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Capturing Rainwater for Urban Living

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Abstract – *Rainwater harvesting simply means that capturing rainwater for the usage of people. Sri Lanka has a long history of rainwater harvesting associated with ancient water harvesting systems. The existing practice of rainwater harvesting is mostly limited domestic purposes which is more effective and economical. Sri Lanka adopts rainwater harvesting policy and amends the acts and by-laws of implementing the same especially in the urban sector usage for better management of water resources. Thus, this research is focussed on identifying rainwater harvesting potential for non-potable use especially in buildings with large roof areas such as factory, public buildings, apartment complexes, etc. located in urban areas within the wet zone of Sri Lanka. Accordingly, monthly rainfall data from 1950 to 2014 for Colombo and Ratmalana have been analysed. A relationship between the probability of success and water demand for a given roof area has been developed. Results showed that for a roof area greater than 800 m^2 with a tank of 75 m^3 provide a minimum of 60% probability of success.*

Keywords: Non-potable use, Rainwater harvesting, Urban area

1 INTRODUCTION

With the beginning of civilization, people built their houses close to the natural water bodies such as lakes, springs etc. to fulfil their water requirements, which is the key to life. Rain is considered as a gift from God and our ancestors worshipped it. With an increase in population, people had to find alternatives, because they faced difficulties in drought seasons due to lack of water. This can be seen predominately in arid and semi-arid areas. Rainwater harvesting (RWH) is identified as one of the best solutions to overcome this problem.

Although close to three-fourths of our planet is made of water, not all of it is suitable for use. As a result of that, there is a constant shortage of water which is suitable for drinking, household use and industrial usage. Only 30 per cent of the total population was urban in 1950 and is expected to rise it up to 60% in 2030. However, between 1950 and 2018, the urban population in less developed regions were increased from 17% to 51% showing the higher level of urbanization in developing countries (UN, 2019). Unplanned and inadequately-managed urbanization may affect sustainable development in urban areas. Forest cover will be also reduced due to industrialization and the water pollution will also increase. This tends to a shortage of water soon and precautions should be taken to overcome this situation.

In the context of Sri Lanka, which a tropical island, is situated in between 5^0 to 10^0 North latitude and between 79^0 to 82^0 East latitude with a total of 65,610 km^2 land area. The average rainfall and the temperature of Sri Lanka vary from 900 mm to 6000 mm and 20^0 to 34^0 Celsius respectively (Department of Meteorology, Sri Lanka). The country experiences a variation of rainfall which covers both dry periods as well as excess rainfall periods throughout the year.

29% of the total population of Sri Lanka represents the urban population and only 67% of the same is supplied with pipe-borne water but not fully provided with 24-hour water supply (NWSDB, 2020). Thus, it is seen that the existing water supply is not adequate for the present rate of water consumption for domestic and day to day needs of the population, especially in urban areas. On the other, providing treated pipe-borne water for the increasing population is becoming expensive when considered with the high level of investment required and the operations and maintenance costs of improved activities in urban areas. In the light of this, Sri Lanka has achieved impressive progress in piped onto premises at the urban water supply coverage from 37% in 1991 to 67% in 2010 (Mcloughlin & Harris, 2013).

The National Water Supply and Drainage Board (NWSDB) is the sole public body responsible for water supply and sanitation facilities in Sri Lanka. NWSDB mainly divides the water supply schemes as urban and rural considering the consumption of water. Water supply schemes which have 1000 or more service connections are termed as urban water supply schemes (Ariyananda, 2007). Industrial and service sectors in Sri Lanka are mostly dependent on treated water supply provided by the NWSDB mainly, besides they use a small quantity of water pumped from groundwater and rivers. Also, the water tariff system in Sri Lanka provides water at low cost for domestic users while higher rate charges for commercial and industrial water users. At the current rate of water consumption, domestic and other water needs of the population concerning the water supply cannot be met with the current level of supply by NWSDB. Therefore, there is an urgent requirement to find different alternatives for water supply.

