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Is rainwater harvesting sufficient to satisfy the emergency water demand for the prevention of COVID-19? The case of Dilla town, Southern, Ethiopia

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Abstract

Rainwater harvesting could be an optional water source to fulfil the emergency water demand in different setups. The aim was to assess if the rainwater harvesting potential for households and selected institutions were sufficient to satisfy the emergency water demand for the prevention of COVID-19 in Dilla town, Southern, Ethiopia. Rain water harvesting potential for households and selected institutions were quantified using 17 years' worth of rainfall data from Ethiopian Metrology Agency. With an average annual rainfall of 1464 mm, households with 40 and 100 m^2 roof sizes have a potential to harvest between 15.71-31.15 m^3 and 41.73-82.73 m^3 of water using Maximum Error Estimate. Meanwhile 7.2-39.7 m^3 and 19.11-105.35 m^3 of water can be harvested from the same roof sizes using Coefficient of Variation for calculation. Considering mean monthly rainfall, the health centres and Dilla University can attain 45.7% and 77% of their emergency water demand, while the rest of the selected institutions in Dilla Town can attain more than 100 % of their demand using only rainwater. Rain water can be an alternative water source for the town in the fight against COVID-19.

Keywords: COVID-19, Dilla, Emergency water demand, Ethiopia, Rain Water Harvesting

Highlights

- Adequate water supply is one of key component in combating pandemics.

- In Dilla Town, almost two third of the inhabitants are served by the town water supply service. However, the water supply system with regular interruption and unfair water distribution poses a serious challenge.
- Rainwater harvesting can be used as an alternative water source in the town to tackle the emergency water shortage in the era of COVID-19.

Introduction

COVID-19 is a viral infection caused by a coronavirus which is novel (new) and identified in Wuhan, China (WHO 2020). According to the technical brief on Water, sanitation, hygiene (WASH) and waste management for COVID-19, provision of safe water, sanitation and hygienic conditions play an essential role in protecting human health during all infectious disease outbreaks, including the current COVID-19 outbreak (UNICEF 2020). UN Habitat also stressed that, vulnerable people, mainly those who live in informal settlements and rural community settings will be the world's most affected by COVID-19. Providing quick, just-in-time community water access points (including provision of soap) in unserved urban and rural areas is critical (UN-HABITAT 2019).

In many countries found in sub-Saharan Africa, water demand surpasses available resources with water stress (<1700 m^3 per capita per annum) or water scarcity (less than 1000 m^3 per capita per annum), and nearly half of all people using unimproved water sources live in this region, calling for alternative water supply sources (Ngigi, 2009).

However, available water supply sources are diminishing owing to the poor water governance, extreme social inequality, population rise, climate change, and pollution, causing a globally acknowledged situation of water scarcity, especially in developing countries mainly in Sub-Saharan Africa (Bocanegra-Martinez et al. 2014; Fang C. *et al*. 2007). To make things worse the situation posed by COVID-19 response affects the capacity of the water and sanitation utilities to operate normally, when staffing is not optimal, financial resources not met, and energy supply disrupted. In such emergency times technical, material and financial resources can be provided on a temporary basis to restore the problem (UNICEF 2020).

Preventing or combating potential pandemics such as COVID-19, is likely to increase water demand for domestic and health uses. Supply and storage solutions are needed to ensure there is adequate water available. Ensuring sustainable access to adequate amounts of potable water and resilience will require strengthening water resources management so that water is available where and when it is needed to combat the current and future pandemics (Joshi & Nicol, 2020).

Rainwater harvesting is a widely used term covering all those techniques whereby rain is intercepted and used “close” to where it first reaches the earth, and it has been proposed as one of the options to improve water supply especially in rural and peri-urban areas of low-income countries. It plays a critical role in the mitigation of water-scarcity and water crisis problems, and support when existing water supply systems are inadequate in areas where there is an abundant annual rainfall (Parker et al. 2013; Nijhof *et al*. 2010)

As international aid budgets might be reduced due to the economic effects of Covid-19, there is a small but growing body of evidence that Nature based solutions (NBS) such as Rain water harvesting systems are cost-effective, efficient, and adaptable compared to gray infrastructure, and they also offer co-benefits. Rain water harvesting can improve water storage and supply, thereby increasing water availability and potentially reducing competition between different water users and uses (Liquete et al, 2016; Seddon, 2018; Oral *et al*., 2020).

