The Potential of Rainwater Harvesting as an Optional Water Supply of Building XYZ

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Abstract

Harvesting rainwater to supply the water demands is a growing trend as a viable option to augment the water supply system in the Philippines. Increasing water demand has triggered an initiative to look for an alternative water supply providing sustainable water management. The paper aims to assess the rainwater harvesting potential and storage requirement for the operation of building XYZ. Rainwater harvesting potential for the building will be quantified using a 10-year worth of rainfall data from the Philippine Atmospheric, Geophysical, and Astronomical Services Administration (PAGASA). The average annual rainfall in Metro Manila is 2785.6 mm. Building XYZ has a roof area of approximately 500 sqm. The researcher shall identify the rainwater harvesting potential of the residential building XYZ located in Metro Manila Philippines and conduct a water demand forecast using a naïve forecasting model. The water demand of building XYZ was forecasted by utilizing a naïve forecasting method that resulted in an absolute percentage error of 16.23%. The rainwater harvest could provide 15 toilet flushes during the driest season and 320 toilet flushes during the rainy season in each unit of building XYZ.

Keywords

rainwater harvesting, forecasting, naïve forecasting model, water supply

1. Introduction

The reduction of water quality in the Philippines gives a huge impact on human livelihood because of the rapid increase of the country's population, continuous urbanization, and industrialization (WEPA, n.d.). People who are living in the urban area are now having difficulty gaining access to sufficient clean water for everyday use. Other than human activities contributing to the water crisis of the country an unforgiving phenomenon is continuously giving a threat to the community which is the El Nino. According to Water Roam (2020), the unusual warming of the water surfaces of the eastern Pacific Ocean causes droughts and severe rainstorms. As most of the cities develop and the limited supply of natural water, the demand for water resources increases and more people are challenged to find ways to provide adequate water.

Rainwater harvesting is described as a technique of collecting water and storing it for the purpose of using it to avoid a shortage of usable water. According to Mishra S. et al (2020) when it comes to the conservation of water, rainwater harvesting is a good method for responding to meet the water demands of the community. When it comes to the problem of water shortage rainwater harvesting is an emerging countermeasure to respond to the effects of climate change (Lee et al., 2016). To meet high water demands currently, a continuous piped water service is the accepted standard for urban water utilities. The country's water resources are under mounting stress because of rapid population growth, increasing demand for food production, urbanization, pollution, excessive and inefficient use of water, and climate change (Asian Development Bank, 2013).

Building XYZ is located in a highly urbanized city making its water supply sourced by a pipe system providing potable water for its residents. The building is 5 storey high housing 86 units with an average of 4 members living in each unit. The study intends to assess the potential of rainwater harvesting of building XYZ on a household level and estimate the size of the required storage tank of the building. The researcher will use a seasonal forecasting naïve method to illustrate the water demand of the building and if the rainwater harvest could supply the demand of building XYZ.

The demand for potable water, especially in the urban areas has been increasing and it is affected by the phenomenon of Climate Change making the water cycle more volatile resulting in the idea of rainwater harvesting to complement the piped water source and provide water security. The study evaluates the potential of rainwater harvest in Building XYZ and reduces the demand for potable water from the utility company which would be beneficial for the residents.

2. Literature Review

The method of collecting rainwater was an ancient practice as it greatly helped for the survival of early communities and played an important role in community development (Anchan & Prasad,2021). The system of rainwater collection has been increasingly becoming a sustainability trend that reduces the cost of water utility (Struck, 2011). The method of harvesting rainwater to supply the water demand is emerging and could be applied in building XYZ to supply the water demand (Mitchell et al, 2007).

Water is an important element in our daily life. The country of the Philippines has an annual per capita of the renewable water source of 6,100 cubic meters which is 6 times larger than the threshold globally of 1000 cubic meters (ADB, 2013). Unfortunately, situations such as the El Nino phenomenon and climate change cause water shortage and the unreliability of piped water access in Metro Manila (WHO, 2019). Water shortage has become an imminent problem in high-density populated cities in the country because of the rapid economic growth of the state that causing an increase in water consumption (Anchan & Prasad, 2021).

The rooftop rainwater harvesting system has become an initiative for the citizen to provide an effective way to utilize water. In order to decrease the reliance of the population in the water supply provided by the water utility companies or authorities, scholars have reported that the system of rainwater recovery is effective (Chilton et al., 2000). The piped water service supply of building XYZ is from the water utility company and has a regular and consistent supply. The use of rainwater involves important information to be gathered including the monthly rainfall data.

