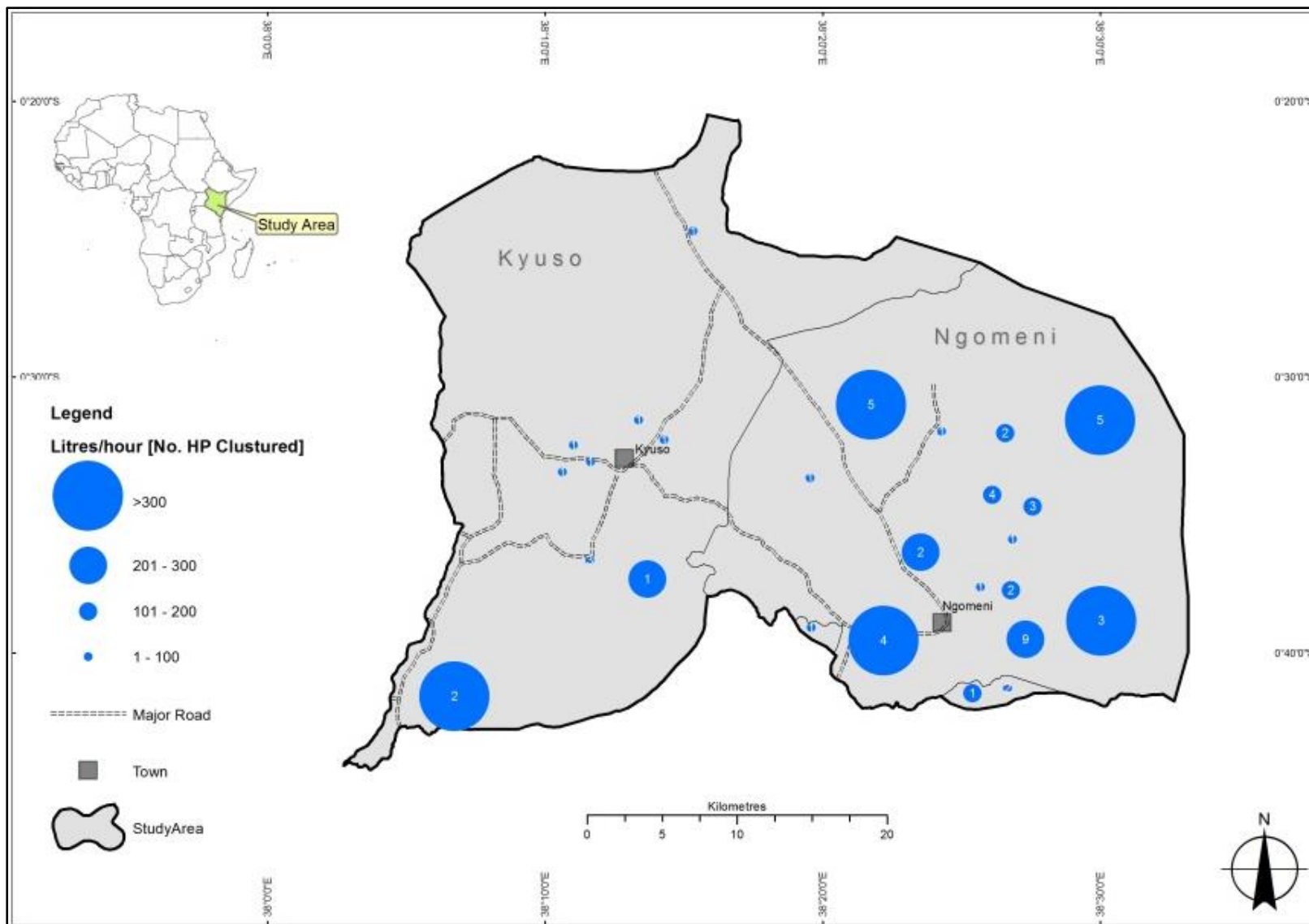


An effective system would need redundancy in order that in the event that the mechanics had other commitments or were ill (as occurred twice during the trial) the maintenance system does not cease to function. Based on this trial, we would suggest that in an area of similar geography to Kyuso a sustainable system could be run using two mechanics looking after up to a maximum of two hundred pumps between them. With higher pump density and better roads, then this could increase, with two repairs possible per mechanic per day; in more dispersed and remote settings than Kyuso this number would certainly fall. To avoid perverse incentives mechanic wages would be structured by long-term performance, not per repair.

The data generated by the WDTs can be used to illustrate patterns of pump use over different scales, for example:

1. Different levels of use throughout the day, comparing wet and dry periods (right);
2. Spatial distribution of water use over the district (below);
3. Variation in weekly use across the year between all pump (overleaf).



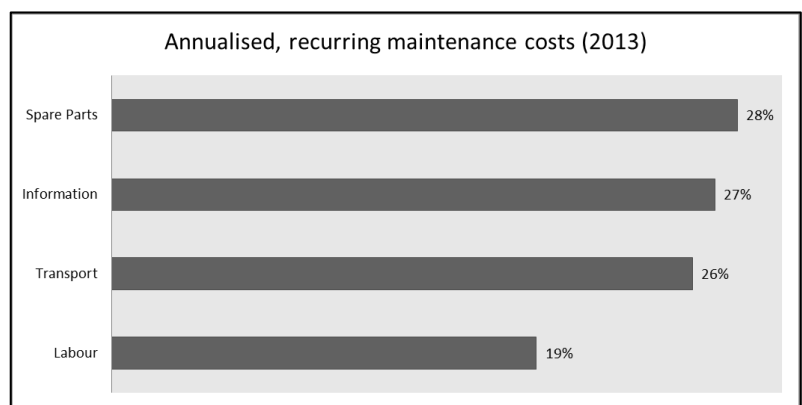


4.1.3. Operational Costs

All recurring maintenance costs were systematically recorded. A detailed inventory was kept of spare parts used and costs; each visit was monitored by time, distance and spare parts used; and information costs. The annualised, recurring cost per repair in the trial was USD 62. With 136 repair visits this sums to USD 8,368 in 2013, with a crude average of USD 127 per handpump.