For instance, Feki *et al*. (2014) studied the potential of rainwater harvesting in multi-story buildings in southern Ethiopia, by which they found that with an average family members of 4, roof area of 60 m^2 and mean annual rainfall of 900 mm, 46 m^3 of rain water can be harvested, which can cover all potable and non-potable water needs at a family level. According to Balogun et al., (2016), using the maximum error estimate approach, the rainwater harvesting potential for the area of study ranges between 18.16 and 27.45 m^3, while applying the coefficient of variation approach, the rainwater harvesting potential ranges between 15.23 and 30.40 m^3. The finding also showed that domestic rainwater harvesting has the potential to meet 27.51– 54.91% of non-potable household water demand as well as 78.34–156.38% of household potable water demand for a six-member household.

Previous assessment conducted in Dilla Town showed a number of challenges such as; delivering an average per capita consumption less than 20 Liter person/day, frequent complaints by water customers, regular interruption of water supply and unfair water distribution (Debela and Muhye, 2015; Kanno *et al*. 2020) which clearly indicate that there is a huge gap between the water supply and demand in Dilla town. Therefore, our study intends to assess if the rain water harvesting both at household and at the institutional level is adequate and can supplement the water supply system to fulfill the emergency water needed for the prevention of COVID-19 in Dilla Town, southern Ethiopia.

Materials and Methods

Study Area

The study was conducted in Dilla Town, which is located in Southern Ethiopia at a distance of 359 km from the capital city, Addis Ababa, on the way from Addis Ababa to Moyale. It is located at 6° 22′ to 6° 42′ N and 38° 21′ to 38° 41′ E longitude with an altitude of about 1476 meters above sea level (Demelash, 2010). The 17 years (2002-2018) mean annual rainfall in the area is 1464 mm. The wettest months occur between March and October and the driest months occur during November to February. Precipitation is characterized by a bimodal pattern with maximum peaks during April and May ("small rainy" season) and during September and October in the "main rainy" season (ENMA 2018). The city's water supply represents an annual consumption of 494,164 $m^{3,}$ in 2018 which is abstracted from ground water (70 %) and surface water (30%) sources (Kanno *et al.* 2020; Columbia Water Center, 2016). However, in recent years, owing to the high rate of urbanization coupled with industrial development and population growth, as well as change in precipitation patterns, the available water to satisfy the water demand has radically decreased, representing a 38% deficit between2016-2018 (Kanno *et al.* 2020).

Data collection, methods and analysis

Rainfall data was obtained from Ethiopian Meteorology Agency in digital form and further analysed in a spreadsheet (ENMA, 2018). According to (Shakya and Thanju, 2013) rainfall is the most unpredictable variable. Therefore, a reliable rainfall data, preferably for a period of at least 15 years is required from the nearest station during calculations to consider the variations. Hence, a monthly rainfall data for Dilla town for the recent 17 years (2002-2018) was utilized for this analysis. Taking the assumption that most household's roof material in Ethiopian Towns (Mourad & Yimer 2017) was corrugated iron sheets, and the average roof size of 60 m^2 and a runoff coefficient of 0.8 was employed to account for evaporation loss and possible first flush (Thomas and Martinson, 2007). To include households with different range of roof sizes, rain water harvesting potentials for seven typical roof sizes (40, 50, 60, 70, 80, 90, and 100 m^2) were calculated.

Statistical variability (Rainfall Variability) in monthly rainfall data (intra annual) and accumulated annual rainfall (mm) inter annual were expressed with coefficients of variation CV, using equation

$$CV = \frac{Sd}{Mr} * 100 \qquad (1)$$

Where CV is monthly/seasonal/annual coefficients of variation

Sd: is mean monthly/seasonal/annual standard deviation

Mr: is mean monthly/seasonal/annual rain fall

Seasons were classified based on (ENMA 2018) classification as; **Summer** (Kiremet) heavy rain fall seasons June, July, August and September; **Winter** (Bega) dry season with frost in the morning, which includes October, November, December, and January; and **Autumn** (Belg) seasons with occasional showers of rain includes February, March, April and May.

Estimation of the Rain Water harvesting potential and storage requirements

Rainwater harvesting potential for our study was calculated using the monthly balance approach. The monthly harvestable rainwater (Qm) was calculated as a function of the product of mean monthly rainfall ($\bar{R}_m$), roof area (A), percentage of roof area utilized for rainwater harvesting (β=50% (0.5) was utilized)) and roof run-off coefficient (C) as given in Equation 1.

