DEVELOPMENT OF A GRAPHICAL USER INTERFACE (GUI) FOR RAINWATER HARVESTING SYSTEM

Sabbir Ahmed*[1]

[1]*Undergraduate Student, Ahsanullah University of Science & Technology, Bangladesh, e-mail: sabbir14295drmc15@gmail.com*

***Corresponding Author**

ABSTRACT

Rainwater harvesting (RWH) system has a good potential to supply drinking and cooking water in water-scarce coastal areas in Bangladesh. However, improper design of the storage reservoir, the key element of a RWH system, can result in a failure of the system. The size of a storage tank depends not only on water demand but also on supply (precipitation amount and variability). Therefore, a dynamic reliability based tank sizing tool is imperative for the successful implementation of RWH. This paper aims at developing a graphical user interface (GUI) to ease sizing of storage tank of RWH system. A behavioral model is applied in a MATLAB environment based on a dynamic demand-supply approach to calculate the reliability of the system associated with storage tank sizes. Both time and volumetric reliability are incorporated in the model to provide with the number of days demand is fully met, and also the percent of total demand met by the system respectively. Precipitation data (1953 -2010) from the Bangladesh Meteorological Department (BMD) is used as one of the inputs to the model. In addition, household size, per capita water demand, roof area, roof material are important parameters of the model. The model shows that a 15-m^3 storage reservoir can provide 99% reliability for a typical household having a roof area of 360 ft^2 and a daily demand of 100 liters if precipitation variability in Khulna, a coastal district, is considered. However, maximum 53% reliability can be achieved from the system for the same roof configuration if daily household demand doubles (200 liters). Similar findings for two other adjacet districts (Mongla and Jessore) suggest that model results can be generalized to entire southwest coastal region in Bangladesh.

Keywords: *Coastal, GUI, Rainwater, Harvesting, Reliability.*

1. INTRODUCTION

The right to safe water is recognized as a foundation of all other human rights. According to UNICEF (UNICEF, 2018), more than 97% of the population in Bangladesh have access to improved water sources in 2013 indicating significant. However, still only 34.5% population has access to safe drinking water and 19.4 million people are still drinking arsenic contaminated water. Especially people in coastal zone are suffering from acute water scarcity, as there are relatively fewer surface water bodies there, which are frequently flooded with saline water (Hoque, 2009; Islam, Afrin, Redwan, & Rahman, 2015; Khan, Xun, Ahsan, & Vineis, 2011). So, an alternative method must be sought for. One such method is harvesting rainwater. Rainfall in the coastal areas and roof catchments are suitable for rainwater harvesting (RWH) making it a good source to supply drinking and cooking water in the coastal areas of Bangladesh (Islam, Chou, Kabir, & Liaw, 2010; Islam, Akber, Rahman, Islam, & Kabir, 2019).

Many studies have investigated different components of RWH. Some studies have assessed the financial feasibility of it (Akter & Ahmed, 2015; Bashar, Karim, & Imteaz, 2018), while others applied different modelling approach to calculate how reliable the system is (Islam, Afrin, & Rahman, 2015a; Islam, Chou, & Kabir, 2011; Islam, Afrin, & Rahman, 2015, 2016). The feasibility of RWH system for purposes other than domestic uses (e.g. irrigation and water sensitive urban design) have been explored in some studies (Ghimire & Johnston, 2019; Wahab, Mamtaz, & Islam, 2016). However, lack of interactive rainwater tank sizing curves in coastal zones in Bangladesh prohibit people getting full benefit from RWH system.

This study aims at developing graphical user interface (GUI) of RWH system to make rainwater tank size choosing easy. It takes precipitation variability of three coastal districts into account while developing the tank sizing curves to make the GUI robust as Bangladesh shows distinct seasonal pattern in precipitation (Islam, Afrin, Ahmed, & Ali, 2014, 2015; Islam, Afrin, Redwan, et al., 2015). This paper presents tank sizing curves for RWH system considering both volumetric and time reliability concept.

2. METHODOLOGY

2.1 Study Area

This paper focuses on three coastal districts in Bangladesh: Khulna, Jessore and Mongla as people there have been suffering from water scarcity for a long time. The fresh surface water and ground water sources in those coastal areas are contaminated with saline water (Islam, Afrin, & Rahman, 2014, 2015; Islam, Afrin, Redwan, et al., 2015)

2.2 Data Collection

I collected precipitation data of three study sites from Bangladesh Meteorological Department (BMD). It was daily rainfall data ranging from 1950 to 2010. The study sites have residential, commercial, educational and other community buildings having roof area ranging from 45 ft^2 to 5000 ft^2 (Islam, Afrin, & Rahman, 2015; Islam et al., 2015, 2016). For the sensitivity analysis and inter-site comparison, I used a roof area of 360 ft^2.

