The Water Diary Method – proof-of-concept and policy implications for monitoring water use behaviour in rural Kenya

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Abstract

Africa is lagging behind global progress to meet the Sustainable Development Goal for 'universal access to safe and affordable drinking water' services. New knowledge needs to understand and respond to water service inequalities which are not revealed by high quality but snapshot and infrequent household surveys. We design and pilot a 'Water Diary' in Kenya to document the daily sources, uses, cost and sufficiency of water, along with weekly household expenditures. Water use behaviours vary across water supply alternatives, rainfall extremes and economic conditions to affect 'sufficiency' for competing drinking, bathing, laundry, hygiene, and productive uses. Findings reveal water for hygiene uses is reduced during drought, and while water expenditure is the lowest of seven categories, it spikes for a minority. We evaluate the Diary Method by measurement, internal and external validity criteria and conclude that the longitudinal approach offers complementary insights to address the gaps in current monitoring methods.

Keywords: Affordability, Gendered Inequalities, Kenya, Monitoring, Sustainable Development Goals, Water Security, Water Use Behaviour

Introduction

Drinking water is part of everyone's life, every day. Recognition of this universal and material necessity has motivated the ratification of the human right to (drinking) water by the United Nations in 2010 and its legislation as a constitutional right in many countries, including Kenya (Laws of Kenya, 2010, UN, 2010). Global policy, as set in Sustainable Development Goal (SDG) (Target 6.1), aims to achieve "universal and equitable access to safe and affordable drinking water for all" by 2030 to address the 2.1 billion people without 'safely managed' drinking water in 2015, of whom 884 million lack a 'basic' service (WHO/UNICEF, 2017, UN, 2015b). Achieving this unprecedented target requires identifying and characterising the populations at risk, so that investments in infrastructure and institutions can be channelled to where they are required most. This, in turn, requires appropriate research methods that can effectively evaluate indicators of safely managed water services, monitor changes over time, and assess impacts of development interventions (Jepson et al., 2017). Current global and national monitoring of progress in drinking water services, which mainly relies on cross-sectional data from large-scale surveys, are poorly equipped to provide meaningful insights to the processes and practices of water uses to evaluate policy alternatives and responses (Vedachalam et al., 2017, Bartram et al., 2014). In rural Africa, where progress has been the slowest, this methodological challenge is compounded by the complex intersection of factors including climate variability and extremes, high poverty with variable income flows, gendered inequalities, weak governance and unreliable water supply infrastructure (World Bank, 2017, Banerjee and Morella, 2011).

The SDG framework moves beyond the binary improved/unimproved classification of 'infrastructure type' used for the Millennium Development Goals (MDGs) to include 'infrastructure performance' characterised by accessibility, availability and quality of drinking water services (WHO/UNICEF, 2017). This framework emerged from a global consultation led by the Joint Monitoring Programme (JMP, co-led by UNICEF and WHO) which reflects

balancing methodological pragmatism with political expediency in collating relevant policy data of sufficient accuracy within an acceptable cost. The JMP service ladder progresses from 'surface water' to 'safely managed' drinking water services that involve the use of an improved source located on the premises, available when needed and free from contamination (WHO/UNICEF, 2017). 'Affordability' is included as a distinct indicator, implying that payments for water services should not prevent individuals from acquiring other services and goods protected by human rights such as food, housing, health, clothing and education (UN, 2015a). The JMP emphasises on reducing wealth and gendered inequalities in provision of water services, paying particular attention to women who bear the burden of water collection in rural Africa, estimated to be about 40 billion hours per year (UN, 2012).

Monitoring progress in drinking water services is constrained by data gaps stemming from traditional methodological approaches. Nationally-representative surveys, such as the Demographic and Household Survey (DHS) or the Multiple Indicator Cluster Survey (MICS), and censuses remained the dominant source of data for the SDG baseline assessment, with support from administrative data from national water regulators (WHO/UNICEF, 2017). These surveys typically ask questions about the main sources of drinking water, the distance travelled/ time required for collection, the availability of water at the source, and the payments for water supply services (Vedachalam et al., 2017). While this information is helpful in profiling the water services situation at aggregate levels, often dichotomised into urban and rural areas, they fail to capture the complex dynamics of water use behaviour resulting from seasonal variation in demand/supplies, failures/downtime in infrastructure, unpredictable shifts in rainfall patterns, economic/political instability and intra-household shocks (Koehler et al., 2015, Thomson et al., 2012). Estimating payments for water as a percentage of monthly expenditures may adequately reflect 'affordability' in contexts where households have connections to piped water systems or rely on paid sources only. However, in areas with severe water stress or weak governance, people often resort to unimproved and unpaid sources to cope with unreliable or absent water supply services (Vedachalam et al., 2017).

There is an increased need to advance alternative methods to address the behavioural patterns in choosing different water sources for different needs from regular water collection and storage practices. Here we address this methodological gap by proposing a 'water diary' method – an intensive longitudinal research tool designed to gather fine-grained empirical evidence on households' water use behaviour in relation to the various hydro-climatic, socio-economic, infrastructure and institutional risks that influence their choices on a day-to-day basis. The water diary documents the sources, volumes and cost of water collected every day, along with self-reported changes in 'sufficiency' by consumptive (drinking and cooking), hygiene (laundry, dish washing, cleaning and bathing), and productive uses. It also collates weekly household expenditure data to explore variation in payment behaviours across food, farming, health, education, transport, energy, water and other domains.

In the following sections, we, first, review the issues guiding the design and implementation of the diary method in previous studies. Second, we discuss the methodological design and testing of the 'water diary', with proof-of-concept data for a sample of 11 female respondents in rural Kenya over a 28-day period. Third, we offer a critical evaluation of the measurement, internal and external validity of the method with a view to complement household surveys in monitoring progress in drinking water services in Kenya and beyond. While recognising such intensive qualitative methods are unlikely to be replicated at scale, there remain significant policy questions on the assumptions and validity in non-triangulated methods guiding potentially billions of dollars of investment to 2030, increasingly made in the name of those who carry the burden of unaffordable, unsafe or unreliable water service delivery, particularly women and children.

The Diary Method

The diary method is an instrument for individuals/households to record changes in daily processes or practices which may be subject to unpredictable shifts in behaviour or outcomes,

for example, the effects of seasonality on household incomes and expenditures (Bartlett and Milligan, 2015, Alaszewski, 2006). In such cases, simple 'snapshots' of behaviour at a particular time may not capture the temporal variations. Diaries have been used extensively in psychological and health research (e.g. Wiseman et al., 2005, Cates et al., 2004, Lawson et al., 2004, Fortenberry et al., 1997); however, there are limited examples of its application in studying water use behaviour (e.g. Bishop, 2015, Harriden, 2013, Wutich, 2006) with no documented application in rural Africa.