$$Q\ m = (\bar{R}_m) \times A \times \beta \times C \qquad (1)$$

Balogun et al, (2016), stated that using only monthly rainfall for the estimation of rainwater harvesting potential could be misleading since it can hide rainfall variability which occurs in real-life scenarios. Therefore they suggested that the use of two approaches to be utilized in computing the confidence limits, namely: confidence interval about the mean monthly rainfall as well as confidence interval using Coefficient of Variation (COV) of monthly rainfall as described by Johnson and Kuby, (2012) as well as Bluman. (2013) as:

$$\bar{x} + Z(\alpha/2)\left(\frac{\sigma}{\sqrt{n}}\right) = Upper\ Confidence\ Limit\ (UCL)$$

$$\bar{x} - Z(\alpha/2)\left(\frac{\sigma}{\sqrt{n}}\right) = Lower\ Confidence\ Limit\ (LCL)$$

x = where $\bar{X}$= Mean = $\bar{R}_m$; Z (α/2) =Confidence coefficient; $\sigma/\sqrt{\mathrm{n}}$= Standard error of mean and Z (α/2) $\sigma/\sqrt{\mathrm{n}}$Maximum error of estimate (MEE), σ = Standard deviation of monthly rainfall for each month and n = sample size = 17. The confidence interval adopted in our study was 0.95 which gave a confidence coefficient of 1.96.

The harvestable rainwater equations for the scenarios of upper confidence limit (UCL) of monthly mean rainfall and lower confidence limit (LCL) of monthly mean rainfall according to Johnson & Kuby. (2012); Bluman. (2013) as stated in Balogun *et al.*, (2016) were obtained as

$$Q\ UCL = [\bar{R}m + MEE] \times A \times \beta \times C \ldots\ldots 4$$

$$Q\ LCL = [\bar{R}m - MEE] \times A \times \beta \times C \ldots\ldots 5$$

Finally for the second approach, harvestable rainwater equations for the upper confidence limit (UCL) of monthly mean rainfall and lower confidence limit (LCL) of monthly mean rainfall were also calculated as;

$$Q\ UCL = \bar{R}m \times A \times \beta \times C[1 + COV] \ldots\ldots 6$$

$$Q\ UCL = \bar{R}m \times A \times \beta \times C[1 - COV] \ldots\ldots 7$$

Proposed Basic Water Requirement for households

For water requirement we have used the individual minimum daily water requirement standard set by World health organization (WHO 2003) which is 20 l/c/day from which 7.5l/c/day is for potable (drinking and cooking) purpose and the rest 13.5l/c/d is for non-potable domestic uses (Hand washing at critical times, showering etc) (Sojobi *et al.*, 2015). Average family size of five was utilized for the water demand calculation.

Proposed Basic Water Requirement for health facilities and schools

To assess rain water harvesting potential in the selected institutions in Dilla Town the average roof size was adopted from similar institutions in Addis Ababa (Adugna *et al.* 2018). We took the assumption that the roof sizes of the institutions in the two cities would be proportional. The patient load for the health centres and the hospitals as well as the number of students in the schools and colleges were directly taken from the institutions and were utilized for the water demand calculation as indicated in (Table 1).

Table 1 Assumed average roof sizes and water demand for selected institutions in Dilla Town.

Selected Large Public Institution in Dilla Town	Total number of institutions	Assumed average roof size in (m^2) (Adugna *et al.* 2018)	Daily water demand	Total number of individuals served per day
Hospital (Dilla University referral Hospital)	1	14273	40-60 liters /Patient/day (WHO 2013)	271 patients/day
Health centers	2	1119	40-60 liters/patient/day. (WHO 2013)	66 patients/day
Primary schools	12	2114	3 liters/person/day for drinking and hand washing (WHO 2013)	1200 students/day
Secondary schools	3	2114	3 liters/person/day for drinking and hand washing (WHO 2013)	700 students/day
Technical and Vocational schools	2	7546	3 liters/pupil/day for drinking and hand washing (WHO 2013)	1500 students/day
Colleges	8	23999	20 liters liters/person/day for drinking and hand washing for boarding schools and additional 20 liters per person per day for conventional flushing toilets (WHO 2009)	10,000 students/day

Results and Discussion

Annual, seasonal and monthly rainfall distribution

The average rainfall (for the historical period) was 1464mm (Figure 1). According to the data obtained from Ethiopian Meteorology Agency, out of the total study years, the highest average rainfall in the study area was 2781.1mm, recorded in 2008 while the lowest average rainfall was 974 mm, recorded in 2003. In addition, comparison of annual rainfall for the study period as shown in (Figure 2) indicating increment in yearly rainfall between 2003 and 2008. A general trend of fluctuation was observed after 2008. However, similar study conducted in Mekelle showed that the city has an average annual rainfall of 544.43 mm with the highest annual rainfall of 755.8 mm, recorded in 2010, and the lowest 296.7 mm in 2005, which indicates that Dilla Town has a Bimodal and higher rainfall distribution pattern as shown in (Figure 3) than Mekelle city which has a unimodal rainfall distribution (Taffere *et al.* 2016).

