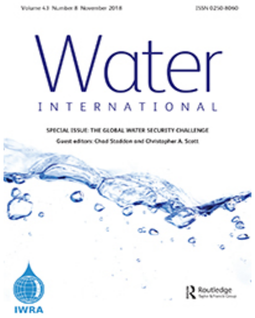

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Why doesn't every family practice rainwater harvesting? Factors that affect the decision to adopt rainwater harvesting as a household water security strategy in central Uganda

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ABSTRACT

This article investigates the reasons householders do, and don't, adopt domestic rainwater harvesting (DRWH). Using a mixed-methods research approach, we collected data in three districts in central Uganda. Factors that emerged as important with respect to uptake of DWRH to address water shortage, especially at the household scale, include the work of intermediary organizations, finance mechanisms, life course dynamics and land tenure.

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Introduction

Notwithstanding two 'Water and Sanitation Decades' and innumerable global conferences, declarations and programmes, more than 800 million people in developing nations still lack even the most basic levels of personal or household-scale water security (AMCOW, 2008; Siwar & Ahmed, 2014; WHO, 2017; WHO/UNICEF, 2015). Although water is essential for maintaining life and for all social and economic endeavours, several authoritative global reports (e.g., World Water Assessment Programme, 2018; UN-Water, 2015) have suggested that urbanization, population growth, industrialization and increasing per capita consumption of all goods including water mean that by 2030 there could be a 40% global water deficit. In some developing regions – especially sub-Saharan Africa and Latin America – water security will actually deteriorate rather than improve, despite decades of investment in water and sanitation infrastructure (WWAP, 2018). Improving water security at any scale (household, urban, national, etc.) presents a massive challenge in a rapidly growing and globalizing world where local needs might not just outstrip local water resources, but where those resources can also 'travel' in the form of physical or embodied exports to other regions (e.g., virtual water export via the global food and horticultural trades, see Allan, 2011; Staddon, 2010). With amplified pressures on water governance through increasing transboundary tensions (explored further by Albrecht et al. in this collection), the deregulatory and laissez-faire impulses of the neoliberal Washington Consensus, climate change uncertainties and anthropogenic pressures, the already severe threat to

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water security in the Global South is continuing to grow (Bakker, 2012; Lovelle, 2016; Owen & Goldin, 2015).

This article focuses on challenges to improving water security in one developing nation, Uganda. Uganda's economic and infrastructure development has been dramatically affected by frequent periods of violent conflict and political repression since independence in 1962. In this context, it is perhaps not surprising that the first National Water Policy was not passed until 1999 (Nsubuga, Namutebi, & Nsubuga-Ssenfuma, 2014; Terry, McLaughlin, & Kazooba, 2015). Since then the country has made huge progress in restructuring and developing water supply and sanitation throughout the country, with access to at least 'improved water sources' at 95% for urban areas and 71% for rural areas by 2015 (WHO/UNICEF, 2015). Unfortunately, as noted above, 'improved water sources' does not necessarily mean that water is either proximate to, or sufficiently clean and plentiful for, all households all of the time, particularly in the poorest and most remote districts.[1] Moreover, there remain significant urban/rural, regional and other disparities. While estimates suggest that 71% of the urban population have some sort of access to potable water managed by the National Water and Sewerage Corporation, this is only about 14% of the total population. The other 86% of the Ugandan population depends on 'other improved' or 'unimproved' sources, which may include local surface water sources, hand-dug shallow wells or groundwater collection schemes (Figure 1; Nayebare, Wilson, Carpenter, Dziewulski, & Kannan, 2014; WHO/UNICEF, 2015).

While many analysts urge policy and practical action at national and international scales, there is much that can be done to improve water security at household and personal scales. Moreover, as Wade argues in this collection, water security needs to be understood as a *scale concept* so that potentially deleterious scale interactions can be mapped and, ideally, avoided. One strategy that has proven useful in addressing household-scale water insecurity is the installation of local storage systems that take in water from specially prepared collection/catchment areas (usually roofs, but sometimes also areas of ground – see Figure 2), and save it in vessels for later use (Abdulla & Al

Figure 1. 'Unimproved' (left) and 'improved' (right) water sources. Photos by the authors.

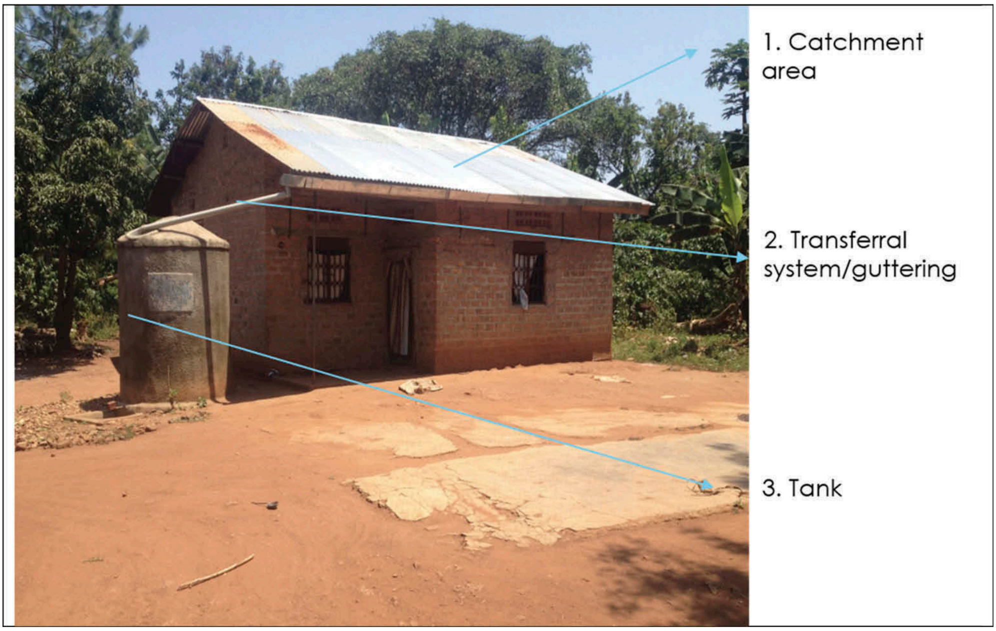

Figure 2. Schematic indicating basic configuration of domestic rainwater harvesting systems in Uganda. Source: the authors.