2.3 Behavioral Model Development

I applied behavioral model in MATLAB environment for the reliability analysis. The behavioral model is a powerful and reliable tool for assessing performance of rainwater harvesting system (Islam, Afrin, & Rahman, 2015; Islam et al., 2015, 2016). This model is based on mass balance equation. The mass balance equation depends on demand and supply. I used rational formula to get supply matrix. The supply and demand equations can be mathematically illustrated as:

$$Supply = C * I * A \quad (1)$$

$$Household\ Demand = per\ capita\ water\ demand * family\ size \quad (2)$$

Where,
I = rainfall intensity
C = coefficient of runoff
A = catchment area

Roof characteristics were assumed same for all the three study sites, and 0.85 was used as the coefficient of runoff. It was also assumed that historical rainfall data accurately reflects the rainfall pattern of the study sites. I used two fundamental algorithms- yield after spillage (YAS) and yield before spillage (YBS) developed by (Jenkins, 2007) to reflect the actual behaviour of a rainwater tank. The YAS algorithm is shown in Equation 3 and 4:

$$Yt = \min\begin{cases} D_t \\ V_{t-1} \end{cases} \quad (3)$$

$$Vt = \min\begin{cases} V_{t-1} + Q_t - Y_t \\ S - Y_t \end{cases} \quad (4)$$

Where
D_t = Demand at time t
V_{t-1} = Volume of water in tank at time t-1
Q_t = Inflow to tank at time t
Y_t = Yield at time t

In YBS algorithm, water is extracted before tank overflow. The YBS algorithm is shown in Equation 5 and 6.

$$Yt = \min\begin{cases} Dt \\ Vt - 1 + Qt \end{cases} \quad (5)$$

$$Vt = \min\begin{cases} Vt - 1 + Qt - Yt \\ S \end{cases} \quad (6)$$

2.4 Graphical user interface (GUI) development

I applied 'Graphical User Interface Development Environment (guide)' in MATLAB to develop the GUI for the RWH system. I developed it in a way that it can take the inputs from the users that are necessary for tank sizing curve generation. The basic inputs for the GUI are roof area, water demand and family size. It has a provision to select any of the three study sites considered in this study.

3. ILLUSTRATIONS

3.1 Volumetric reliability

Figure 1 shows the volumetric reliability (R_v) RWH system for different storage tank sizes in three study sites for three different household water demand scenarios. In Khulna, RWH can have 99.7% volumetric reliability for 50 and 100 liter per day demand scenario (Figure 1-a). However, 100 liter per day demand requires higher storage tank size to get it. Interestingly, R_v shows a nearly linear increase with tank size before reaches to its maximum value for the 100 liter per day demand. When demand is high (200 liter per day), R_v does not increase much with storage tank size and has a maximum value of 52%. Rv shows similar trend with storage tank sizes for the three-demand scenario in Mongla and Jessore (Figure 1-b, c). However, under the high demand scenario (200 liter per day), RWH achieves higher R_v in Mongla and Jessore than that in Khulna. A previous study (Islam, Afrin, Redwan, et al., 2015) conducted in Mongla reported similar R_v for the typical roof areas suggesting the validity of the model in this study.