Compared to other research tools, diaries are less likely to suffer from problems of recall bias as they rely on short-term memory (Bolger et al., 2003). Wutich (2009) found that the diary method yielded the most accurate estimate of per capita water use over a week compared to prompted recall and free recall methods, which either underestimated overall water use or missed out relatively low-volume water use tasks like washing and cleaning. However, as diaries are produced by participants in their own time and setting in absence of the researcher, participants need to be trained thoroughly to ensure accuracy of data being recorded and minimise confusions in making entries (Wiseman et al., 2005). Regular communication between the researcher and the participant is required to keep the latter motivated and build trust between both parties. This can restrict the sample size due to resource constraints, creating a trade-off between breadth and depth of data collected.

The design and implementation of the diary method is often guided by issues relating to (1) the structure and content; (2) duration and frequency; (3) respondent attrition and fatigue; (4) compensation; and (5) use of complementary methods. Water diaries intended to capture household water use behaviour usually involve structured charts, outlining the sources, purposes and volumes of water used by individuals (e.g. Harriden, 2013, Wutich, 2006). However, if the research requires participants to record the social interactions embedded in their daily quest to access to water and reflect on these events from their own perspectives, the researcher may design an unstructured or semi-structured diary (e.g. Bishop, 2015). As

diaries usually require participants to read and write or have someone to make entries on their behalf, pictorial diaries often proved to be more appropriate in settings with high levels of illiteracy. Wutich (2006), for example, used illustrations of different water sources, water use tasks, and container types to estimate the source and volume of water used by each household member for consumptive, hygiene and domestic needs in an urban slum in Bolivia. While pictorial diaries can potentially overcome the literacy barrier, care must be taken to ensure that illustrations are sensitive to cultural perceptions (Wiseman et al., 2005).

The duration and frequency of the diary keeping exercise largely depends on the data requirements of the research. Shorter diaries, maintained over a few days to a week, require less time commitment from the participants and are unlikely to be affected by fatigue or drop outs. Harriden (2013)'s study of intra-household water use behaviour in Australia, for example, required participants to record all water use activities over a week, particularly noting who used water, for how long, in what quantity, at which time and for what purpose. Longer diaries, on the other hand, can suffer from respondent attrition and research fatigue, but may be necessary to capture temporal variations. A noteworthy example is Wiseman et al. (2005)'s study of financial transactions in rural Tanzania and the Gambia, where participants were asked to maintain a pictorial financial diary every day for a year. The authors noted a drop-out rate of around 20% and found that successful maintenance of longer diaries depended on the level of trust between the diarist and the field researchers, who visited the diarists regularly to keep them engaged. It is important not only to note the drop-out rate but also ensure that those who dropped out are not systematically different from the whole population. Longer diaries can also create a 'conditioning effect', whereby participants may become tired of keeping records on similar-seeming activities leading to abbreviated or less thorough entries (Wiseman et al., 2005). If they miss an entry, they may also go back and 'fill in' what they missed, thus, undermining one of the core purposes of using diaries (Bishop, 2015, Bolger et al., 2003).

Since diaries require long-term commitment from the participants, researchers often provide financial incentives to motivate participants or to compensate for their time and effort. This raises methodological and ethical concerns among the research community. As experienced by Meth (2003), offering payments for participation can specifically attract economically vulnerable people and may cause resentment among those not selected for the study. Others argue that the need for compensation depends on the complexity of task required (Bartlett and Milligan, 2015). The water use behaviour study by Wutich (2006), where each household was offered USD 2.50, involved day-long diary keeping by each household member, followed by extensive interviews that required participants to recall their water use activities during the preceding week.

Diaries are often combined with alternative research tools such as interviews, observations, questionnaire surveys and focus group discussions (FGD) (e.g. FSD Kenya, 2014, Wutich, 2009, Wiseman et al., 2005). These are necessary for collecting baseline data that can better inform the diary design, for engaging participants at different stages of the research process, for ensuring compliance and proper recording of events/activities, for keeping up participants' morale, and most importantly, for triangulating data from different modes of enquiry. An example is the 'financial diaries' methodology, which involved baseline questionnaire surveys on demographics, income sources, assets, and financial tools, followed by year-long bi-monthly financial diary visits during which interviewers captured detailed data on all cash flows over the preceding two weeks, as well as any events that may have influence household welfare during that period (Anderson and Ahmed, 2015, FSD Kenya, 2014, Collins et al., 2009).

Piloting a 'Water Diary' in Kitui County, Kenya

Our 'water diary' was designed to gather fine-grained empirical evidence on households' water use behaviour in relation to the choices they encounter on a day-to-day basis. It was piloted

with 11 female respondents living within a small area clustered around a handpump in Mwingi-North sub-county of Kitui County in Kenya. In this section, we first describe the state of water services in the study site and then discuss the key stages involved in designing and piloting the water diary, complemented by other interdisciplinary research tools.

Study context

Rural Kenya is characterised by increasing rainfall variability and extremes, high levels of poverty and disappointing progress on the delivery of drinking water services (Koehler et al., 2015). Between 2000 and 2015, the proportion of population using 'basic' drinking water services in rural Kenya increased by 14 percentage points to 50%, while dependence on 'surface water' decreased by 7 percentage points to 29% (JMP, 2017). Our study site is a semi-arid region at the base of the Horn of Africa, with temperatures ranging from 14°C to 34°C throughout the year. There are two rainy seasons - the long rains occurring from March to May, and the short rains falling between October and December. The rest of the year is dry and the annual rainfall ranges between 250mm – 1050mm with 40% reliability for the long rains and 66% for the short rains (The County Government of Kitui, 2013). During the study period, Kenya was in the midst of a severe drought due to the combination of below average rainfall in 2016 and the delay of the long rains in 2017 until April. This created extreme hardship for millions of people and led to the Government of Kenya declaring the drought a 'national disaster' in February 2017 (NDMA, 2017).