Shareef, 2009; Ahmed, Mustafa, & Khalid, 2011; Mati, 2007). Such domestic rainwater harvesting (DRWH) systems are relatively easy to build with local skills and resources and can be commissioned in households at risk of water insecurity relatively quickly, though they do bring with them challenges of appropriate sizing to meet demand under future climate uncertainty, asset maintenance and water quality management. As of June 2017, throughout Uganda there were approximately 21,000 rainwater harvesting tanks serving 126,000 people, around 1% of the rural population (Funk et al., 2005; Ministry of Water and Environment [MWE], 2017; UNFCC, 2007). Significant upscaling of appropriately sized DRWH systems will be required to meet future demands and safeguard communities facing the threat of water that is scarce and of inadequate quality. Building on ongoing research in Uganda (Terry et al., 2015), in this article we report on recent research into the reasons householders do, and don't, adopt DRWH. Using a mixed-methods research approach we collected data in three districts in central Uganda: Luweero, Wakiso and Mukono (Figure 3). The three study areas were chosen for relative ease of access to the capital and their contrasting experience with DRWH schemes. Factors that emerged as important with respect to uptake of DWRH to address water shortage, especially at the household scale, include the work of intermediary organizations, finance mechanisms, life course dynamics and land tenure. Better understanding of the factors influencing adoption of DRWH should assist in formulation of better policy by governments and development NGOs in Uganda and elsewhere in the developing world.

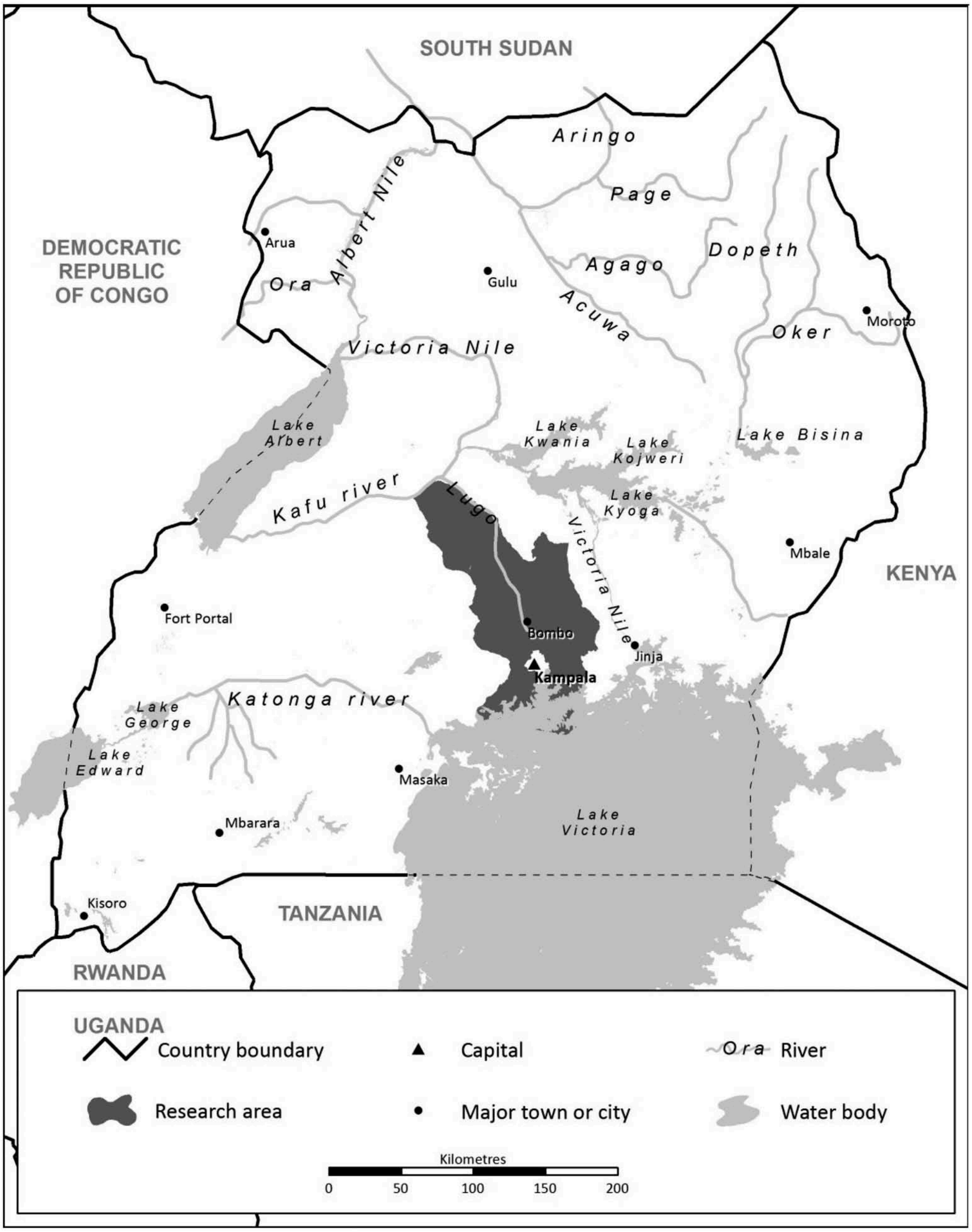

Figure 3. Map of Uganda indicating key study areas north of Kampala. Source: the authors.