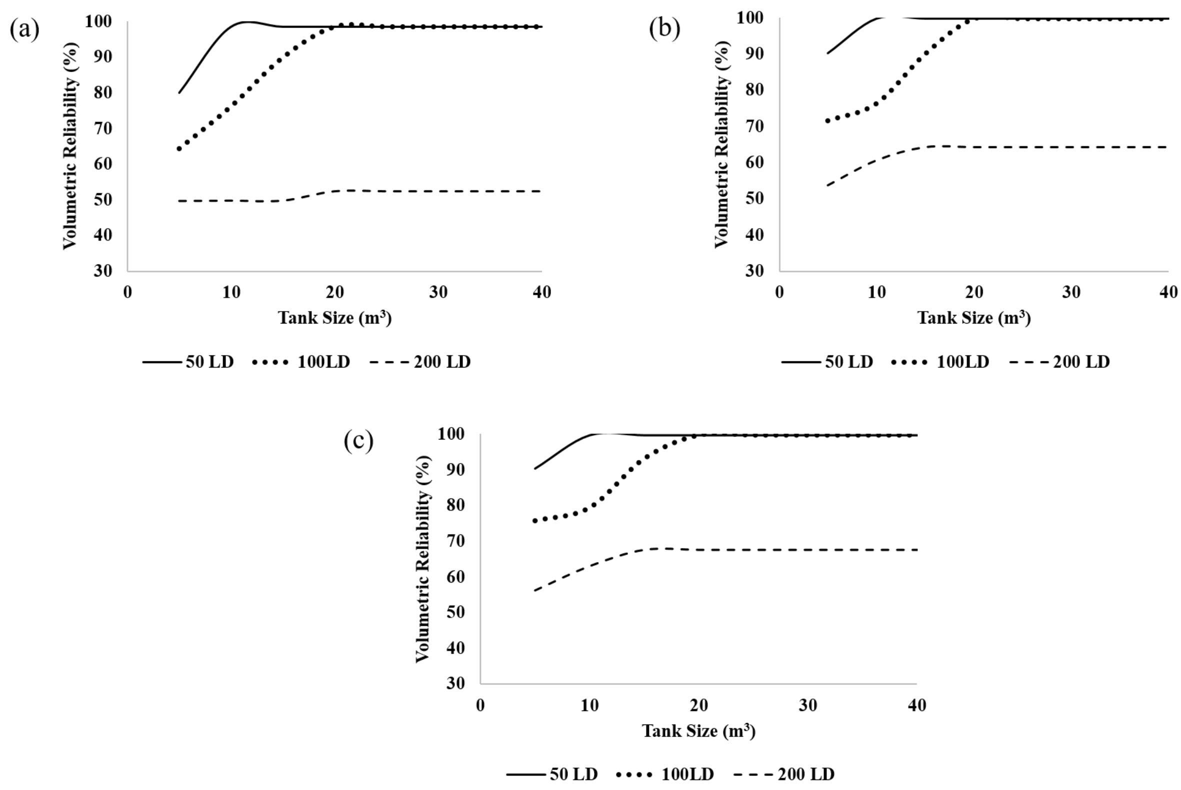

Figure 1: Volumetric reliability curves for (a) Khulna, (b) Mongla and (c) Jessore

3.2 Time reliability

Figure 2 shows the time reliability (R_t) curves of RWH system in three study sites for three different household water demand scenarios. Like Rv, Rt reaches to its maximum earlier for 10 liter per day demand (10 m^3) relative to other two higher demand scenario in all three study sites. In general, RWH shows promise in terms of R_t for the 50 and 100 liter per day scenario in all three sites. Among the three sites, R_t is the highest in Khulna for any tank size indicating that RWH in Khulna can endure higher percentage of days when demand is fully met compared to Mongla and Jessore.

3.3 Graphical user interface (GUI)

As mentioned earlier, the main objective of this study is to develop an interactive GUI to ease deciding about the appropriate tank size. Figure 3 shows the GUI developed for sizing storage tank. The inputs are roof area, household water demand and family size. It also has a provision to take input about the location. Right now, user can choose any of the three locations. The output is a reliability curve for different tank sizes that will help choose the suitable storage tank size given the roof and water demand characteristics of the household.