Water resources are limited in the dry periods particularly before the onset of the short rains which creates acute demand on limited and variable surface water sources and increasingly leads to drying of shallow wells. Water for drinking and domestic purposes is sourced from a variety of improved and unimproved sources, which differ in terms of their accessibility, quality, quantity, affordability, and reliability. The government water service provider for Mwingi-North sources water from the Kiambere Dam on the Tana River and distributes it through a limited

piped network and water kiosks that allow unconnected households to buy water at a subsidised rate of USD 1 per m^3 (KSh 2 per 20 litres) (KIMWASCO, 2014). However, the supply is unreliable and the coverage is largely insufficient. As a result, a number of small piped water schemes have been developed, supplying water from deep boreholes and natural rock catchments that store rain water, and delivering it to people through water kiosks at tariffs ranging from USD 1 - 2.5 per m^3 (KSh 2 – 5 per 20 litres) (Goodall et al., 2016, Hope et al., 2015). In addition, there is a number of community or private handpumps, usually Afridev pumps installed on hand-dug wells, which have been constructed by communities independently or with assistance from the government or NGOs. A programme of research since 2012 in the study area by the authors provides detailed data of water usage behaviours on which this paper builds (Hope et al., 2015, Koehler et al., 2015, Hope et al., 2014, Thomson et al., 2012).

While kiosks and handpumps are usually the main water sources, they remain non-functional from time to time, due to seasonal declines in shallow groundwater or infrastructure breakdown. To cope with these breakdowns, people often obtain water from alternative unimproved sources, such as open hand-dug shallow wells, earth pans, scoop holes in dry riverbeds, and open reservoirs of the rock catchment (Hope et al., 2015). Water vending is also quite popular among those who can afford to pay, especially during the dry periods. The costs of vended water usually range between USD 2.5 – 10 per m^3 (KSh 5 – 20 per 20 litres); however, during our field visit we observed prices as high as USD 15 – 25 per m^3 (KSh 30 – 50 per 20 litres) as schools and other institutions struggled to access water due to the severe drought crisis. These vendors obtain water from a wide variety of sources, including public standpipes, water kiosks, and privately or community owned wells, and deliver it to consumers using donkey-pulled carts, motorcycles or pick-up trucks.

Designing the water diaries

We iteratively co-designed the 'water diary' to better understand households' choices to obtain water from the sources described above, which can be shaped by a range of concurrent factors, including rainfall variability, operational disruption of infrastructure, costs of water, household income and expenditures, and time spent in collecting water. The diary comprised of two sections, one for water supplies and the other for financial expenditure. The first section contained two sheets for each day, whereby respondents recorded the sources of water collection (if any), the amount of water collected (in number of 20-litre jerrycans), the total cost of water and payments due (if any), and whether the amount was sufficient for drinking and domestic purposes. The second section comprised of one sheet for each week, where respondents documented their expenditures on major categories such as food, farming and livestock, healthcare, education, transport, energy and water. Although there was one sheet per week, respondents were required to record their expenditures every day adding up to the weekly total.

Preliminary design and pre-testing

The initial design of the diary was based on an extensive review of the literature on the diary method and the state of the water supply situation in rural Kenya, as well as the context specific knowledge and expertise of researchers working in the region. Our aim was to make the diary as simple as possible so that it was easily comprehensible by the respondents, many of whom were known to be illiterate but some had successfully completed pictorial games previously, such as a choice experiment (Hope, 2015). The water sources were arranged in order of their likelihood of usage, thus, sources like rivers or streams and piped water supply were placed to the end of the list. To capture the variation in distance and ownership within the same type of water source, we further disaggregated the hand-dug wells, handpumps and kiosks to sources owned by the household itself, by another household within the village, by the community in which the household resides, and by the community or a private owner

outside the village. Similarly, vended water was divided into those supplied by donkeys/carts and those delivered by motor vehicles as this affected the cost. Instead of asking respondents to quantify the amount of water used for different domestic purposes, we simply required them to specify whether it was sufficient or not based on their subjective judgment. For the second section, we outlined eight broad expenditure categories with description of the types of items within each category. The English diaries were then translated into the local language 'KiKamba' for pre-testing.

The preliminary diary design was pre-tested in late March 2017 with adult women from an all-female water user committee that had been part of designing and testing a local maintenance service provider since 2013 (Hope et al., 2014). We invited about 15 women to attend a 2-hour FGD. Women were intentionally recruited as they are usually responsible for fetching water for the household and hence, have the best knowledge on this matter. The purpose of the FGD was to explain the diary method to the participants, and identify whether the methodological design was appropriate for the local context and easily comprehensible by the participants. Moreover, it was important to assess the ability of the participants to complete the diaries, and whether visual symbols would be helpful in this context, especially to deal with issues of literacy. We also wanted to identify whether the participants would be willing to maintain these diaries every day for a month, and what compensation would be most appropriate for the task. Our intention was to conduct one FGD and ask the participants to maintain their diaries for the next two days, after which we could collect the diaries and discuss the challenges faced by the participants in recording the data. However, only four women attended the FGD. Consequently, we had to organise a second FGD which was attended by 11 women, including those that attended the first one. This process, in fact, proved to be beneficial, as the experiences gained during the first FGD enabled us to improve the methodological design and address specific challenges faced by the participants in comprehending the diary charts.

The FGDs were facilitated by two female researchers fluent in KiKamba, one a local woman studying for a technical degree in water management and the other a PhD student enrolled at the University of Nairobi. During the first FGD, the facilitators explained the water diaries to the four participants, going through each of the rows and columns in detail, after which the participants were asked to complete the water diaries for that particular day. This is because the FGD was held early in the morning and the participants did not have time to collect water for that day. Among the four participants, two could not read and write, which made it difficult for them to fill their diaries although they completed the process quite well. In this case, the literate women assisted their neighbours to complete the diaries. The participants felt that the diary methodology was comprehensible and agreed that it would help them provide accurate information daily, which could be distorted if they were asked to give the same information months later. They expressed water scarcity as the major challenge for residents in their area and were willing to participate in the diary process, so that this information could improve water supply management in the future.

The sections on water sources and payment for water were easy to comprehend; however, the sufficiency section seemed confusing. This is because the sources and payments were captured in a single table to be filled every day, while the sufficiency data was structured in a way that the data for the whole week was to be filled in one sheet with different columns for water uses and rows for the different days of the week. We noted these concerns and improved the water diary structure for the second FGD. The respondents agreed that the categories on the financial diary were well organised. They were advised that although the dairy was intended to capture the weekly expenditures, they should record their expenditures on each day to avoid issues with recall. Participants had difficulty in calculating the total, which we explained was not required.

The structure of the water diary (Figures 1A and 1B) was modified for the second FGD, based on the discussion and challenges identified during the first one. First, the combined category

on surface water was split up, with separate rows for rivers and streams, dry riverbed scooping, and earth dams. As rock catchment seemed to be an important water source, it was mentioned as a distinct sub-category under rainwater harvesting. Secondly, the part on sufficiency was split up, so that it appeared at the end of each day's water diary instead of a combined weekly one. Thirdly, and most importantly, drawings and photos were used to depict each of the water sources and domestic uses. While we intended to use symbols or drawings for most of the sources, we had to use photos for those that were not available online. The financial diary was largely similar to the previous one, except for the addition of a calendar at the top.