Although the groundwater is an alternative source of water supply it is not very suitable for direct usage in urban areas. The groundwater in urban areas is usually polluted due to the mixing of chemicals, acids and sewage. Also, the cost associated with pumping the groundwater is much higher than the existing tariff system. As Sri Lanka get sufficient rainfall throughout the year, domestic and industrial users can use RWH as an optimum method of getting water. Compared to groundwater, this is a cost-saving and less polluted way to fulfil the day to day water needs of domestic users as well as industrial users.

The rainwater harvesting projects were initially implemented in Badulla and Matara districts from 1995 to 1997 as a World Bank project especially focusing on drinking water at the domestic level (Dissanayake & Ranasinghe, 2018). Later RWH practices were gradually widespread in other areas and also extended the application towards public institutions too. Having identified the importance of water resource management and the availability of water for everybody, the Government of Sri Lanka (GoSL) assisted rainwater harvesting (RWH) projects. In 2005, the National Policy on Rainwater Harvesting and Strategy was adopted and rainwater harvesting was made mandatory for certain buildings under Municipal and Urban council areas (NRPS, 2005). Accordingly, legislations were amended to incorporate rainwater harvesting in the Municipal council and Urban Development Authority administrations (Gazette, 2007; Ariyananda & Wickramasuriya, 2009).

The application of rainwater harvesting in large housing projects, commercial and public buildings have been studied by Jayasinghe (2004), Gunatilake (2006) and Ariyananda & Wickramasuriya, (2009). Those findings explained that 50 – 70% of non-potable water demand can be supplied by using RWH with the incorporation of proper water treatment whenever necessary. It is noteworthy to examine the analysis by Lo & Koralegedara (2015) on the effects of climate change on RWH in Colombo under six different scenarios ranging from residential to non-residential. It further discussed the monthly water security of RWH systems with the selected scenarios. Thus, the main objective of this research is to provide a guideline of finding the success of the application of RWH for different water demands and a given roof size by analysing monthly rainfall data at Colombo and Ratmalana. As the research is mainly focused on urban living, only large tank capacities were considered.

2 METHODOLOGY

In the methodology, both quantitative and qualitative approaches employed for data collection and analysis. Field visits were carried out for several commercials, industrial, government and non-government bodies to collect data and information regarding the technologies used in their RWH systems and cost savings arise to those organizations as a result of implementing RWH system. Few experts in the RWH field were interviewed to identify the existing problems relating to the rainwater harvesting and to aware the currently used technologies, new techniques which can be used in this field, etc.

2.1 Rainfall Data

Colombo and Ratmalana urban areas are selected as the study area and monthly rainfall data was collected for the past 65 years from 1950 to 2014 at Colombo and Ratmalana meteorological stations.

2.2 Determination of catchment area and the runoff

The amount of rainwater collection depends on the rainfall intensity, catchment area and the runoff coefficient. The maximum amount of rainwater that can collect from the roof can be calculated using equation 1 (Gamage, 2006).

$$\text{Runoff} = A \times (\text{Rainfall} - B) \times \text{Roof Area} \quad (1)$$

Where,
A = runoff coefficient
B = Loss of rain due to absorption and wetting of the surface. This value is neglected in the calculation.
For the calculation of the catchment area, the horizontal plane area (Roof Area=XY) should be considered as shown in Fig. 1.

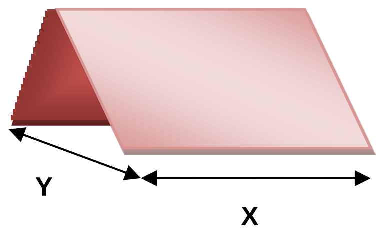

Fig. 1. Roof dimension

Runoff coefficient varies with the type of roofing material and it takes into account any loss due to leakage, overflow, evaporation and transportation. Considering different roofing materials, the Runoff coefficient is taken as 0.8 for this study. Table 1 shows the typical values for runoff coefficient for different roofing materials (*RWH Practitioners Guide for Sri Lanka, 2009*).