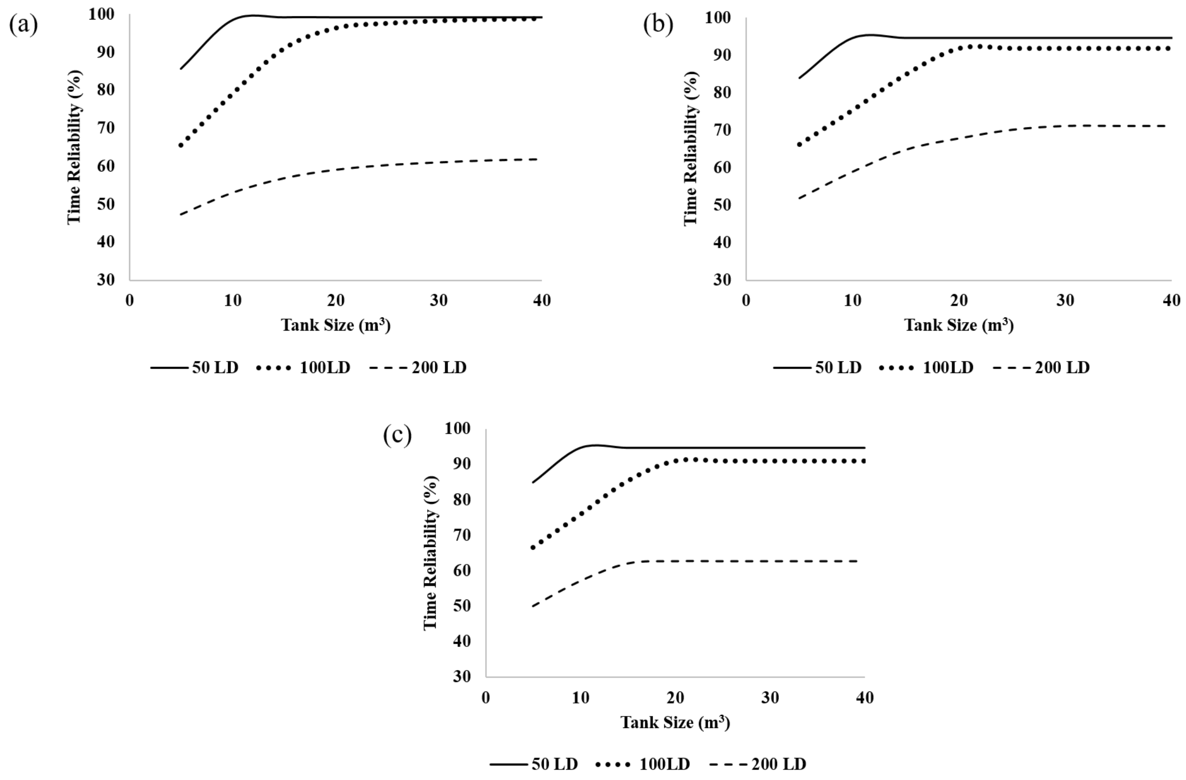

Figure 2: Time reliability curves for (a) Khulna, (b) Mongla and (c) Jessore

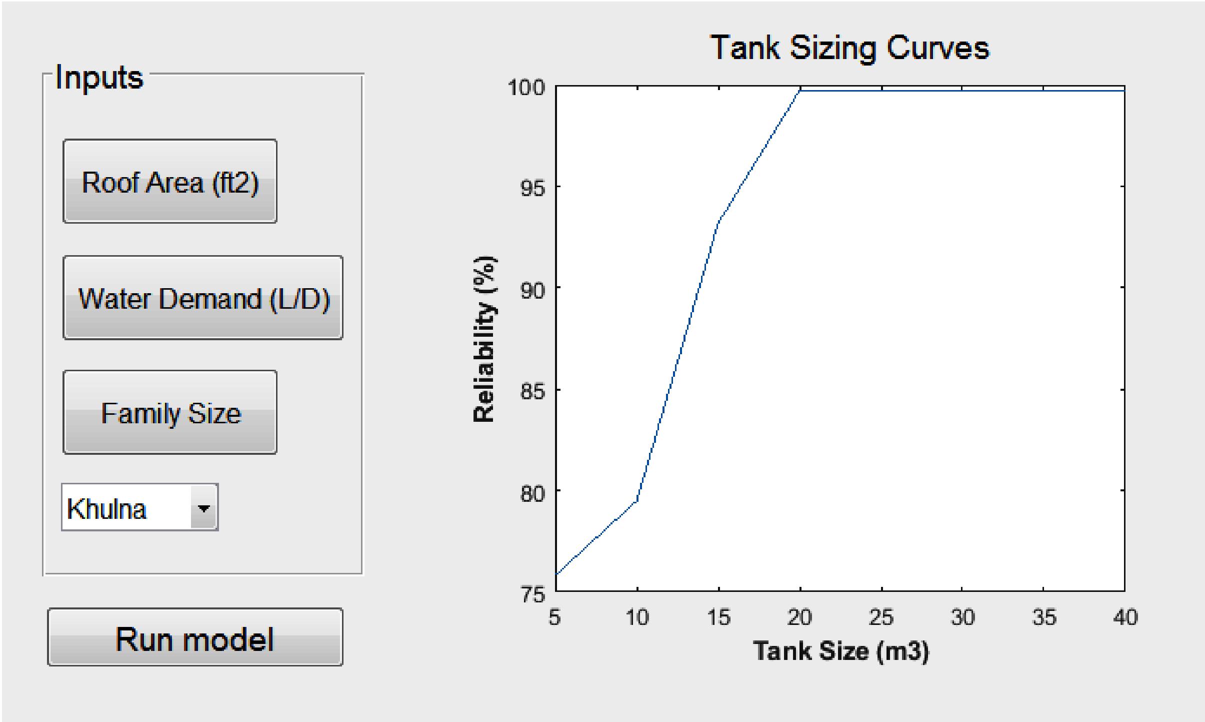

Figure 3: Graphical user interface for the RWH tank sizing

4. CONCLUSIONS

This study develops a graphical user interface to get reliability-based storage tank sizing curves. This user-friendly GUI would encourage people in coastal areas implementing RWH system. This paper also does a comparison of RWH reliability between three adjacent coastal districts in Bangladesh. Both volumetric and time reliability curves show similar trend between the study sites suggesting that RWH system designed according to precipitation scenario of any southwest coastal districts should work for the whole region. RWH shows promise to meet lower household water demand. However, for higher water demand, consistently lower reliability with storage tank size increase indicates that household either needs to extend the roof catchment to harvest more water or manage other sources to meet their excess water demand.

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