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ENSURING AVAILABILITY AND SUSTAINABLE MANAGEMENT OF WATER AND SANITATION FOR ALL

Statistical analysis of water storage capacity and days-storage for single-family households in Accra

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In order to evaluate whether installed water storage capacity for single-family households in Accra are large enough to harness the full potential of rainwater harvesting (RWH), we compare this capacity, and its associated days storage, with that required for RWH, and examine the relationship between roof area, household size and each of these storage capacities. Results show that (1) installed capacity is 25.6 m^3 significantly smaller, and more varied, than that required for RWH; (2) consequently, the associated days storage for installed capacity is 110 days significantly smaller, and more varied, than that for RWH; (3) unlike the capacity for RWH, which had a significant relationship with only roof area, there was no significant relationship between roof area, household size and installed capacity. We conclude that the decision on installed storage capacity ignores the potential of RWH, thereby, making it smaller than what is required to harness this potential.

Introduction

Although domestic rainwater harvesting (RWH) can be an alternative source of water supply for households that lack adequate access to pipe-borne systems (Ahmed, 1999; Handia, Tembo, & Mwiindwa, 2003), adequate storage capacity must be installed to harness its full potential (Londra, Theocharis, Baltas, & Tsihrintzis, 2015; Silva, Sousa, & Carvalho, 2015). . If water policy makers in Ghana can affirm that "Rainwater harvesting has a great potential to increase water availability…" (MWRWH, 2007, p. 3), then households should not only make full use of this sustainable resource for purposes of reducing the pressure on pipe-borne systems (Abdulla & Al-Shareef, 2009; Belmeziti, Coutard, & De, 2014; Eroksuz & Rahman, 2010; MWRWH, 2007), but more importantly, to minimize possible expenditure on accessing water, since rainwater, compared to water from WTS providers is virtually free. A key decision in this regard is the size of installed water storage capacity, which could be determined by factors such as roof area and household size.

Some single-family households in Accra, those inadequately served by a water distribution system, are observed to have installed storage facilities for holding water purchased from water tanker services (WTS) and also for harvesting rainwater. A previous study we conducted on a sample of such households showed that (1) per capita water consumption obtained from WTS varied from 21 to 117 lpcd (with a median value of 51.89 lpcd), and the probability that this consumption exceeds 50 lpcd was 0.555; (2) per capita water consumption obtainable from RWH ranged between 17-240 lpcd (with a median value of 36.5 lcpd), and the probability that this consumption exceeds 50 lpcd was 0.239. These results indicate that an adequately sized water storage facility will increase the volume of water that can be accessed by these households.

The purpose of this present study was to evaluate whether the installed storage capacity for our sample households are large enough to harness the full potential of RWH, and whether the decision on this capacity bears any relationship with some of the key variables that affect the size of rainwater harvesting tanks, namely: household size and roof area. Specifically, (1) we compare the capacity of installed storage tanks with what would be required for rainwater harvesting; (2) we also compare the associated number of days-storage afforded by the installed capacity with that which could result from a capacity that is based on rainwater harvesting; (3) finally, we investigate whether roof area and household size have any significant relationship with these alternative storage capacities and develop an empirical rule of thumb for determining them. In relation with the existing literature, our study here is similar, in part, to that conducted by Karim, Rimi, & Billah (2015), who found that installed capacity for RWH, constructed by NGOs under various government programs, were under-sized. Our study, however, does not use an average household size, and is also different in analytical approach.

Methods

This study was conducted using middle-income household data from Ashongman Estate, a peri-urban community in Accra-Ghana. The area is a fully developed community with utility infrastructure and social amenities. Households live in single-family houses, designed and constructed as single units and semi-detached units (duplexes). The only setback was the lack of constantly flowing portable water supply from the water utility service provider. This resulted in residents depending on water purchased from tanker service providers (73.3%) and from neighbours (26.7%), as their main sources, and rainwater harvesting as an alternative source.

Data collection for this study was based on a survey instrument specifically designed for this purpose, and applied to a total of 30 households. Household-level variables such as household size, per capita water consumption and roof area were collected. Household size, obtained from a head count of persons in each house, ranged between 1 and 10, and per capita water consumption recorded was 21-117 lcpd. Roof area range between 93-178m^2. The variation in roof area is due partly to design and partly to modifications made by households to the original design.

Rainwater harvesting systems include simple structures, sometimes not making full use of the roof area, to elaborate systems with more expensive materials that form the conveyance system (see Photograph 1). Storage facilities also vary in material type and size; from simple plastic buckets and coated iron drums, to surface and overhead polyethylene (poly) tanks (see Photograph 2). Both surface and underground concrete tanks are also used in the area, mainly by households who obtain from tanker services for re-sale.