Table 1. Runoff coefficients for different roofing materials

Roofing material	Runoff coefficient
Galvanized iron sheet	> 0.9
Aluminium sheets	0.8-0.9
Flat Cement roof	0.6-0.7
Organic(e.g. thatched)	0.2
Tiles	0.6-0.9
Asbestos	0.8

2.3 Probability of Success

When calculating the probability of success, it is assumed that initially, the tank is full incapacity, rainwater removed in the first flush is negligible and the demand does not change with seasonal variation.

Table 2. Number of successive months for the year 1951

Month	Rainfall (mm)	Flow to reservoir (m^3)	Reservoir Deficit (m^3)	Success
January	137.0	-207.6[1]	200.0	0
February	25.0	-330.0	200.0	0
March	158.0	-223.6	200.0	0
April	165.0	-218.0	200.0	0
May	559.0	97.2	0	1
June	238.0	40.4	0	1
July	279.0	73.2	0	1
August	3.0	-147.6	147.6	1
September	329.0	-34.4	34.4	1
October	196.0	-27.6	27.6	1
November	560.0	270.4	0	1
December	149.0	-30.8	30.8	1

A sample calculation of the number of successive months for 1951 at Ratmalana is shown in Table 2. For this sample calculation, the selected tank capacity is 200 m^3, roof catchment area 1000 m^2 and the monthly water demand is 150 m^3.

The selection of success (1) is based on when reservoir deficit is less than tank capacity and failure (0) is assigned when reservoir deficit ≥ tank capacity.

[1]Calculation continues from December 1950 (-167.2 m^3)

According to Table 2, the total number of successive months in 1951 is 08.

The sample calculation for January 1951 (Table 2) is as follows:
Using equation (1), Total runoff = 0.8*0.137*1000 = 109.6 m^3
Flow to reservoir = 109.6 – 150.0 – 167.2 = -207.6 m^3
Reservoir deficit = 200.0 m^3 (Flow from reservoir > 200 m^3)
Hence failure is assigned (reservoir deficit ≥ tank capacity).

The calculation is continued to obtain the number of successive months from 1950 to 2014 in both Colombo & Ratmalana areas. The probability of success of the RWH system from 1950 to 2014 is obtained as follows:

$$\text{Probability of success} = \frac{\sum \text{Number of successive months}}{\sum \text{Total number of months considered}}$$

The total number of successive months for 150 m^3 demand with a roof area of 1000 m^2 and a tank capacity of 200 m^3 is 605, whereas the total number of months considered is 780. Thus, the relevant probability of success is 0.78 (=605/780). Also, the probability of success was calculated for six different tank capacities (75, 100, 125, 150, 175 and 200 m^3) of rainwater, with the catchment area varying from 300 m^2 to 1200 m^2 for six water demands considering the selected 65-year period. Accordingly, the probability vs demand curves was plotted for both locations.

3 RESULTS AND DISCUSSION

From the calculations of the probability of success for different roof areas and different tank capacities, the following results were obtained for Colombo and Ratmalana.