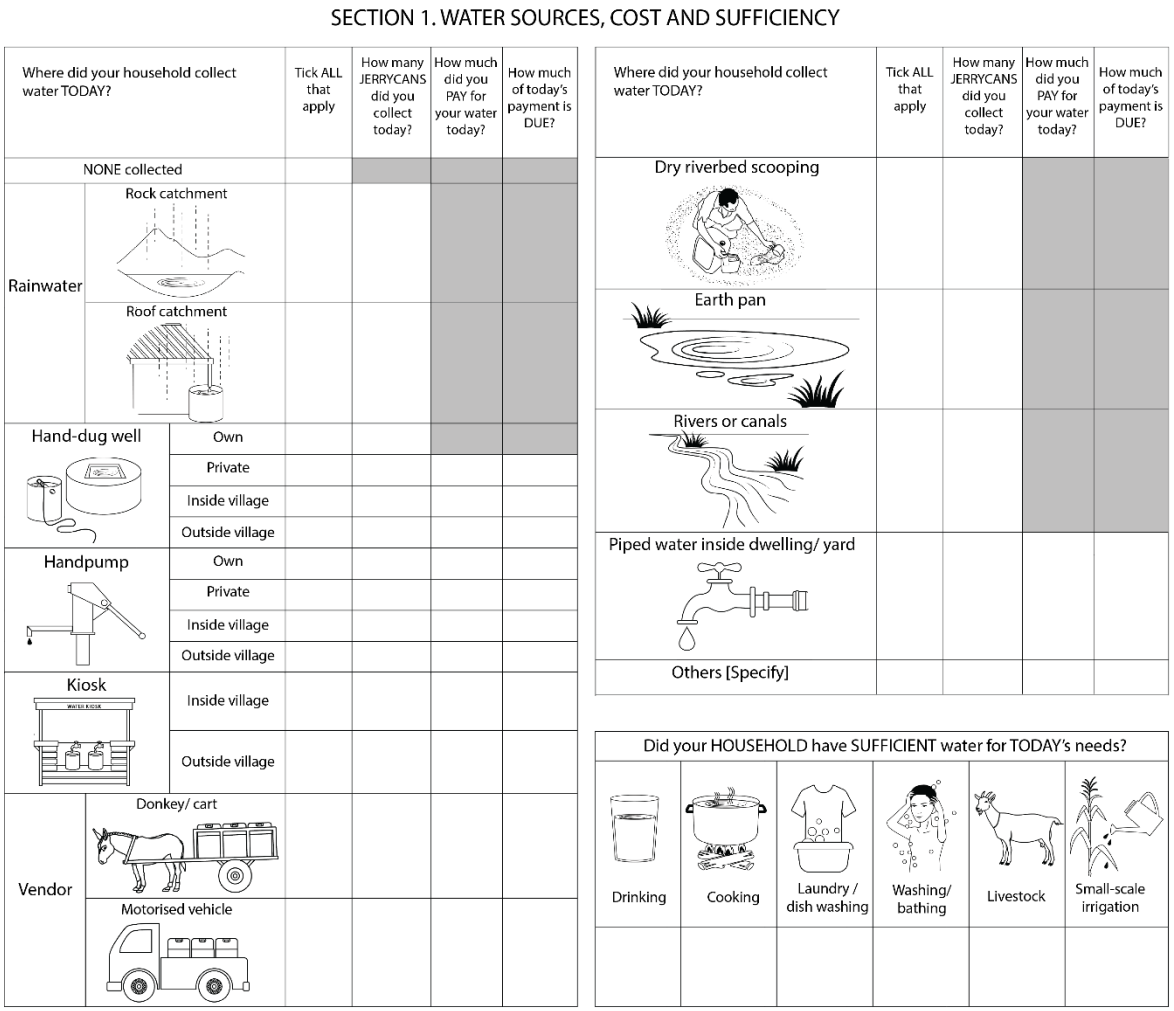

Figure 1A. Structure of the Water Diary[1]

[1] The images shown in Figures 1A and 1B were redrawn after the study to avoid copywrite issues during publication. However, they closely resemble the ones used during the fieldwork.

SECTION 2. WEEKLY FINANCIAL EXPENDITURES

Expenditure Items	Week 1 (Saturday, 1 April – Friday, 7 April)
Food (food bought for eating)	
Farming (crop & livestock) (fertiliser, tools, traction, seeds, hired labour, purchase animals, etc.)	
Transport (matatus, piki pikis, petrol, maintenance)	
Health (medicine, doctor fees, soap, etc.)	
Education (school fees, uniforms, books, pens, etc.)	
Energy (electricity, charcoal, kerosene, solar, etc.)	
Water for domestic and productive uses (cost of water, maintenance of infrastructure)	
Others (building, funerals, weddings, clothes, remittances, air-time, etc.)	
Total	

Figure 1B. Structure of the Water Diary

The participants reported that inclusion of the pictures of the water sources and uses was very helpful, especially for those who were illiterate. However, those who could not read or write were unable to make written entries; they were eventually helped by other literate members within their household or within the FGD participants. The pictures also enabled all participants to clearly distinguish between the sources and uses, and avoid confusions that arose during the previous FGD. Participants were provided with refreshments at the end of both FGDs as a token of appreciation for their time and effort. They expressed that they were not looking forward to any monetary compensation for the pilot phase, as they had benefitted from interventions made by previous projects and had faith in our research activities.

Piloting the revised water diaries

The pilot study was carried out over a four-week period during April 2017 with the 11 women who participated in the second FGD (refer to Table 1 in Appendix). While the average household size was 7, the number of resident members was about 5, as some individuals lived elsewhere for employment or education. Income sources usually comprised of selling crops and/or livestock, casual labour, and remittance from children. The average monthly household expenditure was about USD 80 (KSh 8000), the greatest share of which was spent on food (53.1%), healthcare (9.1%) and education (8.6%) (refer to Table 2 in Appendix).