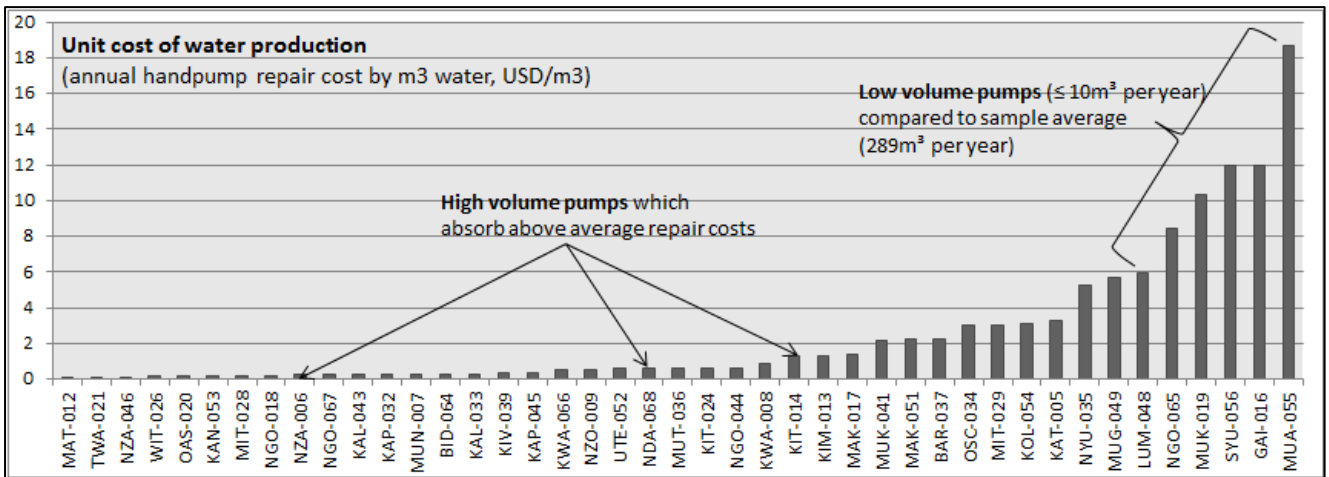
Spare parts represented 28 per cent of total costs. When the mechanic was called out he was instructed to do a basic service of low-cost but frequently failing parts. This led to (rubber) U-seals being replaced in most cases (85%) followed by rod centralisers (43%). Three quarters of total spare part costs were attributable to three larger parts: cylinders (21%), rising mains (23%) and rods (29%).

Information costs represent 27 per cent of recurring costs, including one daily message and a replacement battery. Current power consumption requires battery changes every two years, which can be included in the maintenance programme. In the study period, data transmission was programmed to be sent four times a day embedding hourly batches of data. Hourly data offer a level of understanding important for a research programme but unnecessary for an operational programme where one daily message embedding six blocks of four hourly usage data would be sufficient. While it represents a significant cost, reliable and regular data are critical for the monitoring of maintenance services to ensure service delivery performance is achieved and improved. In addition, pricing, planning and regulation all depend on the data generated.



Transport costs are similar to spare parts and data transmission (26%). Here, transport costs included petrol, repairs and depreciation for an off-road motorbike. Labour costs accounted for a trained, local mechanic at USD 11.6 (Ksh 1,000) per visit.

With estimated water pumped per handpump and repair costs it is possible to measure the unit cost of water production. This controls for the number of repairs per pump by annual water usage. As illustrated below, handpumps with high costs of production are linked to low volumes of water pumped. Lower unit costs of water production are associated with more heavily used handpumps. The year of installation appears a weak guide to production costs suggesting older pumps can be economical if demand is high. The data provide guidance on handpumps that may be uneconomical to repair over time, particular if they are lightly used and co-located near alternative and more efficient handpumps. Maintenance service providers and water service regulators can usefully apply this information in improving operational performance and benchmarking sector guidelines. Further, consistently high production costs can be traced back to installation records to determine if environmental or particular drilling companies may have contributed to above average repair costs.



4.2. Financial Sustainability

Financial sustainability is critical to maintaining rural water services. The financial challenge reflects individual and group constraints, hence attention must be directed to: (a) designing a fair payment system; (b) reducing weak incentives for poor people to pre-pay, and (c) ensuring payments are sufficient to cover both minor and major repairs.

This section shows how the Kyuso model operates financially with arrangements for aligning payments with service delivery, designing a fair and flexible pricing scheme, and pooling financial risk across clustered communities. Answers to the following questions will be provided based on evidence from Kyuso:

- Can individual users be incentivised to pre-pay for handpump maintenance?
- Are current and future payments sufficient to cover operational costs?
- Can the risk be pooled to reduce the burden of high individual repair costs?
- How can pricing be fair across heterogeneous user groups?

4.2.1. User Payment Is Contingent on Service Delivery

The lack of incentives for users to regularly pre-pay handpump fees has been identified as one of the challenges facing rural water supply schemes. If communities fail to save money in advance this commonly leads to long downtimes, increasing dissatisfaction with their water supply system and sometimes abandonment of the handpump. It can also lead to higher overall costs as a mechanic may need to make one visit to diagnose and quote for a repair, and then a second to actually undertake the repair once funds have been collected and spare part procured.

