FINANCIAL FEASIBILITY ASSESSMENT OF RAINWATER HARVESTING SYSTEM IN COASTAL BANGLADESH CONSIDERING PRECIPITATION VARIABILITY DUE TO CLIMATE CHANGE

Mohammad Maksimul Islam*[1] and Sadia Afrin[2]

[1]Assistant Professor, Bangladesh University of Engineering and Technology (BUET), Bangladesh, e-mail: maksimulislam075@gmail.com
[2]Assistant Professor, Bangladesh University of Engineering and Technology (BUET), Bangladesh, e-mail: sadiaafrin9888@gmail.com

***Corresponding Author**

ABSTRACT

Rainwater harvesting system (RWH) is considered an environmentally sound solution to provide safe drinking water. It is particularly suitable for Bangladesh because of its having tropical monsoon with a large seasonal cycle in rainfall. Although few studies dealt with the technical feasibility of the RWH system, reliability based cost-benefit analyses are still scarce. This study aims at assessing the financial feasibility of RWH system in Khulna, a coastal district in Bangladesh. We apply a mass balance based behavioral model named 'Yield-After-Spillage (YAS)' to conduct reliability analysis. We use historical as well as future predicted rainfall data in the model to explore the effect of climate change on reliability and financial feasibility. We conducted a social survey to collect necessary information related to RWH system including roof area, roof material, water demand, existing water supply system and cost of materials. Cost-benefit analysis reveals that 85-95% of total RWH installation cost is for the storage reservoir, making it the most expensive unit of the system. We find 'net present value (NPV)' of a typical RWH system positive indicating that RWH is a financially viable solution in the study area. Payback period varies between 3-13 years depending on the precipitation variability. For 100 litre/day demand, predicted rainfall for the 2041-2070 period showed 1.5 times larger storage tank requirement compared to that for historical precipitation scenario to attain 90% volumetric reliability, which results in a substantial increase in cost, and 20% reduction in NPV. However, for 200 litre/day demand, historical precipitation scenario cannot provide more than 53% reliability.

Keywords: *Cost-benefit, Rainwater, Harvesting, Reliability, Climate-change.*

1. INTRODUCTION

Globally around 1.1 billion people do not have access to safe water (Shaw & Thaitakoo, 2010). However, a safe and reliable source of water is imperative for leading a healthy life (Hunter, MacDonald, & Carter, 2010). According to the Safe Drinking Water Foundation (SDWF, 2018), unsafe drinking water and waterborne diseases cause 80% of all illness in developing countries. Water-related diseases also attributes to 3 million death annually, majority of which are the children under the age of five (World Bank, 2002). Water scarcity is expected to increase in the near future due to climate change (Umetsu, Donma, Nagano & Coşkun, 2019). Especially in coastal Bangladesh, sea level and temperature are predicted to rise along with more frequent extreme events (e.g. floods, droughts, storms) due to climate change (Khan, Xun, Ahsan & Vineis, 2011), which will make scarcity of potable water acute there as coastal people rely on either fresh surface water bodies (rivers, ponds) or ground water (tube well). Around 30 million people there do not have access to safe drinking water and half of them are forced to drink saline water (Hoque, 2009). However, suitable rainfall pattern in coastal areas in Bangladesh makes rainwater harvesting (RWH) system a potential source of potable water, and a medium to fight against water scarcity (Islam, Afrin, & Rahman, 2015b; Islam, Afrin, Redwan, & Rahman, 2015; Islam, Chou, Kabir & Liaw, 2010)

RWH system has many aspects to explore. Some studies focused on assessing reliability (Bashar, Karim, & Imteaz 2018; Islam, Afrin, Redwan, et al., 2015; Islam, Afrin & Rahman, 2015), financial feasibility (Karim, Bashar, & Imteaz, 2015) and water quality (Islam, Akber, Rahman, Islam & Kabir, 2019); some investigated its applicability in urban and rural areas, in irrigation (Ghimire & Johnston, 2019) and in water sensitive water designs (Wahab, Mamtaz & Islam, 2016). However, few studies focused on coastal Bangladesh. For example, Islam (Islam, Afrin, & Rahman, 2015b, 2016) applied behavioral, and storm water management model (SWMM) to calculate reliability of RWH for available roof areas in coastal Bangladesh. Water quality measurement of rainwater to assess its viability for coastal schools is explored in some studies (Islam et al., 2019). However, cost-benefit analysis of RWH, which is a main concern for poor coastal people, has not been explored adequately. There are some studies (Akter & Ahmed, 2015; Bashar et al., 2018; Islam, Chou, & Kabir, 2011; Karim et al., 2015) that conducted economic analysis of RWH system for urban cities in Bangladesh only. Therefore, there is a need of financial feasibility assessment of RWH in coastal Bangladesh.