In order to know the potential of rainwater harvest of a certain roof area of an establishment, climatological normal is important to be considered in the study that includes the average monthly precipitation index of a certain location. the climatological normal serves as the basis of the prediction of the probable conditions through a 30-year summarized data that serves as the benchmark where the latest observation can be compared (WMO,2017).

3. Methodology

The study will be conducted in Brgy. Rosario Pasig City in Metro Manila with a distance of 8.83 km from the science garden Quezon city which is the nearest automatic rain gauge of the PAGASA where the data of the amount of rainfall is collected. According to PAGASA, the mean annual rainfall of the area is 2785.6 mm the data obtained is from the year 1991 to 2020. The data shows (Table 1) that most of the rainfall occurred in the months of June to October while the months of November and April are the driest. The rainfall data are obtained in the climatological data of PAGASA which are the period averages computed for a uniform and relatively long period compromising a ten-year period in the automatic rain gauge station of the Science Garden of PAGASA. The roof of the building XYZ is a corrugated iron sheet with an average roof size of 593.5 sqm the researcher shall identify the runoff coefficients for the accountability of the factors in the accumulation of rainwater. The estimation of rainwater harvesting potential will be calculated using a monthly balanced approach. The paper will propose the basic water requirements of building XYZ and the storage size of the rainwater harvest. The researcher will use a seasonal naïve forecasting method to predict the previously observed value of a similar season of the year. The naïve forecasting method was utilized to strengthen the potential of a rainwater harvest to supply water in the building.

3.1 Data Collection Method

Rainfall data were obtained from PAGASA climatological records. According to WMO (2017), the calculation of the climate normal is used as a forecast of the conditions most likely to be experienced in a given location. Therefore, climatological standard normals are important to predict conditions that most likely to be experienced in a certain area and as a point of reference for long-term changes in climate observation. A reliable 30-year climatological normals data from the Science Garden Station of PAGASA were utilized for analysis. 30 years is a recommended period of reference for the averaging period for calculating quintile boundaries in climatological standard normals (WMO, 2017). The roof of building XYZ is made of corrugated iron sheets with a size of 593.5 sqm and a 0.85 run-off coefficient is used to consider the losses thru evaporation and between the roof and storage tank (Thomas & Martinson, 2007). Table 1 shows the data of climatological standard normal in the science garden station in Quezon City of PAGASA. 12-month water reading data were obtained from the building management for the year 2021 because of the building's full occupancy rate in the year 2020.

3.2 Estimation of Rainwater Harvesting Potential

The study calculated the rainwater harvesting potential of building XYZ by using a monthly balanced approach. (Q m) were calculated as the product of the Roof Area (A), mean monthly rainfall (R m), and the roof run-off coefficient (C).

$$Q\ m = R\ m \times A \times C$$

3.3 Forecasting water demand of Building XYZ

The study will utilize a Naïve forecasting method to know the water capacity of building XYZ. Showing the forecast value for the period t is equal to the observed value for the last period. According to Chen et al (2003), naïve forecasts give a good method for a 12-month forecast. The method has the ability to produce a forecast by short observation when longer historical data are not accessible.

4. Results and Discussion

4.1 Site Location

The site of the building is situated in Brgy. Rosario Pasig City, Metro Manila Philippines. The location is 8.62 km from the site of climatological data of PAGASA as Figure 1 shows the location map of the building. The building is an 84-unit residential condominium with one water closet, one showerhead, one kitchen faucet, one utility faucet, and two lavatory faucets each Figure 2 shows the rendered drawing of the building XYZ.

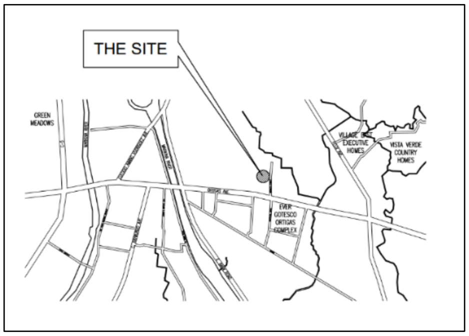

Figure 2. Site Location Map

Figure 2. Rendered Drawing of Building

4.2 Rainfall distribution

The Rainwater Harvesting potential of building XYZ was estimated with the 30-year precipitation or rainfall statistic. The data collected from the Philippine Atmospheric, Geophysical, and Astronomical Services Administration (PAGASA) is considered for the rainwater harvesting study. According to PAGASA, the observations of the several climatic elements are based on the recommended practices of the World Meteorological Organization and the quality-controlled datasets were archived to provide a comprehensive description of the available climate data. The meteorological variable of precipitation data or rainfall data is used to forecast the probable amount of rainwater that could be harvested in building XYZ.