The Kyuso model builds on the premise that the demonstration of an effective maintenance service will generate demand for higher service levels, expressed by a greater willingness to pay for this service by handpump users. The strongest incentives for the users are the speed and quality of service delivered by a trained and reliable mechanic.



The focus group discussions revealed that water users especially value the time-saving dimension of the maintenance service, which allows them to avoid collecting water from more distant, dirty or expensive sources, and pursue income-generating activities instead.

Water users from 630 households at all 66 handpumps were asked about their previous payment levels for handpump maintenance and their willingness to pay on a monthly basis for the new level of service. At the 46 handpumps that broke and were repaired in 2013 there was a three-fold increase in the number of communities willing to pre-pay regularly for handpump maintenance

from 29 per cent to 91 per cent. They also expressed a willingness to pay in the future five times more than previous payment level. Before the trial, the mean monthly household contribution was USD 0.2; following the new maintenance service the willingness to pay has increased to USD 1 per household per month (see below). This corresponds with an average payment of USD 23 per month per handpump.

Service delivery increases willing-to-pay levels

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

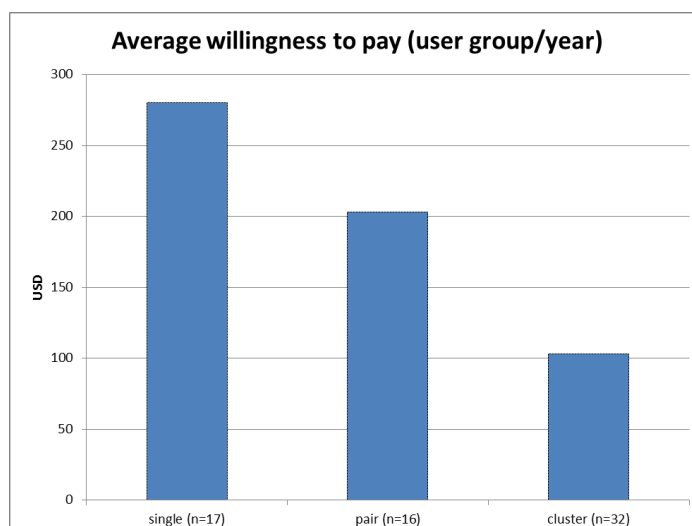
Even the users at handpumps which were not yet serviced (n=20) experienced an increase in terms of willingness to contribute and of revenue levels, as awareness about the service has spread. Overall, those who have experienced the new maintenance service are willing to pay over 50 per cent more (USD 1) than those who have not experienced it (USD 0.6), which underlines the value that Kyuso's handpump users see in the new maintenance service.

4.2.2. Spatial Distribution

Handpump density has important implications for operational management and investment planning. The study found three different ways that handpumps were geographically grouped. These groupings showed different usage patterns, which would inform policy and operational planning. Population density does not vary greatly across all three groups.

In Kyuso we adopted the following geographical density classification:

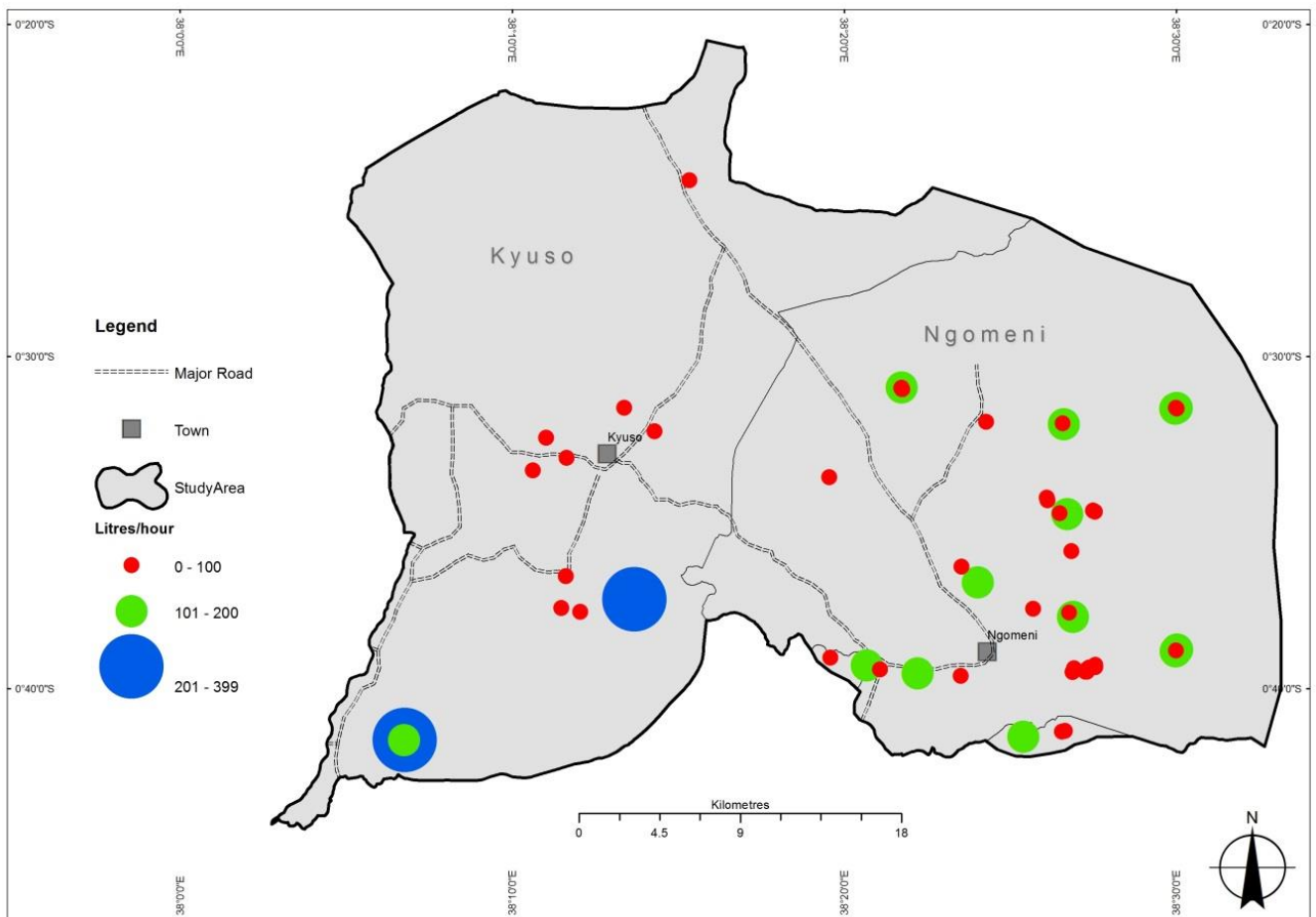
- **Single** - isolated pumps with no improved alternative water sources nearby;
- **Pair** - with one neighbour - pumps often shared between user groups; and,
- **Cluster** - three or more handpumps in close proximity, often found along riverbeds.