In this paper, we assess the financial feasibility of RWH system in a typical household in coastal Bangladesh. We also conduct reliability analysis of the RWH to provide a complete picture of it to coastal people. This study is a part of a big study focusing on reliability and economic analysis of a community based RWH system in coastal Bangladesh.

2. METHODOLOGY

2.1 Study Area

Since this study intends to explore reliability and financial feasibility of rainwater harvesting system in a water scarce coastal area of Bangladesh, we chose Paikgacha pourashava under Khulna district as the study area. Paikgacha is about 67.2 km from Khulna city corporation and very near to Kobadak River. This river and tube wells here are contaminated with high saline water. Pond water is available and comparatively less saline but during cyclone or flood disaster, sea water enters into the ponds and makes the water saline.

2.2 Site survey

We conducted a site survey to get acquainted with the study area and also to collect necessary data for the study. We collected information regarding family size, roof catchment, water demand and existing water supply systems. We also visited local markets to gather information about the cost of different components required for RWH system. We did not discuss outcomes of the site study in this paper.

For this paper, we used the information from the site survey needed for the reliability and economic analysis.

2.3 Mass balance model and inputs

We applied mass balance model (supply vs demand) to calculate reliability of RWH system. I also adopted yield after spillage (YAS) behavioral approach in the mass balance (Fewkes & Butler, 2000). In this paper, we calculated volumetric reliability as a performance indicator that is the fraction of total demand met by the RWH system (Islam, Afrin & Rahman, 2015a; Islam et al., 2016; Karim et al., 2015; Liaw & Tsai, 2004). In the mass balance, I calculated supply matrix using the rational formula that provides the volume of water harvested from a roof catchment (Islam, Afrin, & Rahman, 2015b). Demand matrix is calculated as the product of per capita water demand and family size. The inputs of the supply and demand matrices are discussed in the following sections.

2.3.1 Rainfall Intensity and runoff coefficient

Since we wanted to see how reliability and cost-benefit of RWH system would change under precipitation variability (Islam, Afrin, Ahmed & Ali, 2014, 2015) and future precipitation scenario due to climate change (Rajib, Rahman, Islam & McBean, 2011), we used both historical observed and future predicted precipitation data in this study. We collected historical observed data of the study area from Bangladesh Meteorological Department (BMD). We used future predicted data from a previous study (Rajib et al., 2011) in which a regional climate model PRECIS was used. This data was monthly data predicted up to 2100. We divided the future predicted data into three time periods (2011-2040, 2041-2070 and 2071-2100) to understand clearly the future precipitation trend. Among the three time periods in future, average monthly predicted rainfall was higher during 2071-2100 in all twelve months. For the runoff coefficient (Gould & Nissen-Petersen, 1999), we applied a value of 0.80 that was used in some studies for the study area (Islam, Afrin & Rahman, 2014; Islam, Afrin, Redwan, et al., 2015).

2.3.2 Catchment Area

As mentioned earlier, this paper is a part of a study aiming at exploring reliability and feasibility of community RWH. We obtained roof areas of the study area from the Local Government Engineering Department (LGED). Study area comprises roofs of residential, commercial, educational and other community buildings. For this paper, we used 400 ft2 as the roof area that is the average of all residential households in that community.

2.3.3 Water demand and family size

Water demand is a critical part of the mass balance needed to calculate the appropriate tank size of a household. Household water demand is the product of family size and per capita water demand. During the site survey, we got an idea of the range of water demand and family size of different households. For this paper, we used three household water demand scenarios: 100, 150 and 200 litre per day. We used a family size of 5 members for the inter-period and inter-demand comparison analysis.