The seasonal variation of rainfall for Dilla town is described in (Table 2), where winter recorded the highest seasonal rainfall followed by autumn and summer respectively. The maximum seasonal rainfall of 1400.1 mm occurred in winter, while the minimum seasonal rainfall of 250.1 mm occurred in the summer. The seasonal variations were similar to the findings reported by (Taffere, *et al.* 2016; Adugna *et al.* 2018). The season with the lowest coefficient of variation (COV) of 4.45% was winter, while summer had the highest COV which was 39.3% as shown in (Table 2). Based on Hare's (1983) rainfall variability index (which is COV expressed in percentage terms), the seasonal rainfall pattern was less variable with index of <20% in winter and there is highly variable rainfall in summer with coefficient of variation index of >30% while rainfall in autumn was moderately variable with index between 20 and 30%.

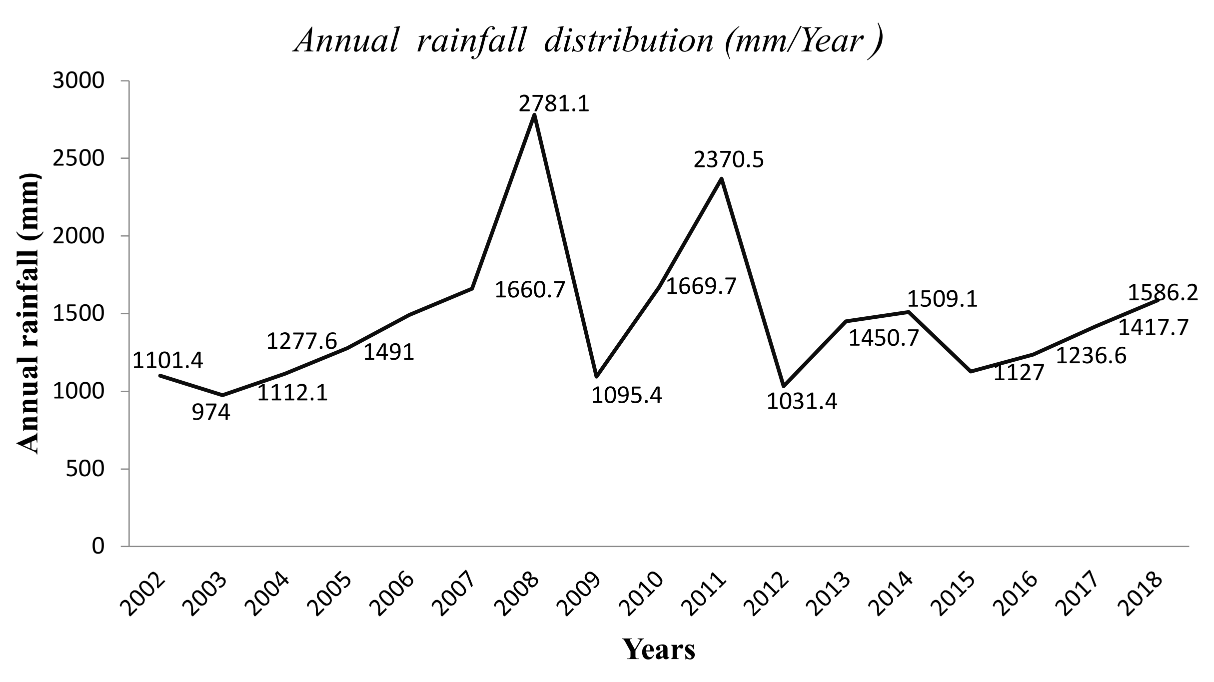

Figure 1: Annual rainfall distribution from 2002 to 2018 in Dilla town, Southern Ethiopia

Between 2002 and 2009, highest monthly rainfall occurred in November and June in 2008, while October 2011 recorded the highest monthly rainfall between the years 2010 and 2018. Besides the fact that this indicates a progressive shift in maximum rainfall from November and June in the pre-2009 period to October in the post-2010 period, it clearly indicates that the seasonal changes from summer to winter are accompanied by heavy rainfall patterns in Dilla town.

Table 2**: Seasonal rainfall distribution pattern of Dilla town, southern Ethiopia**

Parameters	Summer	Autumn	Winter
Mean	381.5	461.1	613.6
Maximum	901.4	735.9	1400.1
Minimum	250.1	313.3	327.3
SD	149.8	126.7	26.9
COV (%)	39.3	27.5	4.4

SD: Standard deviation; COV: Coefficient of Variation

Dilla town has a bimodal rainfall distribution with maximum monthly rainfall was recorded in June and January of 227.2 mm in June and 214.5 mm in January respectively. The minimum monthly average rainfall for the study period (17 years) was 0 mm in (March, 2012, August, 2007 and November , 2013), while the maximum rainfall was recorded 983.2 mm in November, 2008 followed by 894.2 mm in October, 2011 as shown in (Figure 3).