Water security and DRWH

The materials and design of DRWH systems can be quite simple, though care needs to be taken in commissioning and operation to ensure a long life for the asset. For example, poor concrete compaction or incorrect sand–cement mixture in either foundations or tank walls (for ferro-concrete systems) can quickly compromise the entire system (Danert & Motts, 2009; Gould & Nissen-Petersen, 1999; Turner, 1999). DRWH is regarded in the development and water policy literature and by the Millennium Development Goals and Sustainable Development Goals as an 'improved water source' with great potential to provide additional water collection and storage for households in areas of unpredictable rainfall and beyond the reach of centralized reticulation systems (Kahinda, Taigbenu, & Boroto, 2007; MWE, 2014, 2017: Thayil-Blanchard & Mihelcic, 2015). This is important as it means that investments in expansion of DRWH count towards meeting the targets agreed by national governments for water and sanitation as part of the Millennium Development Goals (up to 2015) and the Sustainable Development Goals (through to 2030). In particular, Sustainable Development Goal 6 – clean water and sanitation – commits the governments to the challenging goal of universal drinking water access by 2030:

> Ensuring universal access to safe and affordable drinking water for all by 2030 requires that we invest in adequate infrastructure, provide sanitation facilities, and encourage hygiene at every level. Protecting and restoring water-related ecosystems such as forests, mountains, wetlands and rivers is essential if we are to mitigate water scarcity. More international cooperation is also needed to encourage water efficiency and support treatment technologies in developing countries. (UNDP, 2018)

Baguma and Loiskandl (2010) identify DRWH as a method that can mitigate water shortages, providing additional supply for personal, domestic and local gardening (food security) uses, and Ghimire and Johnston (2015) point out that there is a long tradition of using it. The Ugandan government's 'self-supply' policy supplements conventional centralized or semi-centralized water systems by encouraging households to access water through their efforts (Danert & Motts, 2009; MWE, 2010; Terry et al., 2015). Householders are encouraged to make incremental improvements to their supply using local and easy-to-replicate solutions, including particularly DRWH and, where conditions allow, shallow wells. Smet (2003), Pullan, Freeman, Gething, and Brooker (2014) and others suggest that drivers of the technology in the Global South include: a shift towards sustainable, community-based approaches to water supply; the failure of centralized water supply systems (the often chimeric dream of centralized piped supply); better availability of cheap tanks (especially ferro-concrete and HDPE plastic); and a decrease in the quality and quantity of ambient ground and surface water. Ugandan government policy in this area further notes the long history of self-supply reaching back into the colonial era as a foundation of this approach (MWE, 2010). Although a significant body of research exists with regard to the technical utility of rainwater harvesting to address household water insecurity, research into the reasons for adoption of DRWH in developing countries is more limited. Baguma and Loiskandl (2010, p. 356) assert that 'a knowledge gap exists on why some adopt or reject DRWH technologies and adoption trends continue to be inadequately understood at a household level'.

DRWH systems are a good example of a 'socio-technical' intervention (Linton, 2010; Staddon, 2010), depending as they do on the right mix of both physical and social conditions. Jepson et al. (2017) write that instead of seeing water as only a static physical object that should be 'captured' through clever civil engineering, household water security should be conceptualized as emerging from a 'hydro-social' process. In Figure 2 the basic components of a typical DRWH system are shown. The roof, usually corrugated iron (often this is a requirement of organizations promoting DRWH), is the collecting surface, whose collected water is directed via the guttering to the storage system. Thus, the typical system provides an above-ground storage facility for water for household use. Tanks are normally sized at between 4 and 8 kilolitres, with a view to being filled during wet seasons and therefore providing domestic water security during dry seasons. In this part of Uganda there are two wet seasons and two dry seasons each year. These systems are socio-technical in the sense that successful operation requires owners to undertake regular inspection and basic maintenance and indeed to understand that the water provided will change in quality (deteriorate) from the moment they are filled. This will necessitate attention to processing through on-site filtration and/or disinfection.

The relational approach outlined by Jepson et al. sees water security as a *process* that does not simply capture increments of physical water to satisfy demand (objectively understood in terms of litres per capita per day) but recognizes and understands the wider interactions that take place between people and water. Similarly, Linton (2010) suggests that access to water as a human right should be re-formulated as *the right to be involved in decisions that affect the way in which people and water interact.*[2] Applying this more relational perspective on household water insecurity derived from Jepson et al. (2017), Staddon and James (2014) and others, it is possible to analyze the cultural, social and political relations – what they refer to as the 'human capabilities' – *behind* the securing (or not) of the services we require from water (e.g., hydration, cleanliness, etc.). In other words, the hydro-social model of defining water security in relation to DRWH adoption trends takes into account households' interactions with other actors (private suppliers, government agencies, NGOs, the physical environment, etc.) that have led to securing water, or not securing it, for different purposes. For example, membership in intermediary community organizations or NGOs (such as those promoting DRWH and discussed in this article), access to appropriate technical knowledge and finance mechanisms, or access to a particular level of education may all be examples of wider relations that influence a household's access to water and that the hydro-social conceptualization takes into account (Baguma & Loiskandl, 2010; Jepson et al., 2017). In this sense, achieving water security is seen as a very dynamic process, bridging the gap between socio-political relations on the one hand and the acquisition of physical water on the other.

There are many different ways of defining and measuring water security in the academic literature (see Bakker, 2012; Scott et al., 2013; Staddon & James, 2014; Sun, Staddon, & Chen, 2016 for reviews). Webb and Iskandraani (1998, p. 4) offer the following definition: 'access by all individuals at all times to sufficient safe water for health and productive life'. Other definitions, such as that promoted by Scott et al. (2013), specifically incorporate the natural environment as a water user whose needs must be properly accounted. One simple way of measuring water security is by calculating a demand over supply ratio (e.g., Lanka Rainwater Harvesting Forum, 2001). Thus, where the demand for water outstrips the supply the ratio will be more than 1, and where the demand is smaller than the supply then the household's water security is less than 1. Ariyabandu (2001) suggests that the accessibility, reliability and timely availability of adequate safe water for basic human needs defines water security and that there is also a clear difference between 'perceptional quality' and 'absolute quality', meaning that water security may also be defined with reference to user attitude, perception and judgement. The 'capabilities' approach that we adopt from Jepson et al. (2017) and Wutich et al. (2017) helps us focus on key facilitating intersectionalities related, for example, to 'health and well-being', 'income and resource', and 'autonomy and self-determination'. There is considerable evidence that access to water services is positively correlated with reduction in global health burden (Forouzanfar et al., 2015). Moreover, it is important that we are sensitive to the complex interrelationships between water security policy and practice on the one hand, and socio-cultural factors that may influence water management and allocation (e.g., gifting and reciprocity) on the other.

Located approximately 75 km north of the capital (Figure 3), Luweero's economy is largely devoted to agriculture, both animal husbandry and crop production. Luwero is the smallest and most rural of the three study districts (Table 1). Its chief agricultural products are bananas, coffee, sweet potatoes and maize, though volumes of other products, such as honey, have been growing quickly in recent years (Uganda Bureau of Statistics, 2017a). Unfortunately, economic growth has also led to greater environmental degradation, particularly with respect to lost wetlands and forest cover, topsoil loss and water pollution. Housing is reasonably good, with 65% owning their own homes, 82% of which have corrugated iron roofs. Access to water resources is less salutary, with only 54% reporting access to safe water and 60% access to a pit latrine.