2.4 Cost-benefit analysis and inputs

The cost of a rainwater harvesting system is basically dependent on four elements: roof catchment, guttering, first flush device and storage tank (Islam et al., 2010). Moreover, there are some auxiliary elements such as treatment, pump, overhead tank, operation and maintenance etc. Of these, the roof and the tank are critical in terms of costing. Since most people will have a roof on their house, this may not immediately be the biggest cost, except when it is necessary to improve the roof for water quality reasons. On the other hand, the cost of a storage tank is often high. Table 1 summarizes the installation cost elements of individual rainwater harvesting system.

Table 1: Cost elements of individual rainwater harvesting system

Installation		Operation and Maintenance	Treatment
Storage	**Collection**		
Storage Tank	Gutter	Electricity	UV disinfection
Pump	Coarse filter	Replacing pump	
Riser pipe	Downpipe		
Overhead tank			

2.4.1 Collection System

Collection system involves collection of rainwater from roof to storage tank through gutter, coarse filter and downpipe. The roof materials of the buildings of the study area were satisfactory for a rainwater harvesting system. Therefore, no costs associated with the roof material were considered. Usually UPVC (Unplasticized polyvinyl chloride) pipes are used for making gutter and downpipe. The local market price of 4" standard UPVC pipe is 52 BDT/ft. Coarse filter is placed at the entrance of the rainwater collection system as a primary treatment system that costs 150 BDT/piece.

2.4.2 Storage System

Storage system involves storage reservoir, pump, riser pipe and overhead water tank. Through downpipe water comes from roof and finally accumulates in the storage tank. After that, water is lifted up to overhead water tank by pumping to distribute with enough pressure. Storage tank is the costliest part of rainwater harvesting system. Prior to cost estimation, design had to be done for the storage tank. Conventionally reinforced concrete tanks have been used as storage tank for several decades. The Portland Cement Association (PCA) has publications for designing rectangular tanks, which is comprised of tables of coefficients for calculating moment and shear in two-way slabs (Portland Cement Association, 1996).

After designing the tank, cost was calculated for each tank. Local market price of brick, cement, sand, and rod was collected and summarized in Table 2. Labour cost and transportation cost were also considered while calculating cost.

Table 2: Local market price of cement, sand, brick and rod

Item Description	Unit	Per Unit Cost (BDT)
Best Quality Brick	nos.	7.5
1st class Brick chips	cft	75
Kushtia Sand	cft	30
Cement	bags	410-450
Rebar	ton	57500

Price of pump varies with capacity (HP). There are many pump manufacturing companies in Bangladesh and almost all companies provide two years' warranty for the pumps. We collected the market price of pumps of some prominent companies available in local market and used it in cost-benefit analysis. Different companies have different rates for various HP. We chose the most reasonable price for pump depending on required HP. Desired pump capacity depends on demand and total head to be supplied. Higher the demand and head, higher would be the desired capacity. The formula for determining the pump capacity is as follows:

$$Pump\ Capacity\ (HP) = \frac{H \times Q}{3960 \times Efficiency} \tag{1}$$

Where,
H= Total Head (ft)
Q= water demand (gpm)

Food grade plastic water tanks are popular now as overhead water tank (OHT) and it is comparatively less costly than RCC tank. The price of tanks varies with capacity; however, for a particular specification, price does not vary much among the manufacturing companies. In addition, overhead tank height is an important parameter to supply water to households at adequate pressure. For individual household-based community system, OHT will be above the roof by an elevated structure. We calculated from pressure requirement of the fixtures that tank height above the roof should be minimum 14 ft.

2.4.3 Operation, maintenance and treatment system

Operation cost is the cost of electricity required to run the pump. Since warranty period of pumps is two years, price of pump is also included as maintenance cost for every two year. There are three sequential options of the treatment of rainwater for harvesting: filtration, first flush and disinfection (Kloss, 2008). Coarse filter at the entrance of the rainwater collection system works as a filter. The first flush of rainwater after a dry period helps to clean dust, bird droppings etc. from roof (Rashid & Ahmed, 2012). Locally PVC pipes are used for making first flush device as low-cost technology. Local market price of 4” standard UPVC pipe is 76 BDT/ft. Nowadays UV disinfection process is being used for rainwater harvesting system as UV inactivates general bacteria, total Coliform and E. coli (Redwan, Ghosh & Rahman, 2014) and it is not a costly method. It should be mentioned that to be effective, the water passing though the UV system must be relatively clear and free of particles. The coarse filter and first flush prior to UV system fulfil this criterion. The UV bulbs are of different power. Higher the power, higher the amount of treated water or lower the time required for deactivation of pathogens. The cost of bulbs also varies with power. The capacity, deactivation time and costing are provided on Table 3