Printed copies of the water diaries were distributed among the respondents and the completed diaries were collected and evaluated at the end of each week through visits by the research assistant. The research assistant also called each of the respondents mid-week to ensure regularity in maintaining the diaries and to clarify any questions. Data evaluation involved identification of errors and gaps, and clarifications on the entries made. This exercise was essential in ensuring accuracy and validity of the data. For instance, one of the respondents (see HH7 in Table 2 of Appendix) recorded unusually high amount to expenditures in the 'other' category and the amount of water collected more than doubled in the second week. This was because of her son's wedding and the visitors who stayed during that week. Two other respondents were also collecting large quantities of water for making bricks for their house repair. While the purpose of the 'water' category in section 2 was to cross-check the entries on the 'cost of water' in section 1, the two values did not match in most cases as respondents were either purchasing on water on credit or were paying previously due payments. Similar late water payment behaviour has been documented over decades in coastal Kenya (Foster and Hope, 2016).

Water Diaries within a mixed-methods approach

As part of the pilot, we administered a short household survey to generate basic socio-demographic data, installed an automated weather station (AWS) to collect location specific

rainfall data, and carried out a water point mapping exercise to identify the locations of the water sources mentioned in the diaries. The survey was designed to collect data on the number, gender and age of the person(s) responsible for fetching water and making decisions on this issue, the number of livestock and whether they drink the water collected for the household, and the respondent's perception and preference for each of the water sources included in the diary. A three-point Likert scale was used to rate each source in terms of distance, time or effort needed for water collection, quality and cost, followed by an overall ranking of the sources in order of preference. The survey was conducted on an android tablet using ONA data collection software (www.ona.io).

Data analysis

Quantitative data from Section 1 of the diaries was entered into IBM SPSS 23, with each household and each day being regarded as a case within the dataset, thus, generating 308 data points (11 households *28 days) or water collection events. There were additional 41 data points as some households collected water from two sources on certain days. The dataset had ten variables, namely, water source, number of jerrycans, payments made, payments due and sufficiency for each of the six tasks. Similarly, the data from section 2 was entered into a separate file containing 44 data points (11 households * 4 weeks) and nine variables on the expenditure categories. The data were analysed to identify of the changes or differences in key variables 'within' each household over time and 'between' households on the same day. Findings from the diary data, along with those from the household surveys and AWS, were then used to infer causal relationships qualitatively. While the small sample size of the pilot study limited our ability to conduct statistical tests and model cross-sectional and temporal variations in water use behaviour, it demonstrates the potential of the water diary method in generating rich context specific evidence required to fill the existing data gaps.

Results

Daily data on households' water use behaviour in relation to their overall financial expenditures and rainfall events provided insights into the ways in which households trade-off between different choices and the implications of their decisions for various aspects of water security. In this section, we present the results from the pilot water diaries, complemented by the household survey and rainfall data. Geo-spatial data on the locations of the 11 households and the different water sources used during the study period are illustrated in Figure 2.

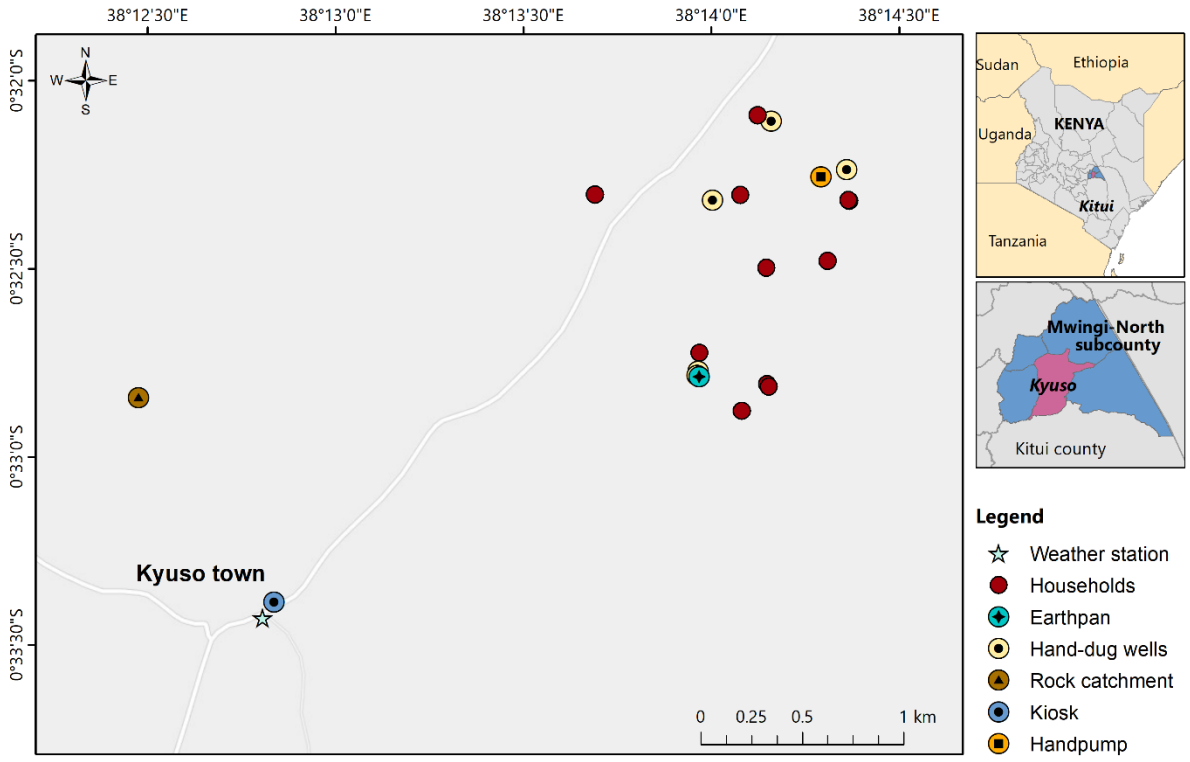

Figure 2. Locations of the study households and their water sources in Kyuso ward, Mwingi-North sub-county, Kitui county

During the four-week period, the participating households used an average of five sources with some households using two sources on five or more days. Three of the most commonly used sources were the rock catchment, the earth pan and the roof catchment, followed by hand-dug wells and kiosks. The choices of water sources closely mirrored rainfall patterns. Delayed onset of the long rains and consequent lowering of the water tables led to severe

scarcity of water during the first week of the study. During the first week, households were mainly dependent on the rock catchment (Figure 3), which provided a valuable water supply when most other sources became unavailable. A few households purchased water from kiosks and vendors on particular days. Between the 5th and 7th of April, the region experienced the first rains of the season followed by two more wet days on the 14th and 18th of April. Almost all households harvested rainwater from their roof catchments on these days, leading to a pivot in preferred water sources around the beginning of the second week. The rains also recharged the hand-dug wells and the run-off was collected in earth pans. Hence, it is inferred that when households ran out of their stored rainwater, they shifted to wells and earth pans in the third and fourth weeks.