Demographic data for Wakiso and Mukono Districts, located immediately west and east of the capital, respectively, are also shown in Table 1. Given their peri-urban status (and therefore better access to the capital) most indices of socio-economic development are higher, including smaller households, higher levels of home ownership and better health statistics (Uganda Bureau of Statistics, 2017b). Consonant with this relative economic prosperity, and proximity to the capital, fewer residents than the national average (27%, compared to 68%) are dependent on subsistence farming. Of the three districts surveyed, Wakiso also has the best statistics for housing quality, availability of piped water supply (51.2%), improved sanitation (99.2%), and access to electricity (62%), but the lowest level of home ownership (44%). In a survey published by the *Daily Monitor* (Kafeero, 2018), Wakiso emerged as the country's richest district, with an average GDP per capita of US$ 3250, compared with US$ 57 in the poorest district, Kagada (in the Western District, near Lake Albert). Mukono has somewhat higher levels of home ownership than Wakiso, but lower levels of access to electricity and a higher proportion of households practising subsistence agriculture. While access to

Table 1. Data for the three study districts (Uganda Bureau of Statistics, 2017a, 2017b, 2017c).

District	Location	Total population	Rural	Growth	Area (km^2)	Population density (per km^2)	No. of households
Luwero	Central Uganda (North of Kampala)	458,158	79%	2.45%	2,557.5	17.7	106,235
Mukono	Central Uganda (East of Kampala)	599,817	73%	2.91%	10,211	58.7	145,575
Wakiso	Central Uganda (West of Kampala)	2,007,700	68%	6.10%	2,807.7	71.5	504,602

sanitation is similar to Wakiso, access to piped water supply is only 22% (Uganda Bureau of Statistics, 2017c).

Methodology

Using a multi-methods approach, this study evaluated adoption trends of DRWH in three rural districts in central Uganda, all within a short drive of the capital, Kampala (Figure 3). Completed over a three-month period in late 2015 and early 2016, the study compares capabilities variables related to household characteristics – such as education, age, access to finance, and membership in an intermediary NGO or community organization – to assess factors correlated with adoption of DRWH. Questionnaire surveys, focus groups and direct observations were all used to collect primary data as part of an integrated approach to data collection and triangulation (Cresswell, 2002; Danielson, Tuler, Santos, Webler, & Chess, 2012; Flick, 2014). The districts chosen for study are shown in Figure 3, and basic socio-economic data for these districts are given in Table 1. NGOs that acted as bridging or linking organizations between the research team and the local communities in the three districts included:

- the Busoga Trust, a community-based NGO working to provide sustainable access to safe water, improved sanitation, and hygiene and health education
- the National Association of Professional Environmentalists, an advocacy organization working closely with communities on economic and environmental issues
- the Katosi Women's Development Trust, an NGO working with women to enable them to improve their social, economic and political conditions.

Working with these organizations enabled the researchers to quickly identify useful study sites and interviewees and gave an easy entrée into these communities for the (white European) researchers. Researchers were also sensitive to the information needs of the partner organizations and sought to assist them wherever possible.

In the first research phase, recent secondary data (from government and other official sources) was collected to provide an up-to-date view of the landscape of DRWH in Uganda generally and the study districts in particular. A limited number of focus groups were also conducted as a way of introducing the researchers to the communities and gauging likely participation rates in the subsequent questionnaire survey phase. An initial, NGO-facing, focus group was organized by the Uganda Rainwater Harvesting Association during a two-day public dialogue in Gulu, northern Uganda, attended by 12 representatives of local government and NGOs. As Danielson et al. (2012) point out, focus groups are a kind of group interview that capitalizes on communication between research participants in order to generate data. This means that instead of the researcher asking each person to respond to a question in turn, people are encouraged to talk to one another, with the researcher noting areas of concord and discord. One key question posed to this group was: 'In your collective experience, what variables impact the decision of households to adopt or not adopt DRWH?' The responses given broadly fell into the five spheres of socio-cultural, socio-economic, financial, attitude, and perception, which were then used to structure the subsequent questionnaire survey.

In the second phase, the research deployed a semi-structured questionnaire survey that focussed on basic household characteristics, experiences of water insecurity and factors affecting adoption or non-adoption of DRWH. A key motivation behind the survey was the need to better understand the complex mix of enablements and constraints that face householders considering DRWH implementation. In all phases of the questionnaire process we were mindful of the dangers of various kinds of bias, particularly social acceptability and acquiescence bias (Gillham, 2008; Staddon & Genchev, 2013; Valentine, 1999). One question in each section of the questionnaire used a Likert scale to gauge the strength of respondents' opinions (Albaum, 1997). It was decided to present the questions verbally, with the use of a translator, due to low literacy rates and also to allow further discussion of open-ended questions. Upon arrival at a household there would be a brief introduction and explanation of the research to gain permission to interview the respondent and observe the respondent's homestead. The questionnaire was then conducted, after which respondents would give a tour of household water facilities. Approximately 25 minutes was spent at each household, although this time could vary significantly. In the third phase, interviews and focus groups with householders were used to add depth, detail and richness to the picture emerging from the earlier research phases. This helped contextualize quantitative understanding of the DRWH situation in Uganda by allowing the researchers to see for themselves the situations that respondents were describing, and also allowing respondents to draw attention to salient aspects of their domestic environments (Sin, 2003).

Examining the drivers of DRWH adoption trends involved surveying household characteristics, and for the purpose of this study it was assumed – guided by previous studies of this kind (Ahmed, Onwonga, Mburu, & Elhadi, 2013; Baguma & Loiskandl, 2010; Zingiro, Okello, & Guthiga, 2014) – that the self-declared head of household (usually the one home when researchers visited) was the most knowledgeable about DRWH issues. Initially, a 'random walk' method was chosen for sampling, starting with a 'seed value' household and then proceeding to every *x*th or *y*th household (Flynn, Tremblay, RFehm, & Wells, 2013). Since enumerators often encountered multiple heads of household together (e.g., neighbours visiting) we elected to move to a 'snowball' sampling method, acceptable since the statistical representativeness of the sample was not the primary desired outcome.[3] The intention was rather the capture of a sense of local lived experience of water insecurity and the creation of a platform for deeper explorations of household-scale strategies for addressing it, with particular emphasis on DRWH adoption. The achieved sample size of 66 was large enough to enable limited descriptive and analytical statistical examination, though (as noted above) not with the intention of necessarily speaking statistically about the larger population (Rogerson, 2010). Completed surveys were received from 12 villages in the three districts, with very few refusals from householders, and indeed a high level of enthusiasm, as householders are very interested in anything that may help improve the local water situation.