Table 3: Capacity, deactivation time and costing (without jacket) of UV disinfection process (adapted from Redwan et al., 2014)

Power of UV bulb (W)	Water treatment capacity (Liter)	Required Deactivation Time (min)	Cost (BDT)
6W	100	30	2500
16W	500	30-45	3500
25W	500	20	4500
55W	3000	30	6000

2.4.4 Benefit element

Local people buy jar water to fulfil the demand. Different NGOs of the study area supply this jar water and each jar contains 10-30 litre water. Benefits of operating RWH facility is altering of charge of this jar water with rainwater. The jar water charge is BDT 0.8 per litre, so by multiplying it with annual rainwater usage, annual benefit was calculated.

2.4.5 Parameters of cost-benefit analysis

We used net present value (NPV) and payback period as the financial indicators for assessing financial feasibility of RWH system under different precipitation and demand scenarios. RWH system has start-up expenditures, operational expenditures (outflow), and incoming cash (inflows) over its economic life. In this paper, we considered an economic life of 20 years, although storage tank and PVC pipes can last more than that. We converted all costs and benefits to present values using a discount rate of 5% as established as an average by the Central Bank of Bangladesh. This rate is also used by Department of Public Health Engineering (DPHE) for evaluation of their long term projects.

3. ILLUSTRATIONS

3.1 Reliability

As mentioned earlier, precipitation data are available from 1950 to 2100 of the study areas in which 1950-2010 are historical observed data. To assess the effect of climate change, we consider four consecutive time periods (1950-2010, 2011-2040, 2041-2070 and 2071-2100), and calculate volumetric reliability for each period applying the behavioural model for a typical household in the study area having a roof area of 360 ft2 and family size of 5 members for different tank sizes. Figure 1 shows the volumetric reliability (Rv) curves for four time periods for two daily household demand of 100 and 200 litre. Highest Rv (99.7%) can be achieved for historical precipitation data at a tank size of 20 m3 for 100 litre/day demand (Figure 1-a). 2011-2040 and 2071-2100 time periods show similar trend of Rv. In both cases, maximum achievable Rv (91.7) occurs at a tank size of 15 m3. 2041-2070 scenario also gives same maximum Rv as the other two predicted scenarios; however, for a larger tank size (25 m3). Higher precipitation in 2011-2040 & 2071-2100 compared to 2041-2070 seems the reason for this. Rv curves for the future predicted scenarios for the water demand of 200 litre/day (Figure 1-b) are similar to lower demand of 100 litre/day (Figure 1-a), although the tank sizes required to attain maximum Rv were larger for the higher household demand. Interestingly, Rv shows a drastic change between higher and lower demand for the historical observed period. Although maximum achievable Rv is the highest for 100 litre/day demand, it is the lowest for 200 litre/day demand for 1951-2010 period indicating that both demand and precipitation scenario play a major role in sizing storage tank for RWH

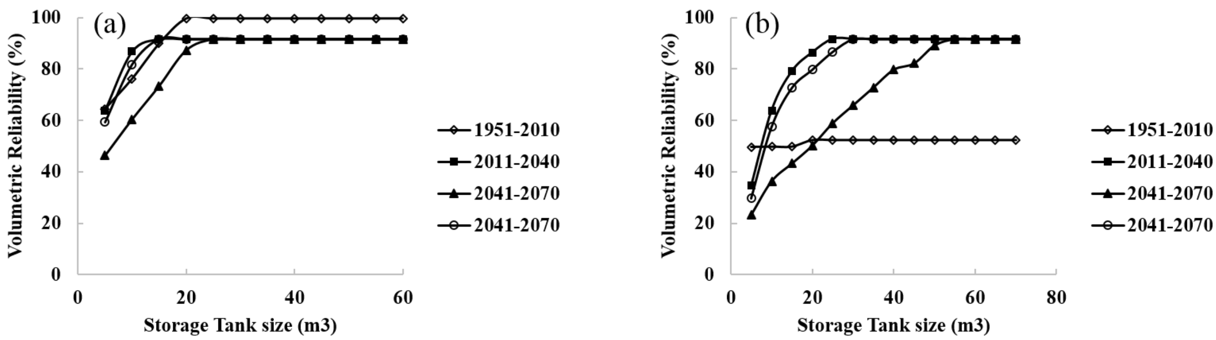

Figure 1: Volumetric reliability curves considering four different precipitation scenarios for (a) 100 litre/day and (b) 200 litre/day household water demand