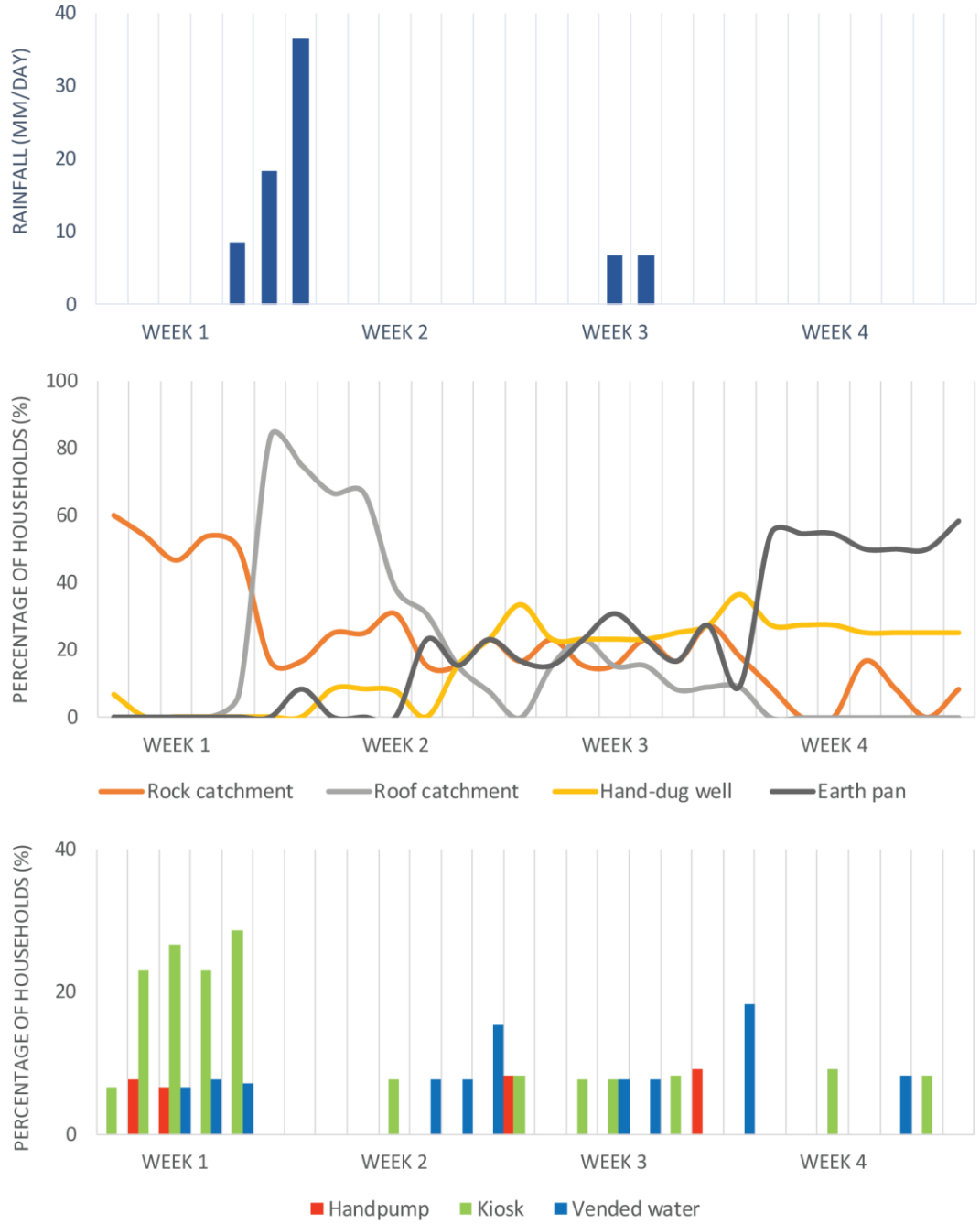

Figure 3. Rainfall events and the sources of water used by households during April 2017

The amount of water collected showed wide variation between households as well as for the same household on different days. On average, households collected 160 litres (eight 20-litre jerrycans) a day, with some fetching as much as 400 – 600 litres to provide drinking water for livestock and visitors or to make bricks for repairing their houses. Water collection and decision-making on this task were mainly carried out by adult women of the household, with

participation from male members in some cases. Of the 59 individuals (above age 10) from the 11 households, 38% of males (10 of 26) and 70% of females (23 of 33) were responsible for collection water, while 31% of males and 40% of females were involved in the decision-making. Around one in five (21%) of the female water collectors were children aged 15 or below; however, among the males, only one child aged 16 was responsible for fetching water. While these differences were not statistically significant owing to the small sample size, they suggest that women and girls disproportionately bear the burden of fetching water rehearsing well-known statistics (WHO/UNICEF, 2017). The amount of water collected was generally sufficient for drinking and cooking across all households over the study period; however, it was mostly inadequate for livestock and small-scale irrigation, except for the wet days mentioned above (refer to Table 1 in Appendix). It is also noteworthy that about half of the households reported not having sufficient water for personal hygiene on a number of days.

On average, households spent about 2.1% of their monthly expenditures on water. It should be noted that only four of the 11 households used paid water sources, that is, handpumps, kiosks, and vended water, on one or more days. The cost of water ranged from USD 1 – 10 per m^3 (KSh 2 – 20 per 20 litre jerrycan). Although none of the four households paid the full amount on the day of purchase, they would have spent about 3 – 11% of their monthly expenditures on water if they had cleared their dues within the four-week period. Interestingly, the consumption of water from paid sources did not lead to higher sufficiency of water for various domestic uses. In fact, these four households used the highest number of sources, including the paid ones, but reported comparatively higher levels of insufficiency for laundry, dish washing, cleaning and bathing. Given the small scale of this study, it is difficult to explain the underlying drivers of such observations. One respondent mentioned, “Yesterday I had money, so I asked someone to fetch water for me. Today I don’t have money, so I had to go to the source myself”.

Households' preferences for water sources were influenced by a combination of factors, including distance and time required, the quality of water and its cost. The household survey data revealed handpumps, rainwater harvesting, and kiosks as the most preferred sources, followed by hand-dug wells and dry riverbed scooping, with rock catchment, earth pans and vended water as the least preferred ones. Handpumps and kiosks provided good quality water at low cost with comparatively lower investment of time and effort; however, unavailability of water during extreme dry periods compelled people to seek alternative handpumps and kiosks that were often located outside the village. While fetching water from earth pans, rock catchments, and dry riverbeds was associated with a higher burden, the respondents appeared to prefer the latter over the former two partly due to the perception of improved water quality.