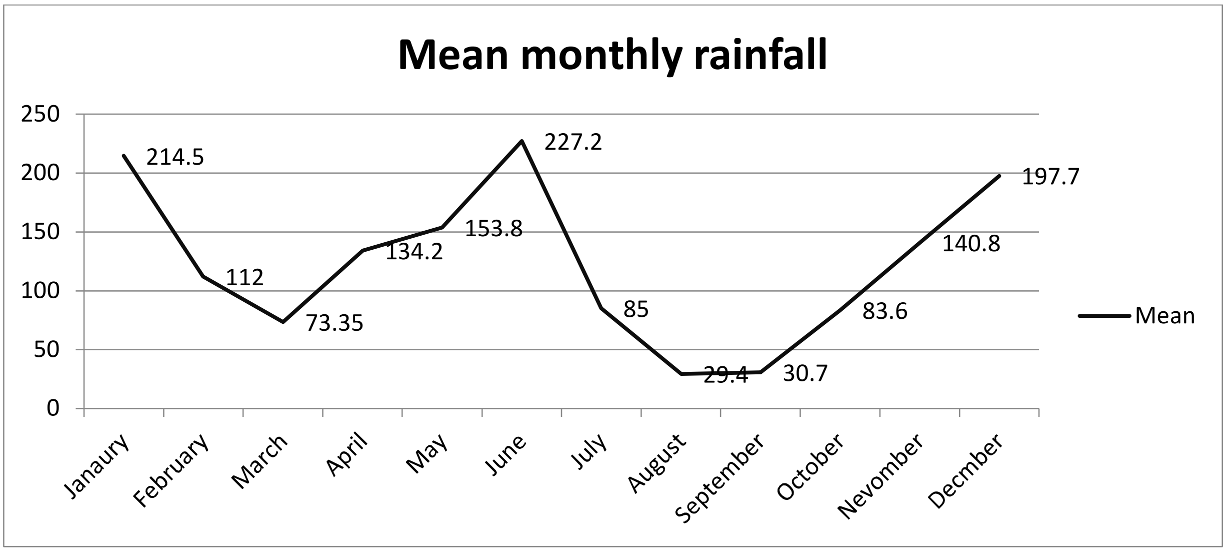

Figure 3: Mean monthly rainfall pattern from 2002 to 2018 for Dilla town, Southern Ethiopia

The highest variability of monthly rainfall were recorded during October and November with COV of 246% and 154.8%, marking the beginning of intense rainfall during the rainy season, while the month with the lowest monthly rainfall variability took place during December with COV of 28%. Based on the Hare's rainfall variability index (1993), all the months exhibited high variability with COV (%) >30% with the exception of December, which exhibited moderate variability between 20 and 30%. The trend in monthly rainfall variability observed in Dilla was similar to the result reported by (Adugna et al, 2018) in the city, Addis Ababa, which exhibits non-uniform rainfall patterns (90-117%) of variability.

Rainwater harvesting potential for households in Dilla Town

In the proposed household roof sizes, June and August recorded the highest and lowest rain water harvesting potential respectively. This result was obtained by considering the maximum error estimate for the calculation of monthly harvestable rainwater (MHRW) in the three scenarios of upper confidence limit (UCL), Mean and lower confidence limit (LCL) at household level (Table 3). Households with minimum roof size of 40 m^2 have the maximum rain water harvesting potential of 4.86 m^3 during June and minimum water harvesting potential of 0.18 m^3 in August. A household with a roof size 100 m^2 have a maximum potential to harvest 12.91m^3 of rain during June and a minimum of 0.49 m^3 during August. The second maximum and minimum RWH months were 10.65 m^3 in January and 2.01 m^3 in August respectively (Table 3).

Table 1 Monthly harvestable rain water Data with different assumed household roof sizes using MME approach