Volumetric reliability appears to be significantly higher for two time periods in future (2011-2040 & 2071-2100) compared to historical period whereas reliability in 2041-2070 seems lower (Figure 4.10). Higher precipitation in 2011-2040 & 2071-2100 compared to other two periods is the reason for this. However, in each case, maximum reliability that could be achieved is about 91% and increase in tank size cannot increase the reliability. The main difference among the curves is the minimum tank size for which that maximum reliability is achieved. These minimum tank sizes corresponding to highest volumetric reliability are 2000, 2200, 1200 and 1400 m³ for 1950-2010, 2011-2040, 2041-2070 and 2071-2100 time periods respectively.

3.2 Cost-benefit analysis

3.2.1 Cost of different component of RWH

As a part of the cost benefit analysis, we want to compare the cost of all major components of a RWH system in the study area. Figure 2 shows the proportion of cost of different components for 100 and

200 litre/day demand for the 2011-2040 scenario. Storage tank sizes associated with 90% Rv are considered for the cost calculation. In both cases, storage system is the costliest part of the entire system (94-97%). In storage system, costing of central storage tank is the highest. Cost of operation & maintenance (O & M), collection and treatment system are lower but close to each other.

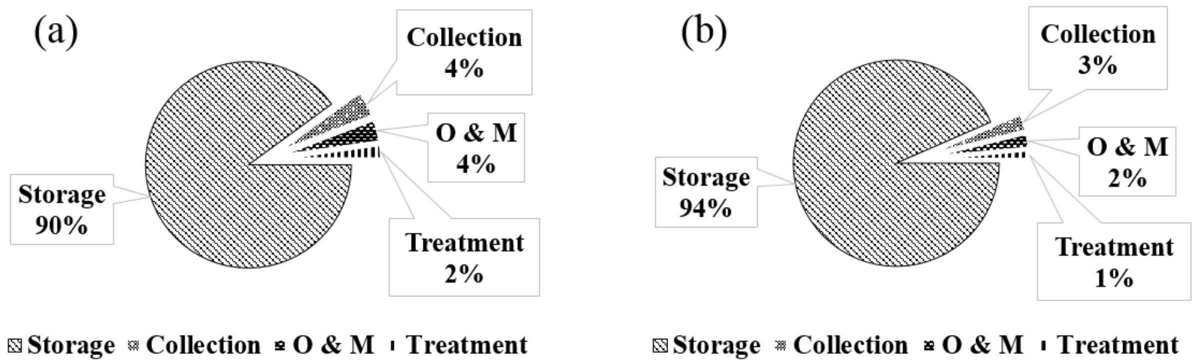

Figure 2: Proportion of cost of major components of RWH system for (a) 100 litre/day and (b) 200 litre/day household water demand

3.2.2 Net present value (NPV)

Figure 3 shows NPV associated with the RWH system for four time periods, and three household demands. As mentioned earlier, storage tank required for 90% Rv was considered for the cost-benefit analysis for each scenario. Since, 90% Rv is not achievable for 1951-2010 period, NPV is not calculated and shown in the figure. For each time period, a higher water demand shows a reduction in NPV. Increase in storage tank size associated with 90% Rv with increased household demand makes the overall cost of the system higher and thus NPV lower. Note that, reduction in NPV with higher water demand is substantially higher for 2041-2070 period compared to other two predicted precipitation scenario suggesting that household water demand should be chosen based on the precipitation scenario of the area to get a profitable RWH system.