Discussion

Findings from the design and piloting of the 'water diary' in rural Kenya demonstrate the potential of the method in complementing national and global monitoring of drinking water services by providing novel insights into the decisions and outcomes for marginal and vulnerable households in particular times of need. The water diaries generated a wealth of quantitative evidence on the trends in households' water use behaviour, in terms of the sources, quantity and costs of water and its sufficiency for drinking and domestic needs, as well as patterns of households' financial expenditures on different items. Triangulation of data from the diaries, the household survey, the weather station and the waterpoint mapping exercise revealed the drivers and outcomes of changes within and between households across time. In this section, we critically evaluate this methodological approach, in relation to the design, implementation and interpretation of results, and highlight issues that need to be considered when replicating the method in different contexts. We frame the discussion in terms of 'measurement validity', that is, whether the methodological design adequately measures the parameters required to monitor progress towards safely managed drinking

water services; ‘internal validity’, that is, whether the observations and inferences derived from the method are accurate representation of the reality and not due to issues related to research design; and ‘external validity’, that is, whether the method can be applied to other populations and settings.

Measurement validity

The water diary, complemented by the other interdisciplinary methods, was designed to provide a nuanced understanding of households’ water use behaviour, with a view to address the existing data gaps in monitoring progress in drinking/domestic water services. Data on water sources and their geospatial location reflected the trade-offs between ‘accessibility’ and ‘reliability’ and how these were linked to rainfall and infrastructure type. For example, the rock catchment, which was least preferred due to its distance (about 3km away), seemed to be the most reliable source during extreme dry period, while handpumps and kiosks, which were among the most preferred, were largely unavailable.

The indicator on ‘sufficiency’ reflected respondents’ perception of ‘what is adequate’, instead of comparing quantities to standard requirements. While we collected data on the amount of water collected each day, estimations of per capita water use were not possible as the same source was also used for livestock and garden irrigation, the demands for which varied considerably. Unlike previous studies that included rigorous measurements of the water quantity used by each individual for particular tasks (e.g. Harriden, 2013, Wutich, 2009), such measurements were neither part of our research objectives nor desirable as they would have placed unnecessary burden on the respondents.

The columns on ‘cost of water’ and ‘payments due’ and the section on ‘weekly household expenditures’ were purposively designed to explore ‘affordability’, not just as a percentage of total consumption expenses, but also in terms of the variable consumption from paid improved

sources like handpumps and kiosks. Under-consumption from paid sources can be driven by both choice and/or inability to pay for water services, while sufficient consumption may be achieved at the cost of forgoing other basic goods (Thomas, 2016). However, the short time frame and small sample size of the pilot study restricted such analysis. Unlike previous examples of financial diaries that required participants to record the purpose and amount of every monetary expenditure (e.g. FSD Kenya, 2014, Wiseman et al., 2005), we simply provided broad categories of household expenses along with short description of the items included in each category. Pictures were not included in this section as the participants felt that the categories were relatively straightforward.

Overall, this methodological approach has a reasonable level of measurement validity as it provides a detailed understanding of the factors influencing water use behaviour and their implications for achieving water security. Here, we could only associate changes in water sources with rainfall events. Increasing the spatial coverage, sample size and study duration, and incorporating water quality assessment would help understand whether particular groups are more vulnerable than others and identify the barriers to attaining the SDGs.

Internal validity

Internal validity of the water diary is influenced by a number of issues, including the degree of bias in selecting participants suitable for the research objectives, the level of training and monitoring to ensure that all participants can comprehend and complete the diary exercise regardless of their literacy status, the duration and frequency of diary keeping necessary to capture variation in water use behaviour, and participant drop-outs and research fatigue related to recording seemingly mundane tasks over the long-term.

Selection of households for the water diary requires a sampling frame of suitable households across a range of policy relevant issues. Baseline information from household surveys can

identify ‘at risk’ households to monitor their behaviours and choices to understand how to better design policy responses. Typologies of ‘at risk’ groups may be structured by the SDG framework of water quality, sufficiency, affordability, reliability and accessibility. Equally the behaviour of households with notionally low to no risk should also be monitored to understand variation in water use choices and whether social or cultural factors undermine provision due to intra-household dynamics, gendered inequalities, rainfall extremes or economic shocks. Households in our pilot study were located within an area of 1km^2, which ensured that they faced similar levels of hydro-climatic and infrastructural risks; thus, variations in observed behaviour between households could be attributed to their individual circumstances, including differences in wealth status. Understanding inequalities between the rich and the poor is crucial for tracking progress towards the SDGs. Hence, replicating the method at a larger scale would entail a random selection of households stratified into different wealth quintiles, the information for which can be obtained from baseline surveys on welfare indicators and households’ geocodes.

The water diary requires participants to self-report their water use behaviour. Thus, it is imperative for all participants to understand the nature of the data sought and record it accurately in the relevant sections. This requires extensive training and close supervision, especially in the initial few days, which in turn limits the sample size due to resource constraints. In our study, the 11 women were part of a close-knit community, with a couple of them taking leadership roles and supporting others in filling the diaries based on their verbal data. Thus, it was sufficient to train one respondent from each household regardless of their literacy and train all respondents together during the FGD. In future studies involving more households spread across the sub-county, we plan to train respondents individually at their own residence, so that other literate members within the household can help with the written entries based on information from the respondent.

573 The unpredictable nature of the water supply situation in rural Africa, as exhibited by our
574 findings, necessitated the use of 'daily' diaries to capture the high degree of variability in water
575 use, which was closely associated with rainfall events, amount of cash in-hand, infrastructure
576 breakdown and other idiosyncratic factors. While there is no ideal recall period, the best
577 interval depends on the actual frequency of water insecurity events in a given context (Jepson
578 et al., 2017). Longer recall periods may be suitable in contexts with near constant water use
579 behaviour, for instance, using the same source every day for few months of the year; however,
580 in cases like rural Kenya that exhibit high variability, such retrospective reports may represent
581 the usual habitual behaviour.
582
583 To the best of our knowledge, our four-week pilot study is the longest duration for which water
584 behaviour has been recorded continuously. Such intensive research methods, however, are
585 likely to suffer from respondent attrition and research fatigue. These require further testing
586 given this study worked with a known and supportive community. Mindful of the costs of and
587 general resistance to longitudinal research a frugal design with strong local partnership is
588 suggested. Nevertheless, the structural design balance parsimony and respondent fatigue
589 with eliciting relevant information for policy and monitoring. Compensation is increasingly
590 provided in these types of research, which not only raises ethical and resource concerns, but
591 can potentially affect the phenomenon being studied (Head, 2009). In this case, providing
592 cash, basic food items like flour or mobile credit may interfere with the dynamics of water use
593 behaviour by allowing participants to directly pay for water or indirectly afford paid sources at
594 certain times by saving on other expenses. For the pilot study, we only provided refreshments
595 at the end of both FGDs.
596