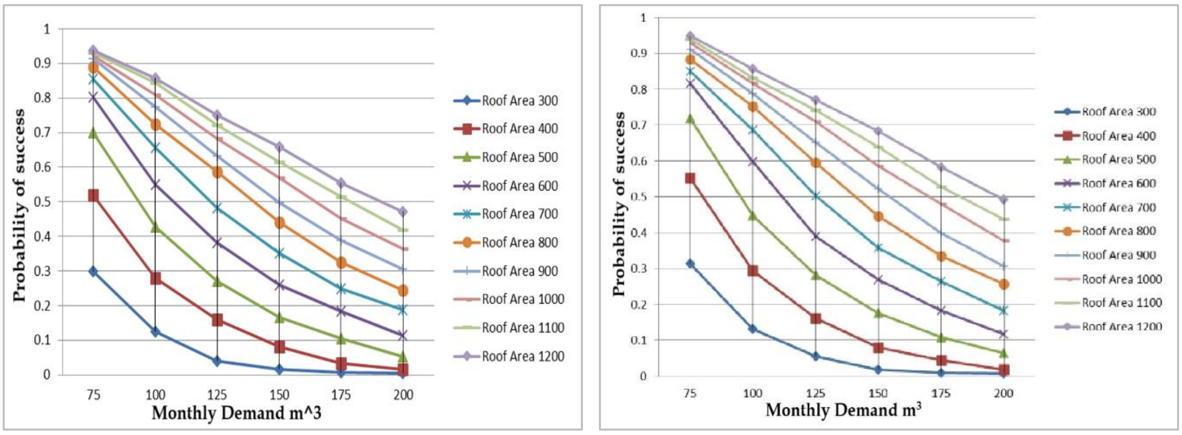

Fig. 2. Probability vs Demand curve for 75 m³ tank capacity at Colombo (Left) & Ratmalana (Right)

The results of Probability vs. Demand curves for Colombo and Ratmalana rainfall region for tank capacities of 75 m³, 150 m³ and 200 m³ are shown in Fig. 2, 3 and 4 respectively.

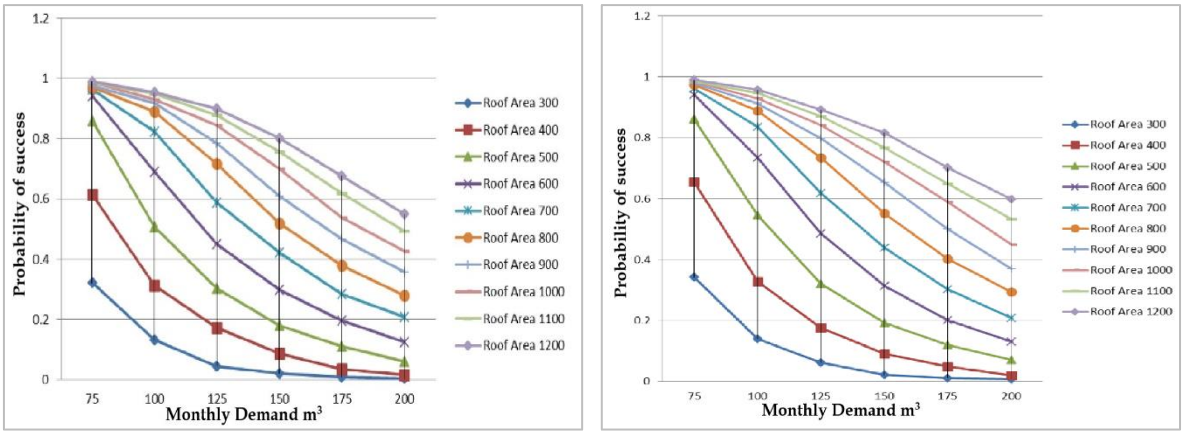

Fig. 3. Probability vs Demand curve for 150 m³ tank capacity at Colombo (Left) & Ratmalana (Right)