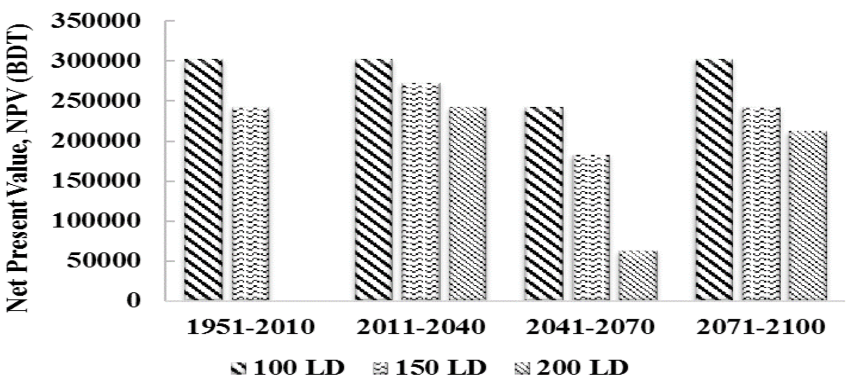

Figure 3: NPV of RWH systems considering four different precipitation scenarios for three different household water demands. Storage tank sizes associated with 90% R_v are considered for this calculation.

3.2.3 Payback period

Figure 4 shows the cumulative NPV at each successive year of the economic life of RWH system to indicate the payback period for the 2011-2040 scenario. Three water demands are considered as before to see the effect of water demand on payback period. When demand is 100 liter/day, payback period is 4 year indicating that it takes 4 year to recover initial investment for the RWH system. If the water demand doubles (200 liter/day), payback period also almost doubles (7 year). This figure indicates that for a typical household in the study area, RWH system is profitable; however, it takes years to get back the initial cost depending on the water demand to be met.

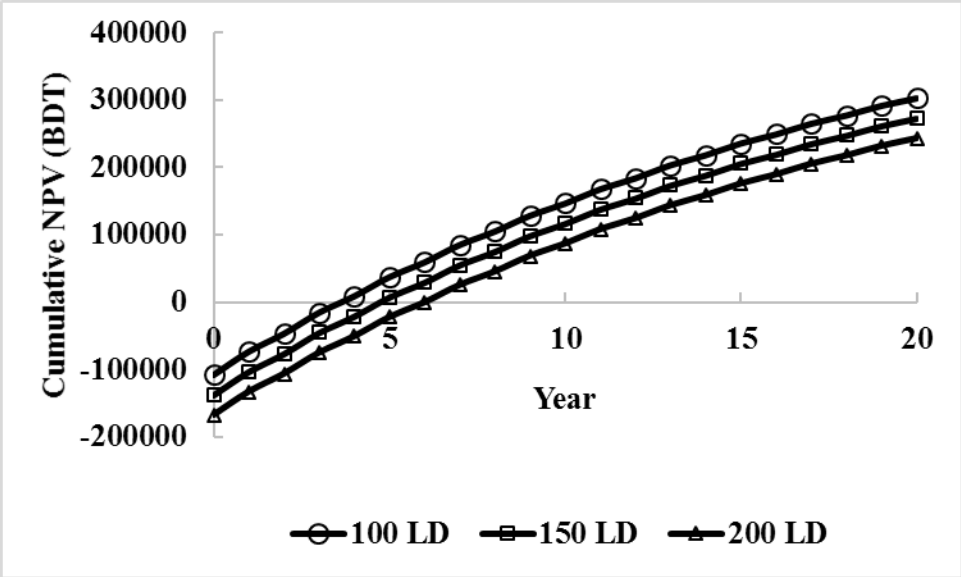

Figure 4: Cumulative NPV in each successive year of the economic life of RWH systems for three different household water demands. Storage tank sizes associated with 90% R_v are considered for this calculation.

4. CONCLUSIONS

This study assesses financial feasibility of RWH system in a typical household in a coastal district in Bangladesh. Results show that RWH is financially viable in the study area. However, for a higher water demand scenario, NPV decreases and payback period increases. Relative proportion of costs of major components of RWH does not change with water demand though. This study also conducts reliability analysis. Precipitation variability under future climate change scenario seems to affect reliability of RWH of the study area. For 100 litre/day demand, predicted rainfall for the 2041-2070 period showed 1.5 times larger storage tank requirement compared to that for historical precipitation scenario to attain 90% volumetric reliability. However, for 200 litre/day demand, maximum 53% reliability can be achieved for historical precipitation scenario.