The classification reflects different pump use behaviours contingent on location. In Kyuso, we found 17 singles, eight pairs and four clusters (eight pumps on average per cluster). While single pumps do not have the highest pump volume per hour, the users' willingness to pay for the new maintenance service is highest (USD 280 per year). As is well-rehearsed in the literature user demand is often shaped by the availability of alternative water sources. Pairs pump the highest volume of water and also face the highest average repair costs, at USD 141 per year; their willingness to pay is USD 203 per year. Clusters had the lowest willingness to pay with payment matching repair costs at USD 103. Since many alternatives are available, the need for a high payment to keep a specific pump operational may not be perceived as strong.

It is notable that only one out of the two in any pair was non-functional at any given time – and in cases of breakdown users were usually allowed to use the other pump. Clusters also had at least 50 per cent of their pumps working at any given time, suggesting excessive redundancy. This may represent an inefficient investment in infrastructure, as well as reducing the financial sustainability of the maintenance service. As the figure below illustrates, and in contrast to the earlier mapping figure, volumetric use by spatial distribution is critical to quantify both performance of past investments and to provide an objective basis for future investments. Investment decisions without such data are opaque at best and open to manipulation by vested interests that may weakly reflect water needs.

Handpump volumetric use by average litres per hour, 2013



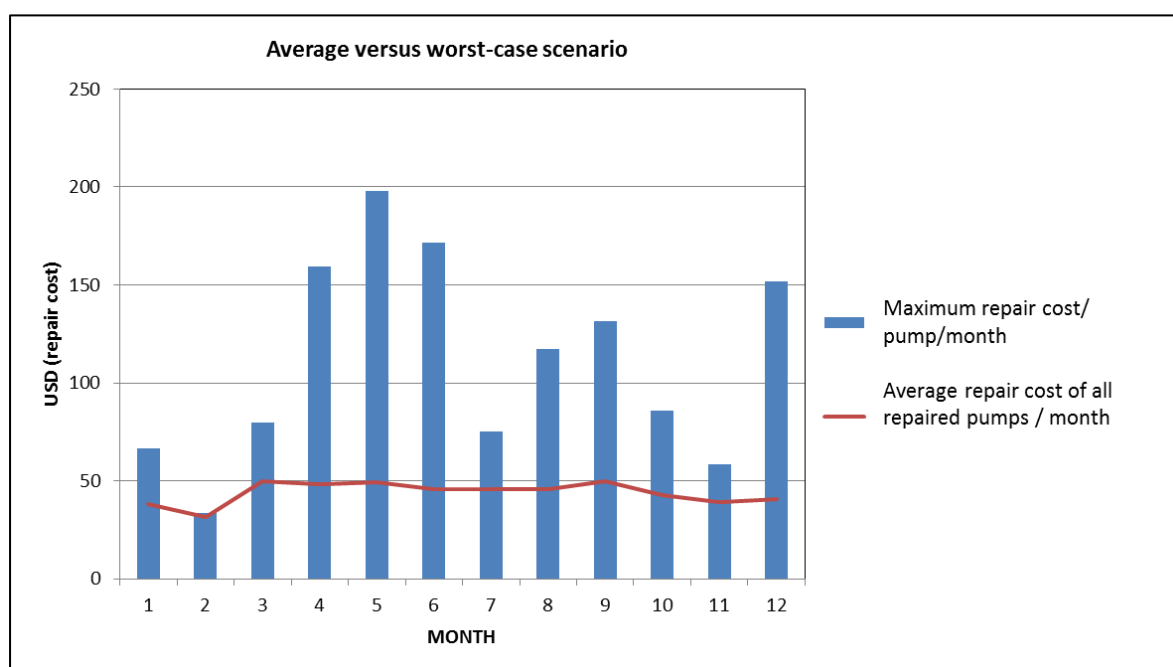
4.2.3. Scale Reduces Risk

It is difficult for communities to meet unpredictable and volatile repair costs over time. However, if handpumps are pooled, financial risk can be smoothed and water service reliability increased.

4.2.3.1. Repair Cost

Of our sample of 66 handpumps 70 per cent required at least one repair in 2013. The number of repairs ranged from one to eleven; 63 per cent of broken handpumps required more than one repair. Repair costs per handpump ranged from USD 54 to USD 649. The latter was for one handpump requiring eleven repairs. The average cost of each repair was USD 62.