Roof size m^2	Limits	January	February	March	April	May	June	July	August	September	October	November	December	Total
40	UCL(m^3)	4.01	2.11	1.47	2.61	2.85	4.86	1.72	0.76	1.47	2.61	3.92	3.23	31.15
	MEAN(m^3)	3.43	1.79	1.17	2.15	2.46	3.63	1.36	0.47	0.49	1.34	2.25	2.87	23.42
	LCL (m^3)	2.85	1.47	0.88	1.68	2.07	2.41	0.99	0.18	0.29	-0.23	0.59	2.49	15.71
50	UCL(m^3)	5.01	2.63	1.83	3.26	3.56	6.07	2.15	0.94	0.86	3.63	4.89	4.07	38.93
	MEAN(m^3)	4.29	2.24	1.47	2.68	3.08	4.54	1.69	0.59	0.61	1.67	2.82	3.59	29.28
	LCL (m^3)	3.57	1.84	1.10	2.11	2.59	3.01	1.24	0.23	0.37	-0.28	0.74	3.12	19.64
60	UCL(m^3)	6.02	3.16	2.20	3.91	4.28	7.29	2.58	1.13	1.03	4.35	5.87	4.89	46.72
	MEAN(m^3)	5..15	2.68	1.76	3.22	3.69	5.45	2.04	0.71	0.74	2.00	3.38	4.31	35.14
	LCL (m^3)	4.28	2.21	1.32	2.52	3.11	3.61	1.49	0.28	0.44	-0.34	0.89	3.74	23.57
70	UCL(m^3)	7.11	3.68	2.56	4.56	4.99	8.51	3.01	1.32	1.21	5.08	6.85	5.7	54.5
	MEAN(m^3)	6.01	3.13	2.05	3.76	4.31	6.36	2.39	0.82	0.86	2.34	3.94	5.03	41.00
	LCL (m^3)	5.00	2.58	1.54	2.94	3.62	4.21	1.74	0.34	0.51	-0.40	1.04	4.36	27.5
80	UCL(m^3)	8.02	4.21	2.93	5.21	5.70	9.72	3.45	1.51	1.38	5.80	7.83	6.52	62.3
	MEAN(m^3)	6.86	3.58	2.35	4.29	4.92	7.27	2.71	0.94	0.98	2.67	4.51	5.75	46.86
	LCL (m^3)	5.71	2.95	1.76	3.37	4.14	4.82	1.99	0.37	0.58	-0.45	1.19	4.98	31.42
90	UCL(m^3)	9.02	4.74	3.29	5.86	6.41	10.93	3.88	1.70	1.55	6.53	8.80	7.33	70.08
	MEAN(m^3)	7.72	4.02	2.64	4.83	5.53	8.18	3.06	1.06	1.11	3.01	5.07	6.47	52.71
	LCL (m^3)	6.42	3.32	1.98	3.79	4.66	5.42	2.23	0.42	0.66	-0.51	1.34	5.16	35.35
100	UCL(m^3)	10.65	5.59	3.89	6.93	7.57	12.91	4.58	2.01	1.83	7.71	10.4	8.65	82.73
	MEAN(m^3)	9.12	4.76	3.12	5.70	6.54	9.65	3.61	1.25	1.31	3.55	6	7.64	62.23
	LCL (m^3)	7.58	3.92	2.34	4.48	5.50	6.40	2.64	0.49	0.77	-0.60	1.58	6.62	41.73

UCL: Upper confidence limit; LCL: Lower confidence lim

Based on coefficient of variation (COV) approach, the monthly HRW for the different scenarios of households with a roof size of 40 m^2 recorded the highest and lowest values of 6.21 m^3 in June and 0.07 m^3 in September, respectively. Similarly, households with a roof size of 100 m^2 had highest and lowest monthly HRW potential of 16.5 m^3 and 0.19 m^3, in the same months respectively as indicated in (Table 4).

Table 2: Monthly harvestable rainwater (HRW) based on (COV) approach

Roof size m^2	Limits	January	February	March	April	May	June	July	August	September	October	November	December	Total
40	UCL(m^3)	4.65	2.45	1.79	3.12	3.28	6.21	2.12	1.07	0.91	4.63	5.74	3.68	39.66
	LCL (m^3)	2.22	1.13	0.56	1.18	1.64	1.06	0.59	-0.13	0.07	-1.95	-1.24	2.07	7.2
50	UCL(m^3)	5.81	3.07	2.24	3.9	4.1	7.77	2.66	1.34	1.14	5.79	7.18	4.6	49.58
	LCL (m^3)	2.77	1.41	0.7	1.47	2.05	1.32	0.74	-0.16	0.09	-2.44	-1.54	2.59	9
60	UCL(m3)	6.97	3.68	2.68	4.67	4.92	9.31	3.18	1.61	1.36	6.94	6.61	5.52	59.5
	LCL (m^3)	3.32	1.69	0.84	1.76	2.46	1.59	0.89	-0.19	0.11	-2.93	-1.85	3.11	10.8
70	UCL(m^3)	8.13	4.3	2.13	5.46	5.74	10.87	3.72	1.87	1.59	8.1	10.05	6.44	69.41
	LCL (m3)	3.87	1.97	1	2.06	2.86	1.85	1.04	-0.02	0.13	-3.42	-2.16	3.62	12.58
80	UCL(m3)	9.3	4.9	3.58	6.23	6.57	12.43	4.25	2.14	1.82	9.26	11.49	7.36	79.32
	LCL (m3)	4.43	2.25	1.12	2.35	3.28	2.11	1.85	-0.26	0.15	-3.91	-2.47	4.14	14.4
90	UCL(m3)	10.46	5.52	4.02	7.01	7.39	13.97	4.78	2.41	2.05	10.42	12.92	8.28	89.24
	LCL (m3)	4.98	2.54	1.26	2.65	3.68	2.38	1.33	-0.29	0.165	-4.4	-2.78	4.66	16.18
100	UCL(m3)	12.35	6.52	4.78	8.28	8.72	16.5	5.64	2.85	2.41	12.3	15.26	9.78	105.35
	LCL (m3)	5.88	3.0	1.48	3.12	4.35	2.81	1.57	-0.34	0.19	-5.18	-3.28	5.50	19.11