REFERENCES

Akter, A., & Ahmed, S. (2015). Potentiality of rainwater harvesting for an urban community in Bangladesh. Journal of Hydrology, 528, 84–93. https://doi.org/10.1016/j.jhydrol.2015.06.017

Bashar, M. Z. I., Karim, Md. R., & Imteaz, M. A. (2018). Reliability and economic analysis of urban rainwater harvesting: A comparative study within six major cities of Bangladesh. Resources, Conservation and Recycling, 133, 146–154. https://doi.org/10.1016/j.resconrec.2018.01.025

Fewkes, A., & Butler, D. (2000). Simulating the performance of rainwater collection and reuse systems using behavioural models. Building Services Engineering Research and Technology, 21(2), 99–106. https://doi.org/10.1177/014362440002100204

Ghimire, S. R., & Johnston, J. M. (2019). Sustainability assessment of agricultural rainwater harvesting: Evaluation of alternative crop types and irrigation practices. PLOS ONE, 14(5), e0216452. https://doi.org/10.1371/journal.pone.0216452

Gould, J., & Nissen-Petersen, E. (1999). Rainwater Catchment Systems for Domestic Supply. https://doi.org/10.3362/9781780445694

Hoque, M. R. (2009). Access to safe drinking water in rural Bangladesh: Water governance by DPHE. Retrieved from http://dspace.bracu.ac.bd/xmlui/handle/10361/279

Hunter, P. R., MacDonald, A. M., & Carter, R. C. (2010). Water Supply and Health. PLoS Medicine, 7(11). https://doi.org/10.1371/journal.pmed.1000361

Islam, M. A., Akber, Md. A., Rahman, Md. A., Islam, Md. A., & Kabir, Md. P. (2019). Evaluation of harvested rainwater quality at primary schools of southwest coastal Bangladesh. Environmental Monitoring and Assessment, 191(2), 80. https://doi.org/10.1007/s10661-019-7217-6

Islam, M. M., Afrin, S., Ahmed, T., & Ali, M. A. (2015). Meteorological and seasonal influences in ambient air quality parameters of Dhaka city. Journal of Civil Engineering (IEB), 43(1), 67–77.

Islam, M. M., Afrin, S., & Rahman, M. M. (2015a). A comparative analysis between the application of rational formula and SWMM model for modeling community rainwater harvesting system. Proceedings of International Conference on Recent Innovation in Civil Engineering for Sustainable Development (IICSD-2015). Gazipur, Bangladesh.

Islam, M. M., Afrin, S., & Rahman, M. M. (2015b). Reliability Analysis of Community Rainwater Harvesting System Considering Precipitation Variability Due to Climate Change. Proceedings of International Conference on Recent Innovation in Civil Engineering for Sustainable Development (IICSD-2015). Gazipur, Bangladesh.

Islam, M. M., Afrin, S., Redwan, A., & Rahman, M. M. (2015). Impact of Climate Change on Reliability of Rainwater Harvesting System: A case Study in Mongla, Bangladesh. Proceedings of 10th Global Engineering, Science and Technology Conference. Dhaka, Bangladesh.

Islam, M. M., Chou, F. N.-F., & Kabir, M. R. (2011). Feasibility and acceptability study of rainwater use to the acute water shortage areas in Dhaka City, Bangladesh. Natural Hazards, 56(1), 93–111. https://doi.org/10.1007/s11069-010-9551-4

Islam, M. M., Chou, F. N.-F., Kabir, M. R., & Liaw, C.-H. (2010). Rainwater: A Potential Alternative Source for Scarce Safe Drinking and Arsenic Contaminated Water in Bangladesh. Water Resources Management, 24(14), 3987–4008. https://doi.org/10.1007/s11269-010-9643-7

Islam, M. M., Afrin, S., Ahmed, T., & Ali, M. A. (2014). THE INFLUENCE OF METEOROLOGY ON PARTICULATE MATTER CONCENTRATION IN THE AIR OF DHAKA CITY. Proceedings of 2nd International Conference on Advances in Civil Engineering 2014 (ICACE-2014). Chittagong, Bangladesh.