Even averaging repair costs over a month smooth costs out considerably. The maximum cost was highest in April to June 2013, which may indicate that some communities get major repairs done in the wet season to avoid larger problems in the dry season when water is most needed. The variation in cost underlines the importance of regular payments to smooth repair cost peaks over the whole year. Discussions with the communities confirmed this finding – the user groups at all 66 pumps agreed that payments should be made regularly throughout the year and at the same rate.



4.2.3.2. Previous Payment

The average level of pre-payment across all pumps, prior to the start of the free maintenance service, was USD 80 per year. However, 22 per cent of all handpumps pre-pay with their average payment of USD 353 per year. For the other 78 per cent of handpumps, nothing is saved. So when a handpump fails the first step is to try and get some money together which can take two weeks or longer. It is only when this money has been raised that a mechanic would order spare parts, which may not be immediately available.

4.2.3.3. Future Payment

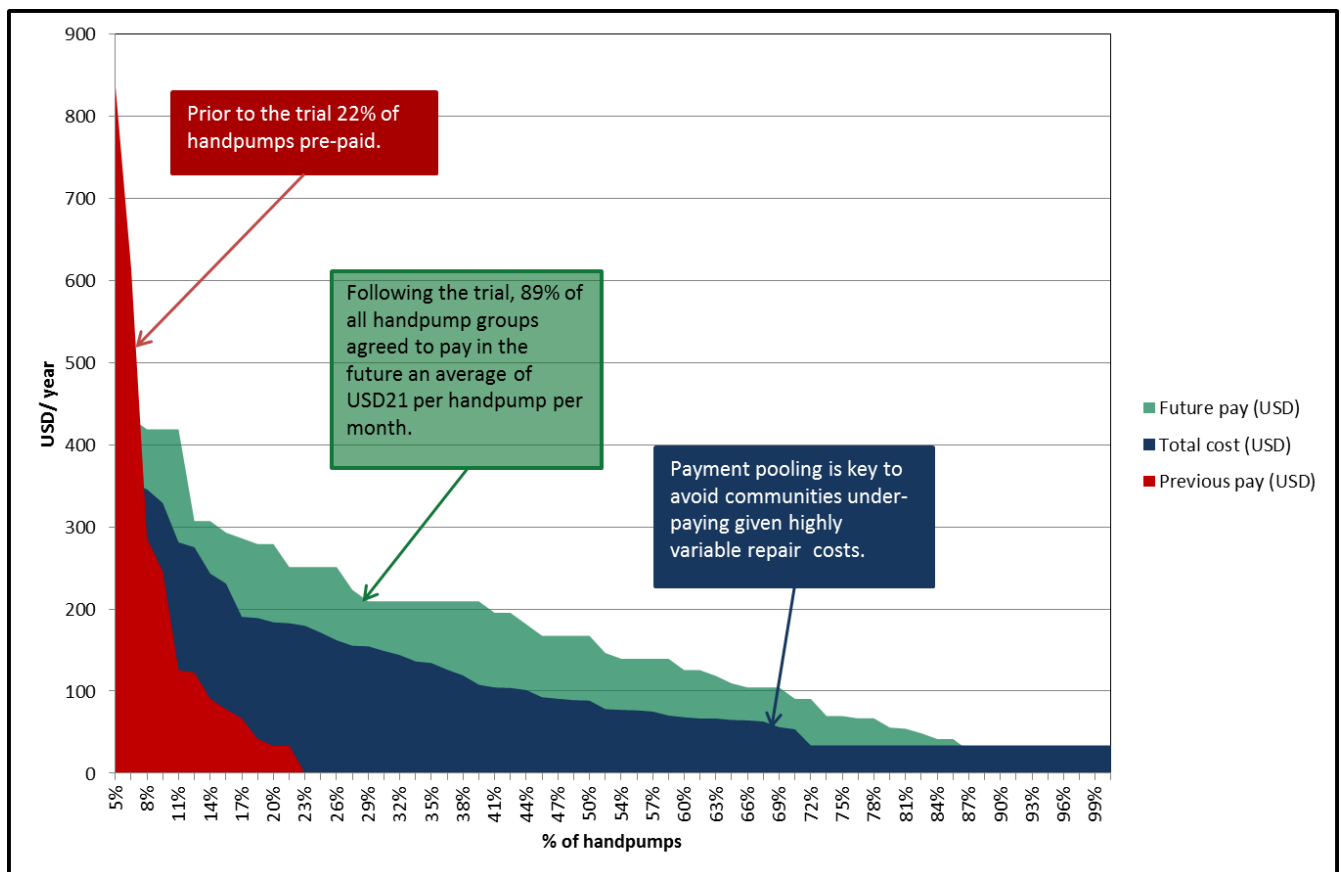
At the end of 2013 as the free maintenance service ended we re-interviewed all communities to learn of their experience of the service. In particular, we wanted to know if they would agree to pre-pay to keep the service running and how much they would pre-pay. This process often took several meetings as communities met to discuss in very active and lively debates. Overall, 89 per cent of communities said they wanted to keep the

maintenance programme running with an average payment of USD 21 per month per handpump, or USD 250 per year. This results in 2.5-fold increase in overall pre-payment finance per year – assuming that all households will pay every month of the year. This increase in willingness-to-pay demonstrates the high value Kyuso’s water users assign to the new maintenance service. Given some large and unproven assumptions on maintaining future payments this underlines the critical role of community finance, but also the almost certain need for external financial support.