Taken together, the focus groups and household questionnaires tell a compelling story about why some families in some locations are more likely to adopt DRWH as part of their household water security strategy than other families in other locations.

Results and discussion

This section presents the results of the household survey, focus groups, and informal interviews and observations, focussing particularly on the stated reasons for adoption/

non-adoption of DRWH. Education, gender, age (of head of household), family size, membership in relevant intermediary organizations and access to credit were all considered. Overall, we found that gender is a better predictor of adoption than education, although neither presents a particularly strong association, whereas, age, family size, membership in a relevant organization, access to credit, land tenure, and attitude all have a significant positive relationship with adoption.

Importance of intermediary organizations

The strongest correlation was between membership in a community or intermediary organization and DRWH adoption, consistent with previous studies (Ahmed et al., 2013; Baguma & Loiskandl, 2010; Zingiro et al., 2014). Figure 4 shows the clear contrast between adopters and non-adopters, with 82% of adopters declaring membership in a community or intermediary organization, while only 7% of non-adopters are members. However, membership in a community or intermediary organization did not entail access to all other necessary enablers of adoption. In other words, membership seems to be a necessary but not sufficient condition for adoption. An NGO representative interviewed made it clear that they do not provide cash subsidies to households, instead opting to assist through supplying information, training and materials that may not be available locally, such as pipes, cement and guttering. This may facilitate adoption better than cash subsidies on their own, as there is evidence that cash subsidies are often used inappropriately (Baguma & Loiskandl, 2010). Following Jepson et al. (2017), it can be asserted that membership in a relevant community organization or NGO boosts household capabilities in the area of DRWH through facilitation of access to information, practical assistance, materials and even encouragement and moral support

Figure 4. Percentage of DRWH adopters and non-adopters who are also members of an enabling organization/NGO. Source: the authors.

(e.g., for HIV widows). From the capabilities point of view, community and non-governmental organizations need to work closely with communities to exchange knowledge and improve uptake of DRWH, including through practical action.

Technical knowledge transfer of the benefits associated with DRWH may be key in this respect (Ahmed et al., 2013). During a public dialogue attended by the researchers in the northern city of Gulu, a representative from the Appropriate Technology Centre (an action research initiative established by the Ministry of Water and Environment, with headquarters in Mukono, just east of the capital) highlighted the need for technical improvements to the operation of DRWH tanks. These included closer attention to fill levels, which affect wetting/drying of internal surfaces, and better management of the limnologic stratification of the enclosed water, which is critical to the production of cleaner water. Ongoing research elsewhere in Uganda is focussing on the finer points of tank construction, including sand–cement ratios, sand types used, setting/curing time, etc., as variables that are strongly correlated with effective performance but which can be poorly understood by local users (Danert & Motts, 2009; Thayil-Blanchard & Mihelcic, 2015).

In a keynote address at the same event in Gulu, a representative of the Ugandan government suggested that DRWH presents a sustainable solution to rural water security issues if implemented by government on an institutional level, where standards can be appropriately policed. This perspective echoes that of other government representatives, where there is a concern that community groups or development organizations acting on their own initiative may achieve suboptimal results through lack of coordination, standardization and appropriate regulation (Sendanayake, 2016). Multiple organizations operating in different communities with somewhat different messages and programmes may boost uptake in the short term, but pose challenges for maintenance of assets designed to varying technical standards. The same representative added that the general lack of knowledge households and communities have surrounding DRWH needs to be addressed. In water-stressed districts where groundwater potential is low and water quality is poor, the Appropriate Technology Centre promotes DRWH using a 'revolving fund' approach through NGOs such as the Shuuka Development Foundation, Katosi Women Development Trust, Busoga Trust and Ugandan Muslim Development Association (Ministry of Water and Environment, 2017). Therefore, much of the sensitization, mobilization and financing work is undertaken by these locally based NGOs, which may explain in part why membership numbers are so high in these regions, and why membership is a strong predictor of DRWH uptake. However, a March 2016 law to curb political electioneering by NGOs in the country may limit the ability of NGOs and other community-based organizations to support DRWH if this is seen as implying criticism of the government or its policies.

Income and finance mechanisms

It was difficult to clearly determine whether monthly income usefully discriminates between adopters and non-adopters due to the skewed (towards poorer households) nature of the sample population. However, analyzing the income of adopters, without comparing them to non-adopters, provides some interesting insights. Although irregular monthly income was a common barrier to adoption noted by respondents, an approximate average monthly income was given for 96% of adopters. The modal average (noted by 37% of respondents) was between US$ 30 and US$ 59 per month, followed by less than US$ 30 per month at 25%, with only 12%

registering more than US$ 89 per month. Even with corrections for 2011 purchasing power parity of US$ 1.90 a day, 62% or respondents are still at or below the national poverty line (Ministry of Finance, 2014; Uganda Bureau of Statistics, 2014a, 2014b). Income is not, by itself, a good predictor of propensity to adopt.

Focus group discussions suggested that stakeholders were concerned that households perceive alternative water sources as 'free' and so are often not incentivized to pay (up to 40% of) the initial cost of DRWH. The usual model for installation involves a modest co-pay plus labour input into the construction of DRWH systems, with the community or intermediary organization picking up the rest of the cost. In some cases (HIV widows, extreme poverty) the local organization may agree to pay 100% of capital costs. This suggests that *absolute* income levels are not a strong predictor of uptake, in part because the surveyed population may have been too poor for the study to detect any relation between household income and likelihood of implementation (i.e., no price elasticity of demand) but also because many are opposed to the idea that water should cost anything. Studies elsewhere have also found that DRWH systems are often more attractive to middle-income households, who are more accustomed to consumerist logic (Ahmed et al., 2013).