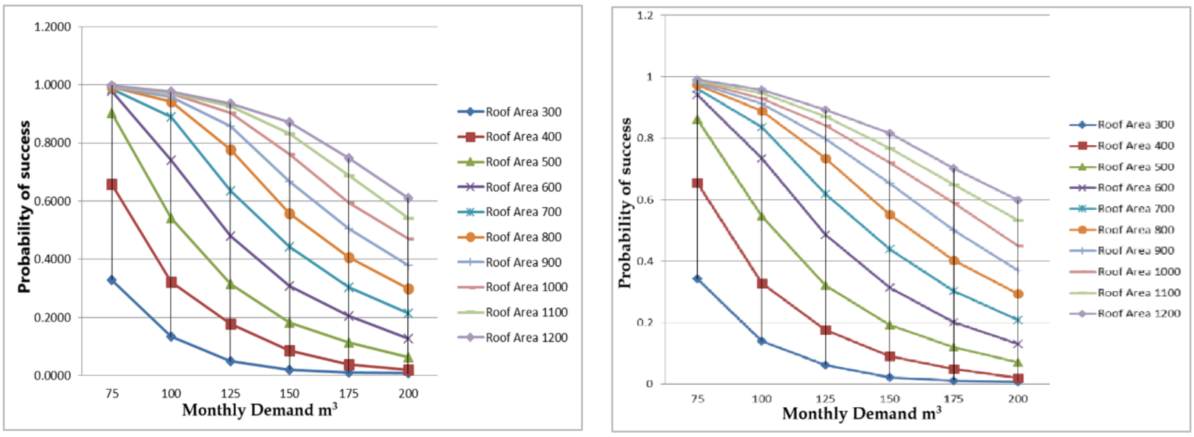

Fig. 4. Probability vs Demand curve for 200 m³ tank capacity at Colombo (Left) & Ratmalana (Right)

In many instances, the success of the RWH was calculated using mean annual rainfall data and it gives a much higher probability of success than the actual situation as shown in Fig. 5. When comparing Fig. 4 (Right) and 5, it is seen that the probability of success using monthly data is 0.78 whereas probability rises to 0.98 when using the mean annual rainfall. Thus, it can be argued that the selection of mean annual rainfall data for the calculation can be misleading in RWH. Therefore, when the tank capacities are sufficiently large, monthly rainfall data are used for the calculations and it gives more realistic results.

The analysis is limited for the tanks with large capacities and hence the effect of daily rainfall data will not significant. Because of the change in rainfall pattern and intensity due to global warming in the recent past, it is necessary to keep abreast of calculation.

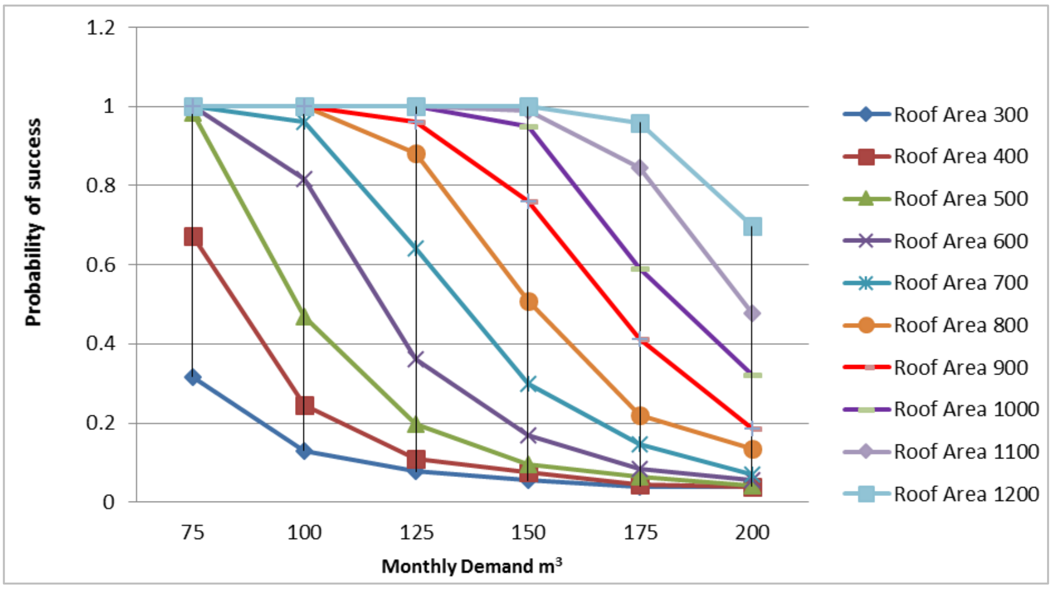

Fig. 5. Probability vs Demand curve for 200 m³ tank capacity at Ratmalana considering Mean Annual Rainfall

4 CONCLUSION

The results of the study conclude that most of the industrial buildings in Colombo and Ratmalana areas, have large roof areas greater than 800 m² and monthly water consumption (non-potable) is around 125 m³. There is a higher possibility of practising RWH and the probability of meeting the demand is as high as 60% even for the tank capacities of 75m³ in both Colombo and Ratmalana regions. Variation of the probability of success is shown in Table 3. Table 3 and figures 2 to 4 serve as a guideline to find the probability of success for the given monthly demand and roof area.