4.2.3.4. Pooling Cost

Scale can smooth uneven repair costs that individual communities can bear in a good year but not in a bad year. No one can predict when a bad year will fall. Repairs can be related to environmental conditions (e.g. groundwater levels), poor installation (e.g. incorrect screens, poor alignment) or wear and tear. An unlucky community may have a badly installed handpump in an area of variable groundwater with a local mechanic who is not competent. Pump MUA-055 experienced such a bad year with the highest number of repairs and highest costs. This could not have been met through current payments; this pump may have been abandoned if the community had been obliged to pay all the repair costs. Scale pools financial risk while smoothing costs. If the stated willingness to pay of all pump user group reflected the actual future payment collected, this would raise sufficient revenue to have covered all repair costs in 2013; however, if communities chose not to pool revenue, 43 per cent of communities would not have met their individual costs. Working alone makes no financial sense. Once the principle of pooling costs and payments is established, a flexible and fair pricing scheme can be developed.

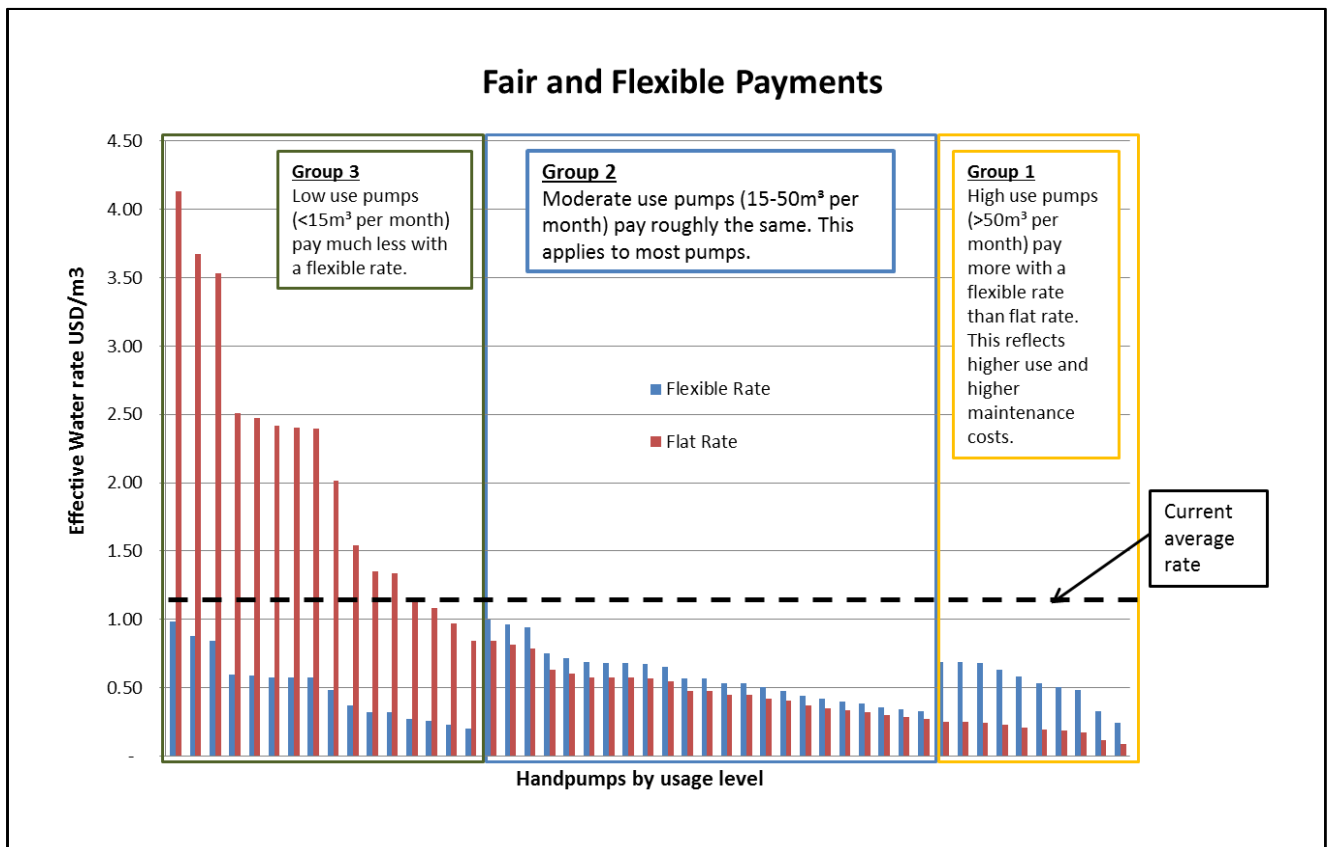
Repair costs, previous and future payments for the maintenance service



4.2.4. Fair and Flexible Pricing

Fair and flexible pricing is possible through observed data on handpump usage. Such a system would balance economic efficiency with fairness better than a “flat rate per pump” method of charging. The data captured by the transmitters shows how this can be possible. Linking the cost of maintenance services with observed usage levels allows the price to be matched to the demand for water. It is more equitable and more likely to be sustained in the longer term than a flat rate system, under which lightly used pumps with few users would, on a per capita basis, effectively be subsidising more heavily used pumps.

A fair and flexible pricing structure could divide pumps into groups based on average usage levels. Each group would pay a corresponding monthly maintenance service fee which is flexible to changes in usage patterns over time (more/less/same). The figure below shows that even a simple system of usage/pricing bands can be shown to create a system that is both simple and equitable, keeping the equivalent rate per unit volume at a sustainable level for all user groups. In contrast the equivalent water rate under a flat-rate-per-pump system that generated the same total revenue is shown; this would have some pump users paying an extremely high rate.



Under the flexible system the average rate user groups pay is the equivalent of USD 0.46 per m³ and the highest rate any user group pays is the equivalent of USD 1.00 per m³. This pricing structure was set so that the revenue that would be generated would cover the local costs of the Kyuso trial (i.e. labour, transport, spare parts and information costs). In comparison, current ‘pay-as-you-go’ rates are 2 Ksh per 20 litre jerrycan (USD 1.16 per m³). This comparison indicates that an information-driven charging scheme can be financially viable and economically efficient (in that it covers the variable costs), while keeping payment rates at a level that is both realistic and equitable in terms of users’ ability and willingness to pay for it.