UCL: Upper confidence limit; LCL: Lower confidence limit

In the study area of Dilla town, with an average annual rainfall of 1464 mm, the result indicated that 15.71-31.15 m^3 of water can be harvested from a household with a roof size of $40m^2$ and 41.73-82.73 m^3 with a roof size of 100 m^3 by using MEE. On the other hand $7.2\text{-}39.7m^3$ of water can be harvested with a roof size of 40 m^2 and 19.11-105.35 m^3 with a roof size of 100 m^2 by using the coefficient of variation (COV) approach. Similar study conducted in Nigeria (Balogun et al.,2016), indicated that using the Maximum error Estimate for calculation, a roof size of 100 m^2 had a rainwater harvesting potential between 18.16 and 27.45 m^3, while 15.23 and 30.40 m^3 of water can be harvested using the Coefficient of variation for calculation using the same roof size. The result is much higher for Dilla Town indicating that even smaller roof sizes such as 40 m^2 can be used to harvest higher amount of rainwater for the intended purpose, in this case water needed for the prevention of COVID-19.

RWH for household level emergency water supply (the prevention of COVID-19)

The potable water demand needed for emergency water supply in the prevention of COVID-19 that could be met by domestic RWH potential was between 114.75 and 227.54% of household roof areas of 40m^2 and between 304.8 and 604.3% of household roof areas of 100m^2 (Figure 4). Whereas, for annual non-potable water demand met by RWH for household roof size of 40 m^2 and 100 m^2 were between 63.76 and 126.37% and between 169.4 and 335.76m^3 respectively, using the Maximum Error Estimate approach. This is much higher when compared to the study done in Arba Minch (a city also located in southern Ethiopia) which can harvest 46 m^3 of rainwater annually with average annual rainfall of 900 mm (Feki *et al*. 2014).

As (Figure 4) indicates increment in roof size results in higher harvested rain water. By using, the harvested rainwater with MEE approach, it is possible to achieve the potable water demand in all the roof sizes and only households with a roof size between 70-100 m^2 were able to achieve their non-potable water demand. Only households with roof size of 90 and 100 m^2 can fully satisfy both their potable and non-potable daily water demand which is 20 litre capita per day.

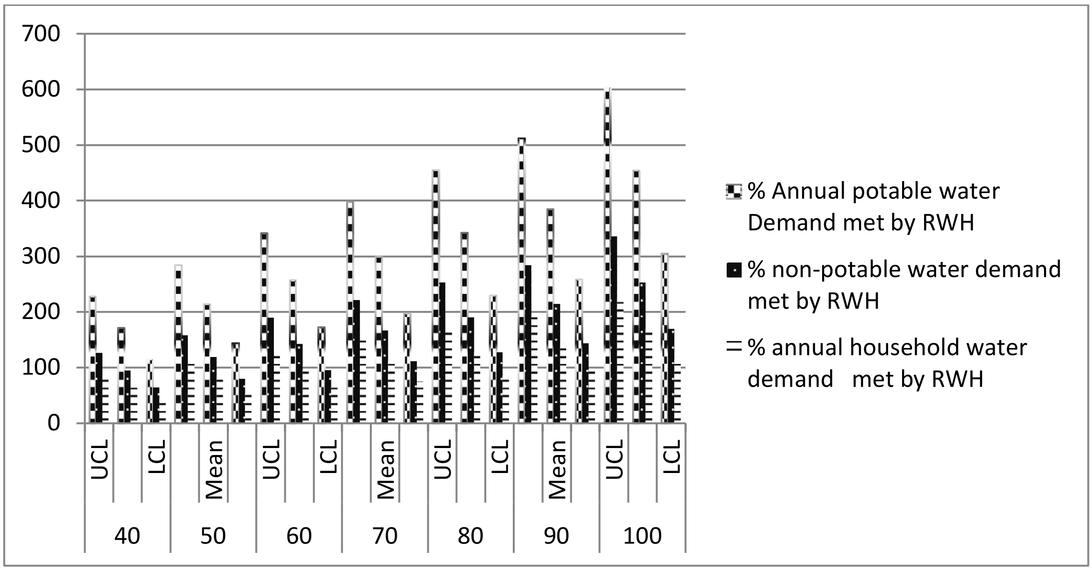

Figure 4: Emergency water demand met by Domestic RWH potential based on (MEE)