Table 3. Guideline to find the Probability of practising Success

Colombo				Ratmalana			
Tank Capacity (m³)	**Monthly Demand (m³)**	**Roof Area (m²)**	**Probability**	**Tank Capacity (m³)**	**Monthly Demand (m³)**	**Roof Area (m²)**	**Probability**
75	≤ 125	≥ 800	≥ 60 %	75	≤ 125	≥ 800	≥ 60 %
100	≤ 125	≥ 800	≥ 62%	100	≤ 125	≥ 800	≥ 65 %
125	≤ 125	≥ 800	≥ 68 %	125	≤ 125	≥ 800	≥ 70 %
150	≤ 125	≥ 800	≥ 72 %	150	≤ 125	≥ 800	≥ 74 %
175	≤ 125	≥ 800	≥ 75 %	175	≤ 125	≥ 800	≥ 77 %
200	≤ 125	≥ 800	≥ 77 %	200	≤ 125	≥ 800	≥ 80 %

The practice of RWH is universal and can be applied in different situations depending on the needs. However, it does not state that RWH can be used in every location. When the demand is very high especially in large buildings in urban areas, RWH can use to partially fulfil the demand with a higher probability of success. Therefore, the potable water used for other purposes can be saved by capturing rainwater in urban areas.

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REFERENCES

Ariyananda, T. (2007). Rainwater harvesting for urban buildings in Sri Lanka, *Proceedings of Subtropical Green Building International Conference,* Taipe, Taiwan.

Ariyananda, T. & Wickramasuriya, S. S. W. (2009). Rain water harvesting in Sri Lanka. *Economic Review,* pp. 40-45.

Dissanayake, D. M. S. B. & Ranasinghe, P. (2018). Effectiveness of national rainwater policy and strategy in Sri Lanka. *Proceedings of International Conference on Water Security through Rainwater Harvesting.*

Gamage, N. P. D. (2006). Preparation of Guidelines on use of Rainwater Tanks for Potable use, http://dl.lib.mrt.ac.lk/handle/123/14290

Gazette. (2007). Urban Development Authority Act No. 36 of 2007. Dated September 21, 2007.

Gunatilake, J. (2006). Application of rainwater harvesting in provincial building complex at new town, Ratnapura. *Engineer,* Vol. XXXIX (01), pp. 38-46.

Jayasinghe, M.T.R. (2004). Rainwater harvesting to supplement water for large housing projects. *Annual Transactions*, Institution of Engineers, Sri Lanka.

Lo, K. F. A. & Koralegedara, S. B. (2015). Effects of climate change on urban rainwater harvesting in Colombo city, Sri Lanka. *Environments,* Vol. 2, pp. 105-124.

Mcloughlin, C. & Harris, D. (2013). The politics of progress on water and sanitation in Colombo, Sri Lanka. *Politics & Governance. https://www.odi.org/sites/odi.org.uk/files/odi-assets/publications-opinion-files/8174.pdf*

National Rainwater Policy and Strategies (NRPS). (2005). Ministry of Urban Development and Water Supply, Battaramulla.

National Water Supply & Drainage Board (NWSDB). (2020). Urban Water supply policy, http://www.waterboard.lk/web/index.php?option=com_content&view=article&id=82:policies&catid=33:organization&Itemid=103&lang=en#introduction-2

United Nations, Department of Economics and Social Affairs, Population division (UN). (2019). *World Urbanization Prospects: The 2018 Revision (ST/ESA/SER.A/420).* New York: United Nations.