Photograph 1. RWH system

Photograph 2. Water storage facilities

For our purposes, we define variables for storage capacity and days-storage for water obtained from WTS and RWH. We define (v) as the storage capacity currently installed by households and (V) as the capacity required for RWH. We will however use term *required storage* interchangeably, to represent V. On days-storage, we define (d) as the number of days of storage associated with v, and (D) as the potential days-storage associated with V.

We estimated v by measuring the capacity of all storage containers in a house, and summing these values. As exemplified in the literature—see for example Ahmed (1999) and Karim, Rimi, & Billah, (2015)— we estimated V using the mass curve analysis method (see Figure 1), assuming that monthly water demand is equal to monthly water supply from RWH In Figure 1, the profile of "supply" is a direct reflection of average monthly rainfall values, which we computed from 10 years of monthly rainfall data obtained from a station called Mpehuasem. . We estimated d by dividing V by daily per capita water consumption afforded by WTS. Here, we estimated consumption from the number of times each storage capacity is filled and used in a month, and converted the output to daily use equivalents. We obtained D by dividing V by the per capita water consumption obtainable from RWH.

We used the paired-sample t-test procedure in SPSS to test for significant difference between V and v, and between D and d, and we used the Linear Regression procedure to investigate the relationship between roof area, household size and storage capacity.

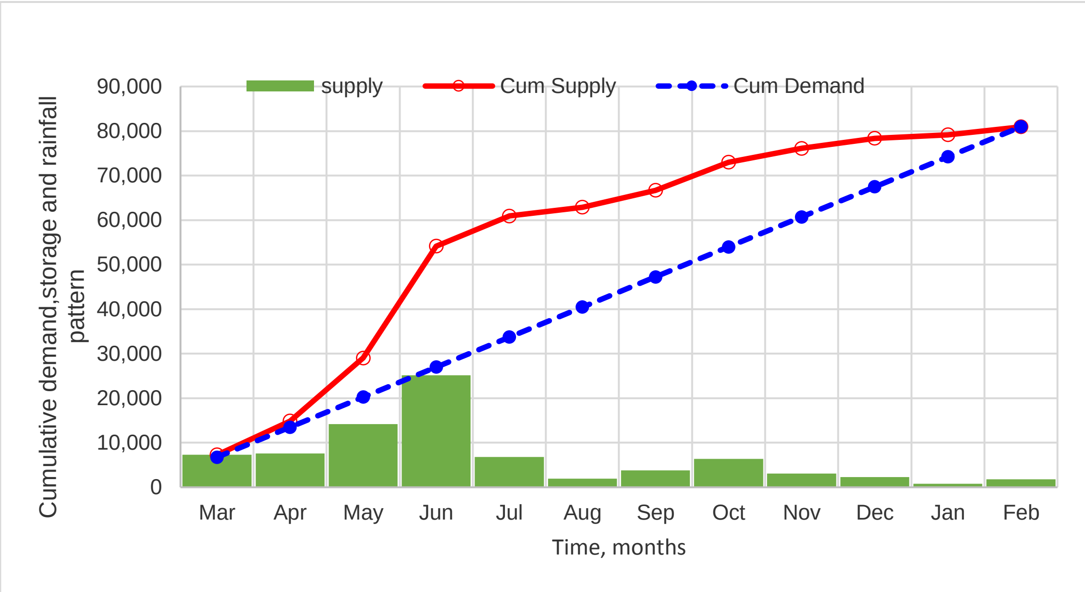

Figure 1. Cumulative household water demand, water supply and rainfall pattern

Source: Author's construction

Results

The distribution of tank sizes and their relative magnitudes are depicted in Figure 2, where CAP_INS data represents data on v and CAPS_REQ data represents data on V. It shows that installed capacity (v) is much smaller than what will be required for RWH. Required storage capacity for RWH seems more varied but seemingly uniform in distribution. Similarly, days-storage resulting from the existing tanks is much smaller than what would result from RWH (Figure 3), and seems to cluster around 120 days (4 months). In Figure 5, Days_INS data represents data from d, and Days_RWH represents data from D.