Often, to qualify for assistance from community or intermediary organizations in setting up DRWH infrastructure, families must demonstrate that they have improved sanitation facilities. This poses several problems for would-be water harvesters, especially in low-income families, as the average cost of improved sanitation is approximately US$ 50, and the community or intermediary organizations that support sanitation development are often different from the ones promoting DRWH.[4] Again, it may be that lack of integration and coordination with the water, sanitation and hygiene (WASH) sector is unduly suppressing progress in water supply and sanitation services. With 62% of adopters at or below the national poverty line, there is great potential for this practice to exclude those most at risk of household water insecurity. It might be assumed, therefore, that access to credit would be necessary for gaining improved sanitation. In fact, though in most cases with an average income less than US$ 59, 80% *did* claim to have access to credit. Consistent with previous studies (Ahmed et al., 2013; Baguma & Loiskandl, 2010), this research found access to credit to be moderately positively correlated with the adoption of DRWH ($r^2 = 0.490$, $n = 66$, $p \leq .001$). Attitudes to using credit for DRWH were also fairly positive, especially where the credit organization was locally embedded and well known, again pointing to the important role played by intermediary NGOs.

However, owing to the absence of a well-developed formal credit system for water and sanitation infrastructure in Uganda, many households tended to use informal, potentially exploitative, credit systems (such as village groups or informal money-lenders with high interest rates) to improve water services. Mpuga (2010) estimates that only 43% of Ugandans have access to a bank account, and fewer than 5% have access to a microfinance scheme. To support poorer households that cannot afford to adopt DRWH, researchers and practitioners have proposed improving access to microfinance for sanitation (Rosenberg, Gonzalez, & Narain, 2009), a finding replicated in our study.[5] Perhaps NGO involvement earlier in the adoption process, supplying hardware subsidies for water supply and sanitation facilities, to reduce dependence on underdeveloped, informal, potentially exploitative credit systems, would be a useful way of improving uptake (Mpuga, 2010; Rosenberg et al., 2009). Reporting on the role of microfinance in increasing access to improved WASH services, Hadi (2000) observed that households involved with credit programmes were more likely to be water secure than others who were equally poor but not involved in such programmes. There may also be room for the development of microfinance (along the lines of the well-known Grameen Bank model) for WASH investment in Ugandan communities (Davis, White, Damodaren, & Thostren, 2008).

Lifecourse dynamics

This study found that age of the head of household is strongly related to the adoption of DRWH, with a significant difference in the mean age of adopters (51 years) versus non-adopters (38 years). The preponderance of older adopters may be linked to several factors, including

- having had more time available to accrue sufficient capital (for example, through having more income-generating members of the household or having been working longer);
- being better able to access to credit, and related knowledge and resources; and
- having more social capital, enabling them to draw on assistance with construction and maintenance (Coleman, 1988; Mpuga, 2010; Seferiadis, Cummings, Zweekhorst, & Bunders, 2015).

There is no indication in our data that attitudes to DRWH vary with age, as our sample of respondents was overwhelmingly positive (90%) towards DRWH (*contra* some reports, e.g., Ahmed et al., 2013), further suggesting that the significance of age is more in the material than in the affective domain.

Interestingly, given the above, we did not find that level of educational attainment was linked to adoption of DRWH. This is consistent with some studies (e.g., Baguma & Loiskandl, 2010) but contradicts others (e.g., Ahmed et al., 2013). The latter study suggests that, as one might expect, more education led to more exposure to information and critical perspectives (e.g., about climate change or well-being), resulting in a more positive view of DRWH and related water security strategies. It is notable that the leadership of older, and better educated, community members (especially clergy and medical staff) can be a critical factor in promoting uptake. ‘Capabilities’ therefore reside in both individuals and in communities, whose networks may be more or less rich and more or less supportive of a given innovation like DRWH (Jepson et al., 2017). Data on education and DRWH uptake are complicated by the potential for NGOs to act as vehicles for perception change and capacity building, separate from formal educational attainments. It is possible that education becomes less significant in relation to DRWH adoption due to the ability of such organizations to expose households of varied education levels to this information, mobilizing households regardless of education. Perhaps Ahmed et al.’s study communities lacked the organizations present in our Ugandan study areas.

An ironic outcome of the above is that it may be younger households that are less likely to adopt DRWH, as a consequence of a lack of social capital, including knowledge, social networks and access to (micro)finance mechanisms (Coleman, 1988). What’s more, ethnic and other sorts of population mixing in communities can pose challenges for knowledge dissemination and the building of social trust across communities, both of which are necessary for growing DRWH uptake (Letki, 2008). Grassroots NGOs, such as local or district WASH programmes, were often created by local churches (especially the Church of Uganda), implying that parishioners would have easier and quicker access to necessary information and other resources to support uptake.

No clear trend between DRWH adoption and gender was found, although slightly higher rates of male household heads were found in non-adopters. Consequently, our findings do not support the widely held assumption that adoption may be higher among females because of their proximity to the practical daily burden of water collection and management. Possibly this is due to the prevalence of male-headed households and the tendency revealed in the questionnaire survey for younger girls (rather than women) to be the main collectors of water. If this is so (and the authors have seen similar results in other parts of Uganda), then there is an important asymmetry here between those who are in a position to make decisions about DRWH adoption (male heads of households) and those who most acutely feel the impact of their decisions (young girls and women). Stevenson et al.'s (2012) study of water insecurity in Ethiopia also found that women's vested interests in household water decisions were often suppressed or obscured by patriarchal control over resource allocation and other household decisions.