597 **External validity**

598 While the diary method discussed here reasonably satisfy the conditions of 'measurement
599 validity' and 'internal validity', application of the method to other populations and contexts

without revision is questioned. The structure, content, duration and frequency of the water diary are well suited to the context of rural Africa, where a wide variety of sources are used to cope with unpredictable but frequent droughts, infrastructure breakdown and socio-economic shocks. However, the design would need significant changes for application in parts of rural Asia, where different hydro-climatic settings result in a different set of challenges. In such cases, the same process of local consultation and testing is suggested.

In relation to building linkages to nationally-representative surveys (DHS, MICS, census) there is the opportunity to use the established enumeration areas as a meta sampling framework and, if ethical permissions allow, to conduct diaries within a sub-sample of the same households. This is a non-trivial methodological and ethical challenge but one that can be actively explored in future research. Alternatively, a pseudo-design could 'mimic' the enumeration area sampling methodology to provide a necessary baseline to evaluate the level of variability in water use behaviours from longitudinal diary data compared to the snap-shot, standard questions which inform global monitoring and shape policy and practice.

Conclusion

The SDG of safely managed drinking water on premises, on demand and without contamination seems a distant prospect in rural Africa based on historical progress of rural piped water coverage increasing from 4% to 5% between 2000 and 2015 (WHO/UNICEF, 2017). Basic water services appear a more realistic prospect but will require an unprecedented shift in identifying new models and evidence for delivery of services people demand. Water Diaries offer a rich and largely unexplored landscape of continuous data to understand water use behaviours to inform and complement established monitoring efforts. The early but promising results from this pilot underline the significant variation in water use behaviours influenced by rainfall, infrastructure, affordability, water quality and convenience. Trade-offs and risks internalised within household water use behaviours start to emerge as limited

627 ‘sufficiency’ leads to differing intra-household choices. This is partly revealed by water for
628 ‘hygiene’ being sacrificed in our study period. Given the near tripling of investments to USD114
629 billion per year to meet the new water SDG (Hutton and Varughese, 2016), the critical
630 importance of targeting national and sub-national policy and investments to leave no one
631 behind is paramount. Again, we find women and girls disproportionately bear the costs of
632 inadequate, unaffordable or unreliable water supply infrastructure. Reducing these gendered
633 inequalities requires stronger evidence to shape better policy. The Water Diary offers a new
634 approach to understand and respond to these gendered inequalities hidden in incomplete or
635 unsatisfactory current methods.
636
637
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Appendix

Table 1. Water collection and sufficiency of the study households

Household ID	No. of Household members	No. of resident members	Water use, collection and decision-making						Sufficiency (% of days)					
			No. of sources used in 4 weeks	No. of days using two sources	Average price (USD per m^3)	Average volume collected (litres	No. of people usually collecting	No. of people involved in	Drinking	Cooking	Laundry and dish washing	Cleaning and bathing	Livestock	Small-scale irrigation
1	6	5	3	0	0	260	1	2	100	100	100	100	75	4
2	9	6	5	1	0	140	5	2	100	96	100	100	50	18
3	4	4	8	1	0.9	120	1	2	100	93	68	54	32	29
4	8	3	6	1	0.6	120	1	1	100	100	89	64	39	29
5	4	4	7	0	2.6	120	2	2	96	100	89	68	29	11
6	13	6	7	5	0.8	160	6	3	100	100	96	100	68	14
7	14	11	4	7	0	260	6	3	100	100	100	100	75	50
8	9	5	4	8	0	220	4	1	100	100	100	96	96	82
9	5	5	4	9	0	160	2	2	100	100	71	96	82	0
10	7	7	4	5	0	180	4	2	100	100	89	100	68	0
11	3	3	5	1	0	120	1	1	100	96	96	100	57	7
Mean	7	5	5	3	0.5	160	3	2	100	99	91	89	61	22

Table 2. Socio-demographic profile and financial expenditures of the study households

Household ID	No. of income earners	Household income sources	Household monthly expenditure									Livestock			
			Total monthly expenditure (USD)	Food (%)	Farming (%)	Transport	Health (%)	Education (%)	Energy (%)	Water (%)	Others (%)	Cattle	Goats/ sheep	Donkey	Do the animals drink water at home?
1	4	Casual labour; remittance from children	77	60.0	0.0	9.8	6.3	16.9	0.0	0.0	7.0	3	15	0	Sometimes
2	6	Selling crops; remittance from children	88	66.5	0.6	8.0	15.5	0.0	4.1	0.0	5.4	3	2	0	Never
3	2	Casual labour	67	58.6	11.2	3.0	13.0	0.0	1.5	6.0	6.7	0	2	0	Sometimes
4	4	Casual labour; selling firewood/ stones	66	54.5	16.6	4.5	10.0	0.0	5.3	3.3	5.7	1	16	2	Always
5	1	Casual labour	81	42.1	19.4	6.1	9.1	6.1	2.6	11.3	3.2	0	2	3	Sometimes
6	7	Selling livestock; small business; remittance from children	72	44.0	0.0	8.4	6.7	0.7	6.6	2.9	30.8	1	3	2	Always
7	6	Selling livestock; cash transfers	907	11.1	3.3	3.9	1.2	10.9	0.7	0.1	68.9	6	25	3	Sometimes
8	4	Selling crops; livestock	183	43.9	1.6	7.1	4.9	21.9	1.1	0.0	19.4	5	8	3	Sometimes
9	2	Casual labour; small business	79	60.6	3.8	4.0	13.9	4.3	1.6	0.0	11.7	0	5	2	Always
10	2	Selling crops and livestock; casual labour	79	48.5	6.3	8.8	4.5	12.6	0.0	0.0	19.2	0	8	2	Always
11	1	Selling crops; casual labour	45	71.7	0.0	5.6	14.2	0.0	8.5	0.0	0.0	0	0	0	N/A
Median			79	49.7	3.8	7.6	9.4	4.4	2.7	0.0	6.8	1	5	2	
Mean (excl. HH7)			84	53.1	5.5	6.7	9.1	8.6	2.6	2.1	12.3	2	8	2	