Islam, M. M., Afrin, S., & Rahman, M. M. (2014). Development of a Design Tool for Sizing Storage Tank of Rainwater Harvesting System in Coastal Areas of Bangladesh Under Future Climatic Scenario. Proceedings of 2nd International Conference on Advances in Civil Engineering 2014 (ICACE-2014). Chittagong, Bangladesh.

Islam, M. M., Afrin, S., & Rahman, M. M. (2015). Correlation Between The Performance Indicators of Community Rainwater Harvesting System. Proceedings of International Conference on Recent Innovation in Civil Engineering for Sustainable Development (IICSD-2015). Gazipur, Bangladesh.

Islam, M. M., Afrin, S., & Rahman, M. M. (2016). RUNOFF SIMULATION USING SWMM MODEL AND RELIABILITY ASSESSMENT OF COMMUNITY RAINWATER HARVESTING SYSTEM. Proceedings of 8th International Perspective on Water Resources and the Environment. Colombo, Sri Lanka.

Karim, Md. R., Bashar, M. Z. I., & Imteaz, M. A. (2015). Reliability and economic analysis of urban rainwater harvesting in a megacity in Bangladesh. Resources, Conservation and Recycling, 104, 61–67. https://doi.org/10.1016/j.resconrec.2015.09.010

Khan, A. E., Xun, W. W., Ahsan, H., & Vineis, P. (2011). Climate Change, Sea-Level Rise, & Health Impacts in Bangladesh. Environment: Science and Policy for Sustainable Development, 53(5), 18–33. https://doi.org/10.1080/00139157.2011.604008

Kloss, C. (2008). Managing Wet Weather with Green Infrastructure Municipal Handbook Rainwater Harvesting Policies.

Liaw, C.-H., & Tsai, Y.-L. (2004). Optimum Storage Volume of Rooftop Rain Water Harvesting Systems for Domestic Use1. Journal of the American Water Resources Association; Middleburg, 40(4), 901–912.

Portland Cement Association. (1996). Underground Concrete Tank. Retrieved from https://www.cement.org/docs/default-source/th-buildings-structures-pdfs/design-aids/is071-underground-concrete-tanks.pdf?sfvrsn=4&sfvrsn=4

Rajib, M. A., Rahman, M. M., Islam, A. K. M. S., & McBean, E. A. (2011). Analyzing the Future Monthly Precipitation Pattern in Bangladesh from Multi-Model Projections Using Both GCM and RCM. Proceedings of World Environmental and Water Resources Congress 2011@ SBearing Knowledge for Sustainability.

Rashid, R., & Ahmed, M. H. B. (2012). Roof Top Rain Water Harvesting System in Dhaka City. Proceedings of the Global Engineering, Science and Technology Conference. Presented at the Dhaka, Bangladesh. Dhaka, Bangladesh.

Redwan, A., Ghosh, S., & Rahman, M. M. (2014). Effectiveness of UV-Technique for Water Disinfection in Dhaka City. International Journal of Scientific & Engineering Research, 5(1).

SDWF. (2018). Water and Human Health. Retrieved October 27, 2019, from Safe Drinking Water Foundation website: https://www.safewater.org/fact-sheets-1/2017/1/23/water-and-human-health

Shaw, R., & Thaitakoo, D. (2010, June 7). Chapter 1 Water communities: Introduction and overview [Book-part]. https://doi.org/10.1108/S2040-7262(2010)0000002004

Umetsu, C., Donma, S., Nagano, T., & Coşkun, Z. (2019). The Role of Efficient Management of Water Users' Associations for Adapting to Future Water Scarcity Under Climate Change. In T. Watanabe, S. Kapur, M. Aydın, R. Kanber, & E. Akça (Eds.), Climate Change Impacts on Basin Agro-ecosystems (pp. 319–342). https://doi.org/10.1007/978-3-030-01036-2_15

Wahab, S. T., Mamtaz, R., & Islam, M. M. (2016). Applicability of Water Sensitive Urban Design (WSUD) in Dhaka City. Proceedings of the 3rd International Conference on Civil Engineering for Sustainable Development (ICCESD2016). Khulna, Bangladesh.

World Bank. (2002). Linking poverty reduction and environmental management—Policy challenges and opportunities (No. 24824; p. 1). Retrieved from The World Bank website: http://documents.worldbank.org/curated/en/347841468766173173/Linking-poverty-reduction-