As in other studies (Ahmed et al., 2013; Baguma & Loiskandl, 2010; Gould & Nissen-Petersen, 1999), our survey found that family size is correlated reasonably strongly with propensity to adopt DRWH. The larger the family, the more likely adoption becomes (r^2 = 0.490, n = 66, $p \le .05$). As Figure 5 shows, the family size of adopters is significantly larger than that of non-adopters, with over 75% registering between five and nine family members, compared with an average rural family size country-wide of 4.8. There is some evidence that this correlation may be at least in part a product of explicit NGO policy around DRWH promotion. In an informal interview with a member of the Busoga Trust, it was suggested that the community-based NGO specifically targets households with larger family sizes because the introduction of DRWH

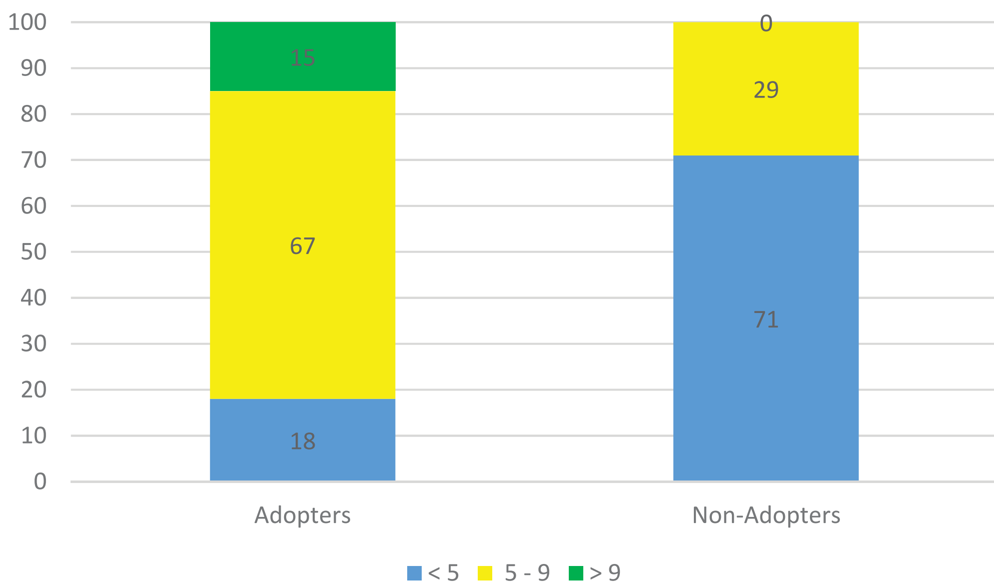

Figure 5. Family size and propensity to adopt rainwater harvesting. Source: the authors.

tanks in these households benefits a larger number of people and may also reach more vulnerable people, particularly young children and the elderly. The authors have found this sort of policy bias, towards benefiting larger families, elsewhere in Uganda as well.

Beyond simple propensity to adopt, there appears to be little relationship between tank size and family size, possibly because the intermediary organizations tend to promote a standard 4 m^3 or 6 m^3 ferro-concrete tank. This is significant because appropriate tank size is crucial to ensure sufficient capacity to get through the dry season (Campisano and Modica, 2012; Kisakye, Akurut, & Van der Bruggen, 2018). An estimation of per capita per day minimum water demand across periods of rainfall deficit is revealing. Typically, Uganda has up to seven months (approximately 215 days) of rainfall deficit spread over one four-month period and one three-month period (Majugu, 2006; McSweeney, New, Lizcano, & Lu, 2010). As defined by WHO (2013), the minimum amount of water required to survive is 7.5 litres per person per day, based on a lactating woman engaged in moderate physical activity in above-average temperatures (DDM, 2012; WHO, 2013). This means that to satisfy only minimum hydration requirements (not including basic hygiene and food preparation), a minimum of 900 litres per person would be required to last out the longer four-month dry period. Thus, a 4 m^3 tank has the capacity (if full and functioning perfectly for the duration of a worst-case drought period) to supply water for only slightly more than four people. With this in mind, it is no surprise that 78% of households with more than five residents indicated they run out of water during dry periods and must revert to alternative, potentially less safe, 'unimproved' water sources.[6] This was confirmed in the data set: 74% of all DRWH adopters surveyed also used alternative water sources, such as open springs, boreholes, vendors and lakes, during periods of deficit, suggesting that DRWH is seen as one of several water sources that can be used in dry periods and not as the sole source on which to depend. Of the three-quarters of adopters who made frequent use of alternative sources, 65% indicated that tanks running out of water was the main reason, while 29% quoted operation and maintenance issues. Possession of a DRWH tank did decrease the distance travelled for alternative water supply, though only slightly, from 2.5 km for non-adopters to 2 km for adopters, still well over the 1 km written into the Millennium Development Goals. The quality of alternative supplies in the study areas was often dubious (Figure 3, left-hand panel).

The above suggests that NGOs involved in promoting DRWH are sometimes promoting a standard-size tank without proper calculation of household size, and therefore need differentials. In some locations, the standard size recommended by the government is 6 m^3, though beneficiaries must contribute higher co-payments to obtain larger sizes, leading to smaller tanks being constructed. In addition to size specification, however, we identify exclusivity of supply (the extent to which a household may or may not have access to other sources) as a key variable in determining the adequacy of a given tank size. Linked to this is the issue of maintenance, since tanks need periodic (at least annual) cleaning to ensure maximum storage volumes and minimization of propensity to store 'bad' water. With regard to operations and maintenance, two of the three NGOs we worked with indicated that after the installation of the tank, their assistance relating to the tank stops, and maintenance becomes the responsibility of the household. With limited resources and skills it may be difficult for households to maintain their tanks, leading to broken pumps or taps, cracks in the tank, and collapsed lids, all of which were seen in the survey. In the focus groups, four district representatives mentioned that DRWH tanks frequently fail to remain operational – in one community of 150 ferro-concrete tanks, 28 were broken 'beyond repair' within only a few years of commissioning. A census of tanks conducted by the authors during the 2017 and 2018 field seasons found that about 10% had suffered (usually preventable) damage inhibiting operation.[7]

Land tenure

A final factor explored in our research and affecting DRWH adoption was land tenure, which had a significant part to play. We found a strong, positive correlation between land ownership and adoption, which was also statistically significant ($r^2 = 0.757$, $n = 65$, $p < .001$). As with other household investments, being free from the worry of eviction appears to embolden households to invest in fixed technical assets like DRWH. Conversely, not owning one's own home or land may deter investment decisions (MWE, 2014; Smucker, Glenn, White, & Bannister, 2000). We also discovered a significant population living on 'disputed land', a situation that sometimes arises in the context of traditional/tribal land tenure systems (where land is given or loaned by patronage) or where there are contestations of inheritance (Figure 6). Interestingly, while a few leaseholders have invested in DRWH or similar innovations, no occupants of 'disputed land' have done so, indicating that security of tenure is an important determinant (Ahmed et al., 2013; Baguma & Loiskandl, 2010).