5. Institutional Transformations for Rural Water Services

The study provides unique insights of observed, hourly data of the usage patterns of 66 handpumps in a remote and poor area of rural Kenya. Results provide new evidence to address institutional, operational and financial challenges of reliable rural water services. Sustainable progress is conditional on regular and reliable information. Information is not costless but amplifies value for water users, government and donors. A least-cost logic that only invests in infrastructure and leaves communities to manage handpumps on their own is neither the preferred social choice nor one that delivers lasting benefits. This entrenched but false economy undermines a sustainable business case for rural water investments and is challenged by the evidence from this study.

Transmitters from smart handpumps generate granular and inclusive data that chart new and accountable pathways to reduce institutional costs and deliver more effective and sustainable services at scale. The transformational opportunity lies in information enabling new maintenance services that smooth financial risk from unpredictable repair costs and promote a new model that is performance-based. The new model promotes an output-based payment model sharing costs between users, government and donors based on quantifiable results.

The new model is based on the following design principles:

1. Institutional and Regulatory Reform

- a. Rural water services regulation to introduce process benchmarks, and then performance benchmarks on water service indicators, that map on to the Human Right to Water.
- b. Accountability promoted by public dissemination of performance metrics through internet and/or social media.
- c. A socially-acceptable, handpump maintenance service model that serves, but is not directly managed by, the community.

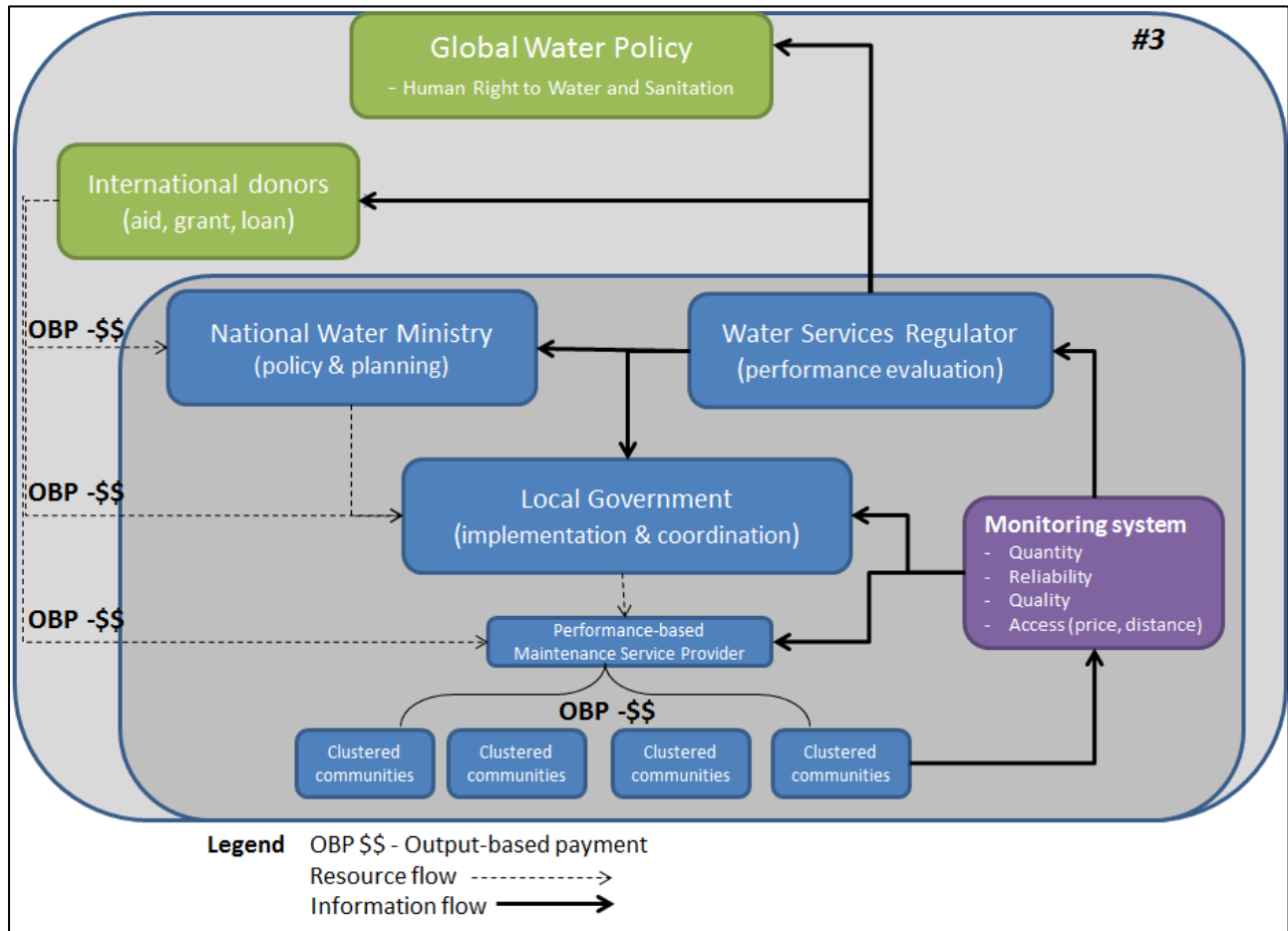
2. Operational Sustainability

- a. Scale to insure against unpredictable risks of high repair costs, both for the users and maintenance service provider.
- b. Operational performance measured and evaluated with objective indicators (i.e. downtime).
- c. Water production costs can be accurately monitored to determine more efficient maintenance and asset replacement strategies.