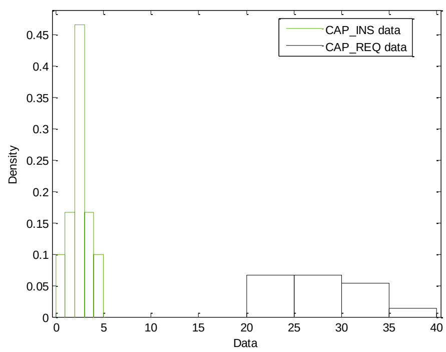

Figure 2. Distribution of installed and required capacity

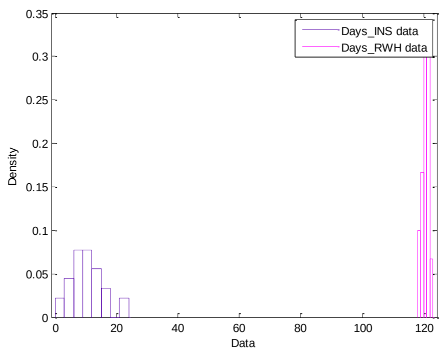

Figure 3. Distribution of days-storage for installed and required capacity

Table 1 quantifies the statistical characteristics of storage capacity and their respective days-storage values. It shows that the mean storage capacity for RWH (V) is larger than what is currently installed—see a similar result in Karim et al., (2015). Besides, the 95% confidence intervals for the two capacities do not overlap. The mean difference of 25.62 m^3 is significant at the 5% level and ranges between 23.76 to 27.49 m^3. Similarly, the resulting days-storage obtainable from RWH is larger than what can be obtained from the existing tank. The mean difference of 110.32 days is significant at the 5% level, with a range of 108.3 to 112.29 m^3.

Table 1. Statistical profile of storage capacity and days-storage, N = 30

	Min	Max	Mean	s.d	LB: 95% CI	UB: 95% CI	Sig
Installed Capacity (v), m^3	0.5	4.5	2.337	1.005	1.961	2.712	-
RWH Capacity (V), m^3	20.4	39.1	27.960	4.920	26.123	29.797	-
Difference in capacity: (V-v), m^3	-	-	25.62	4.988	23.76	27.49	.000
Days-storage, installed: d, days	2.0	23	10.38	5.011	8.51	12.25	-
Days-storage, RWH: D, days	119	122	120.7	1.06	120.32	121.08	-
Difference in days-storage: (D-d), days	-	-	110.32	5.281	108.35	112.29	.000

Results on the relationship between roof area, household size and storage capacity are presented in Table 2. It shows that installed capacity does not have a significant linear relationship with roof area (p-value = .969). The linear relationship between installed capacity and household size is also insignificant (p-value = .586) but surprisingly negative. On the contrary, there is a very strong linear relationship between roof area and storage capacity for RWH (p-value < 0.001), with results indicating that storage tank under maximum rainwater use can be estimated by 0.219xroof area.

Table 2. Relationship between roof area, household size and water storage capacity (significant figures in parenthesis)

Variables	Model 1	Model 2
Dependent Variable	Installed capacity	RWH capacity
Constant	3.627 (.075)	0.011 (.845)
Roof Area	0.000 (.969)	0.219 (.000)
Household size	-0.051 (.586)	0.000 (.922)

Discussion

For single-family households in a suburb of Accra, who depend on water from tanker service providers as their main source and rainwater harvesting as an alternative source, we have estimated the installed storage capacity and the storage capacity required for maximum use of RWH. We have questioned whether there was any difference between the two. We have also quantified and analysed the potential days-storage that results from the two types of storage capacities, and have determined if roof area and household size had significant relationships with each of these storage capacities. We found huge significant differences between installed capacity and required storage capacity under maximum rainwater use, and between their respective days-storage values. Our results also indicated that roof area and household size did not have a significant relationship with installed storage capacity.

The implications of the huge difference between required capacity and installed capacity are clear: in the event of outpouring of rains, the relatively smaller storage tanks accommodate as much as their capacity will allow; excess rainwater is discarded as run-off. This result corroborates that of Karim et al., (2015), who found out that an excessive volume of rainwater is wasted due to undersized storage capacity. This implies that households will make greater volumetric purchases from tanker service providers than will be necessary if they had installed a capacity harnesses the potential of RWH. The economic implication of this sub-optimal decision on storage capacity is not difficult to conjecture. The result that installed storage capacity has no relationship with either roof area and household size is an indication that tank sizing is probably done arbitrarily.

At least two reasons may explain why available tank sizes do not match what will be required for maximum RWH. Firstly, residents were not aware of the potential of RWH to meet their water supply needs. Secondly, even if they knew, knowledge to size an appropriate tank and, in some cases, space for installation is non-existent.

We conclude that the decision on installed storage capacity ignores the potential of RWH, thereby, making it smaller than what is required to harness this potential. Harnessing the full potential of RWH will therefore require considerable increases in the existing storage capacities. This will also increase significantly the days-storage beyond what is presently afforded by the current capacity.. In this regard, an empirical rule of thumb that seems plausible for single-family households in Accra is to install a tank size that is equivalent to 0.219xroof area.

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