However, the link between tenure and propensity to adopt may not be as simple as just implied, not least because property owners may be trying to derive multiple benefits from their limited built and land assets. For example, studies elsewhere have shown that property owners are often attempting to manage land for domestic (subsistence) cropping or set aside for future building projects (accommodating future generations, subletting space for

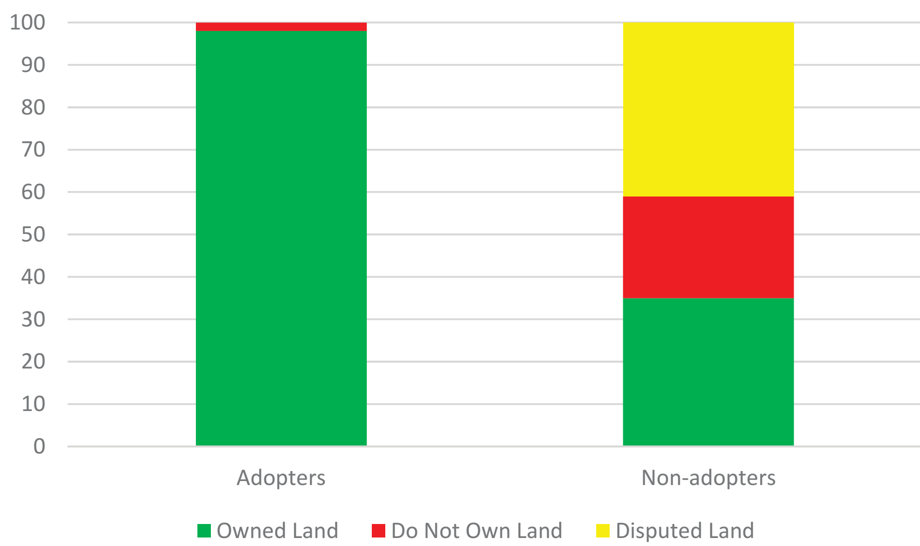

Figure 6. Land tenure and propensity to adopt rainwater harvesting. Source: the authors.

poorer households, etc.). In about a quarter of our study households, there was concern about the space requirements of DRWH. Some householders also mentioned the competing space requirements of sanitation facilities (pit latrines, Ecosan toilets, etc.), which, as we noted earlier, are often prioritized over DRWH or other water supply technologies. And in a few cases adopters clearly articulated that the collected rainwater was not so much for domestic consumptive uses as for the production of market garden produce or a resource for direct sale to nearby households (e.g., for cash to pay school fees) and therefore linked to cash-earning strategies. These findings underscore the importance of understanding what property owners in low-income and high-population-density urban areas want in the context of water services technology innovation and diffusion. Water 'produced' through DRWH can offer many material advantages, some of which are obvious (hydration, hygiene) while some are not (raising cash for school fees, watering animals).

Implications and conclusions

This study of adoption trends of DRWH in three rural Ugandan districts identified both positive and negative factors contributing to the current picture on DRWH adoption. On our evidence we can confidently say that NGOs and community-based organizations (e.g., women's groups and faith groups) are central to the upscaling of DRWH in rural districts in Uganda, but that they can also complicate uptake decisions where they are not sufficiently integrated with other actors in the broader WASH community. For example, it may not be optimal (for district-scale water security) to have different NGOs and community-based organizations focussing on different groups within the broader community, using different finance models and even slightly different physical specifications for the systems themselves. Access to credit and membership in community or intermediary organizations that may offer or organize credit mechanisms (e.g., revolving credit or microfinance schemes) was key to adoption. Therefore, the way these organizations operate, the communities they work with and the ways they implement the technology are all crucial in determining adoption trends. Indeed, this research has highlighted the potential importance of a relational approach to water security and the hydro-social process as the interactions between communities and these organizations largely determines whether households have access to, and are able to adopt, DRWH to improve their water security. Jepson et al.'s (2017) 'capabilities' need, we argue, to be understood as operating in a nested fashion, linking individual household decision makers with the often complex hierarchy of supporting organizations, institutions and policies operating at different spatial scales.

With a greater understanding of adoption trends and drivers, governmental and non-governmental organizations may be able to make more informed decisions on where to focus their work in an attempt to link with communities or households that may previously have been marginalized but that would still benefit from access to DRWH. For example, more attention may be needed to reach those households with small family sizes, with young heads of household, or those who do not own the land on which they reside. We found that all three sub-groups are currently under-represented in the population of those enjoying the benefits of DRWH.

The potential for DRWH to improve household water security, as well as to help with a range of other co-benefits (including gender equality, school attendance, and livelihoods) is high. From a 'capabilities' perspective, DRWH emerges as more than a mere technical 'fix' for household water insecurity; its socio-technical characteristics include links to lifecourse dynamics, governance, regulation, finance and well-being. The fundamental 'capability' that needs development and promotion is the ability to be effectively involved in decisions that affect the ways people and water interact. This article presents some insights into factors affecting adoption, but further multidisciplinary research is required to refine recommendations on policy and practice across a range of stakeholders and actors. Addressing the WASH challenge in the Global South through well-theorized and empirically grounded research should be a matter of global priority.

Notes

1. The World Health Organization defines an 'improved water source' as a type of water source that, by nature of its construction or through active intervention, is likely to be protected from outside contamination, in particular from contamination with faecal matter (WHO/UNICEF, 2015). In the image at right in Figure 2, the 'improved' designation applies because not only is collection structured and made more secure via the retaining wall and tap, but also the uphill area is fenced off to try to prevent contamination.
2. Which is, after all, probably what a 'right to water' ultimately means – see Staddon, Appleby, and Grant (2011).
3. We recognize that there will therefore be a bias in the sample against those households less networked within the community, which would make them less likely to be reached through encountering them when visiting other households.
4. Somewhat akin to the 'community-led total sanitation' approach, it may be useful to think in terms of a 'community-led total water services' approach that tackles water supply and sanitation simultaneously.
5. Lack of an insurance services market (which might, for example, cover DRWH installations) is also a constraint on uptake.
6. Research conducted during the 2018 field season found that tank owners often combined tank water with other sources and even, in some cases, sold tank water for cash income (to pay school fees, for example).
7. Separate research currently underway is examining the root cause pathways to failure in ferrocement rainwater tanks.

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