This clearly indicates that using the mean and Upper Confidence Limit (UCL) scenarios, potable water demand can be sufficiently met with some excess remaining (63.76%, 79.71% and 95.66%) in the LCL scenario for households with roof size of 40, 50 and 60m^2 respectively. For Households with roof sizes of 70 m^2 and above, the rain water is more than enough to satisfy the emergency water needed for the prevention of the current pandemic. In addition, this result also revealed that RWH can be an important option used to reduce the challenges caused by intermittent water supply in Dilla town as described by (Kanno et al, 2020).

Table 5: Emergency water demand met by DRWH potential based on (COV) Approach

Roof size	Scenario	Total annual harvested rain water In m^3	%Annual potable water Demand met by RWH	% Non-potable water demand met by RWH	% Annual household water demand met by RWH
40	UCL	39.66	289.7	161	108.66
	LCL	7.2	52.6	29.2	19.72
50	UCL	49.58	362.2	201.2	135.8
	LCL	9	65.7	36.52	24.6
60	UCL	59.5	434.6	241.5	163
	LCL	10.8	79	43.83	29.6
70	UCL	69.41	507	281.7	190.2
	LCL	12.58	92	51.1	34.5
80	UCL	79.32	579.4	322	217.3
	LCL	14.4	105.2	58.44	39.45
90	UCL	89.24	652	362.2	244.5
	LCL	16.18	118.2	65.7	44.3
100	UCL	105.35	769.5	427.6	288.6
	LCL	19.11	139.6	77.5	52.3

UCL: Upper confidence limit; LCL: Lower confidence limit, RWH: Rain Water Harvesting

By using, the harvested rain water with COV approach, it is possible to achieve the potable water demand using the roof sizes of 80-100 m^2 and only households with a roof size of 100 m^2 were able to achieve both the non-potable water demand. But none of the households with a roof size of 40-100 m^2 can fully satisfy both the potable and non-potable daily water demand (20 liter/c/d) for a household with a family size of five (Table 5). For the COV approach, DRWH has the potential to meet 29.2-161% and 77.5-427.6% of the NPWD for households with roof area of 40m^2 and 100m^2 respectively.

RWH for institutional level emergency water supply (the prevention of COVID-19)

Using the maximum error estimate to calculate the rain water harvesting potential Dilla University referral Hospital could satisfy 94.5% of its emergency water supply needs from rain water even in the worst case scenarios (LCL) and it can achieve 140.8% of its needs using average rainfall, which is more than the (WHO 2013) requirement needed for the infection prevention tasks during this pandemic using rain water as the only source.

As Upper confidence limit using the coefficient of variation (COV) except the health centers in Dilla Town (which can achieve only 77.3% of its emergency demand), all the selected institutions can fulfill more than 100% of their demand only from the rain water as the single source. Lower confidence limit using COV, indicate that only the vocational schools in Dilla Town can achieve their demand when the rainfall declines (data regarding institutional rainwater potential can be found on the supplementary material). According to (Adugna *et al.* 2018), rooftop RWH from large public institutions can replace 0.9-649% of the water supply depending on the season of the year indicating that the importance of storage facilities to use the excess rainwater during the wet season for later uses.

Since, the rain water harvesting potential calculation (for households and institutions) assumes only 50% of the roof size, if a household or the institutions are efficient enough to utilize 100% of the roof area the outcome will be doubled which is very promising. Yet, it should be considered that the upper limit and lower limit calculation of the harvestable water volume, did not take into account the critical real life limitations associated with tank size, water losses, water pollution, or social and cultural issues that are likely to reduce the volume that can be attained in practice. Besides, the water quality issues must be a priority if rainwater has to replace other water sources for the prevention of COVID-19.

Conclusions

Based on this study result, we have concluded that rainwater can be one alternative option as a source of water for both potable and non-potable purposes in Dilla town.

A small household with a roof area of 40m^2 can cover 19.72%-108.66% of the household's emergency water demand for the prevention of COVID-19 whereas a household with a roof area of 100m^2 can cover 114.3-170.5% of the total daily water requirement.

Institutions such as Dilla University referral Hospital (DURH) 43.3-238.5% their emergency water demand needed for the infection prevention of the current pandemic which can cover from rain water as the single source.

Data availability statement

All relevant data are included in the paper or it's Supplementary Information.

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