3. Financial Sustainability

- a. Pooling handpump payments to insure against financial risk.
- b. Fair and flexible water payments align handpump use with maintenance costs.
- c. Payments should follow a trial period to increase participation and revenue.
- d. Pre-payment to smooth repair costs for communities over the year.
- e. The cost of institutional design and uncertainty of actual future payment require government and/or funder support in establishing the new maintenance model. Operational cost variability may make user payments alone insufficient to cover all costs, thus requiring targeted, external support.

An Output-based Payment Model of Rural Water Services



An output-based payment model outlines a new framework for donor and government behaviour in Africa. Investing in information that objectively reveals performance will challenge policy orthodoxy to generate debate and reflection. The model explicitly promotes universal coverage which enforces discipline and coordination of multiple actors at scale. Few African countries have the capacity to manage a fluctuating portfolio of national and international NGOs that often work independently of government and for limited periods of time. Government and NGOs that are committed to universal and reliable water services should support a consolidated and accountable national programme.

A national rural water regulation system that documents existing and new investments by environmental, technical and operational indicators will provide an invaluable resource to monitor and regulate investment behaviour and outcomes at scale. Such a system may be built from below at sub-national levels such as in Kyuso District or a larger political scale to continuously inform national government goals and priorities. For example, Kwale County is introducing the model described above to link with the Water Services Regulatory Board at the national level in Kenya. Lessons from Kyuso are being incorporated in this new programme of work to address the limitations identified.

By 2050 Africa will increase its rural population by 50 per cent to over 0.9 billion people. In the last two decades of rural water investments in Africa major progress has been made but 35 million more people lack improved water access in 2011 than 1990, based on the narrow definition of households' self-reported main drinking water source. This figure will likely under-estimate the Human Right to Water's more expansive and universal goal of

reliable services of sufficient, safe and affordable services each and every day. With a one per cent increase of rural piped water services between 1990 and 2011 (4% to 5%), handpumps will inevitably play a significant role in providing water in the time required for Africa to shift to a wealthier and more urban population. The handpump solution will continue to play a critical bridge in improving the health and welfare of the one in three rural Africans currently without safe water. The Kyuso study exploits an expanding mobile architecture and global policy framework to offer a new model to respond to one of Africa's enduring and more elusive challenges.



6. Appendices

6.1. Data and Methodology

6.1.1. *Experimental Design*

A Randomised Control Trial with two treatment types (Active-Management and Crowd-Sourced) and a control offers statistical validity by reducing potential biases and confounding factors. However, this design was not feasible for methodological, ethical and statistical reasons:

1. Random assignment of fee-paying, control handpumps would have likely co-located some controls with free service, treatment handpumps in a pair or cluster. This would have biased the results as control handpumps would have been abandoned in favour of treatments after the first control failure.
2. Local government (District Water Office) did not support treating rural water users differently on ethical grounds. It was agreed a larger study that could geographically isolate a quasi-control sample would be preferable and this has been implemented in the larger Kwale study launched in January 2014.
3. The sample size in the study area gave sufficient power, with two treatments of equal size, to show the level of effect that we predicted. However, if this had been two treatments and a control of equal sizes, the sample size would not have given sufficient power for statistical inference.

Instead, the design had two treatments and included all the handpumps in the District. The split between the two treatments was not random, but was determined by mobile signal strength sufficient to reliably transmit SMS messages. This may have created a bias in terms of the ability of communities in the Crowd-Sourced treatment to call in breakdowns. However, in all cases there was mobile signal near the handpump. Usually there was signal in the settlement which the pumps served, but commonly none at the handpumps which were usually located in a depression. In some cases there was sufficient signal strength to make a phone call standing by the handpump, but at the level of the transmitter built into the handle the signal dropped.

Distance between treatments and the District Water Office was not controlled for but was similar (c.22 km). Observed water usage levels were not known before the trial though average usage level of the two treatments was found to be broadly similar (66 vs. 75 litres per hour).

6.1.2. *Exclusions*

Handpumps that were non-functional for environmental reasons (e.g. a dry well that required further excavation) were not included in the analysis of *maintenance response times*. There were four repairs after which the same pump needed to be immediately repaired again. In these cases the repairs were collapsed to a single repair, with the overall time to repair used in the calculations. For this reason sample numbers vary depending on the calculation being made. In all cases the calculations are conservative and underestimate downtimes.

6.2. Waterpoint Data Transmitters

6.2.1. *Volumetric Estimation and Calibration*

The transmitters have an algorithm that translates pump usage, measured by the movement of the handle, into an estimate for the litres pumped. Extensive tests in Zambia during the initial proof-of-concept phase (Thomson, et al. 2012) and further tests in Kenya generated a calibration that gave a volumetric output that was +/- 10% of the observed output. However, there are many factors that will vary this accuracy across pumps and for this study pumps were not calibrated individually: the same calibration formula was used for all pumps. As such, we refer to litres pumped primarily as a proxy for pump usage, not as a direct statement of the volume of water used in the way that should be considered equivalent to a water meter.

6.2.2. *Missing Pump Data*

The trial involved the installation of transmitters into 66 Afridev pumps. However, only 61 data streams have been used for analysis. As such the data from five pumps have not been included in the analysis:

- Two of the actively managed pumps, while registering good mobile signal at the time of installation, successfully transmitted insufficient data for meaningful analysis. Variable and unpredictable network performance affected all handpumps causing some data gaps but to a degree that was manageable.
- Two of the silent monitoring pumps did not have their data retrieved as this process took place during the rains and two pump were on the other side of rivers that were not safely passable at the time.
- One transmitter was vandalized (1.5%) with the antenna cable cut.

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Photo credits

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