The mean monthly rainfall pattern of the study area is shown in Figure 3 where the lowest average monthly rainfall occurs in the month of February with 24.4 mm of rainfall. The highest average monthly rainfall in the area is in the month of August with 585.5 mm of rainfall. The average annual rainfall of the study area was at 2785.6mm the study period was shown in Figure 3.

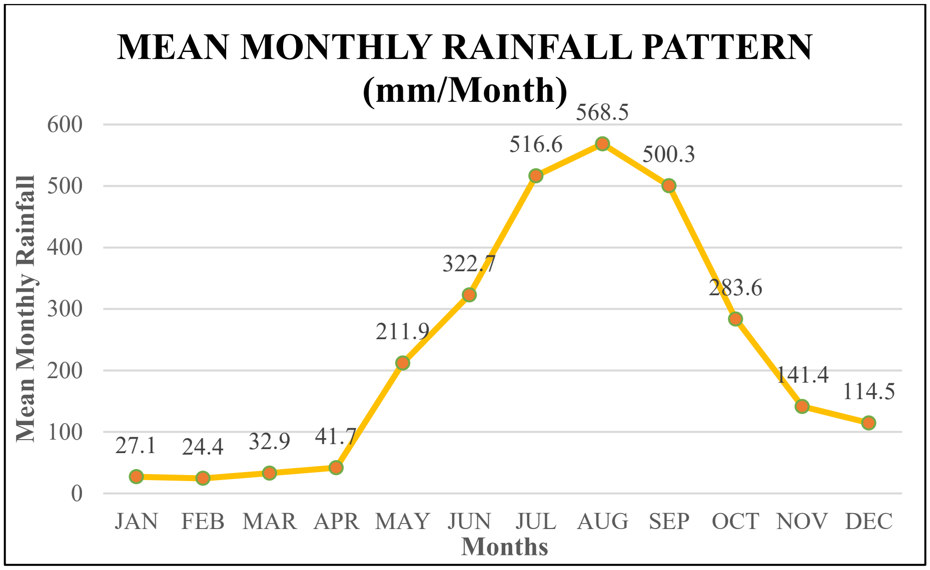

Figure 3. Mean Monthly Rainfall

4.3 Rainwater harvesting potential of Building XYZ

The building XYZ holds a roof size of 593.52 sqm and is made of corrugated metal sheet roofing material Figure 4 shows the shape and size of the roof structure of the building. A 0.85 run-off coefficient is used to consider the losses thru evaporation and between the roof and storage tank (Thomas & Martinson, 2007). The month of February recorded the lowest mean monthly rainfall having a harvesting potential of 21.04 cu m and during the month of August, the harvesting potential is 286.80 cu. m of rainwater. Figure 5 shows the summary of the average monthly rainwater harvest of the roof catchment area of building XYZ.

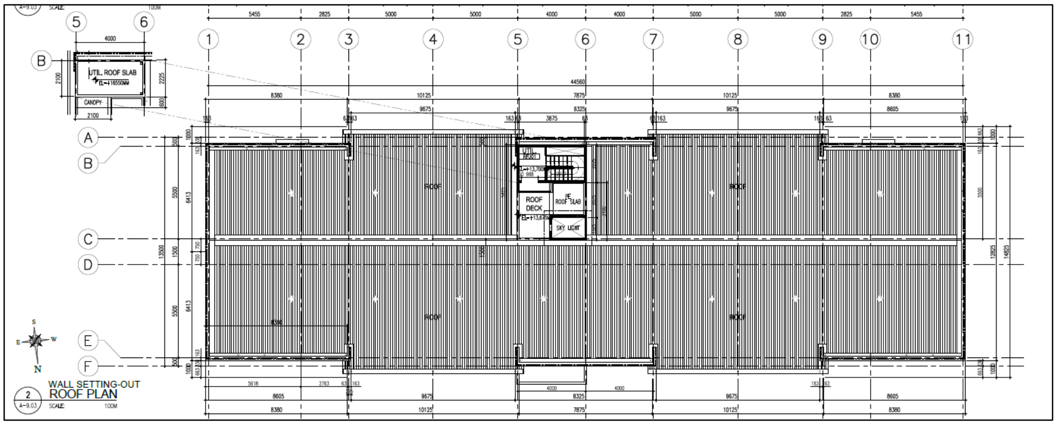

Figure 4. Catchment Area of the Building XYZ

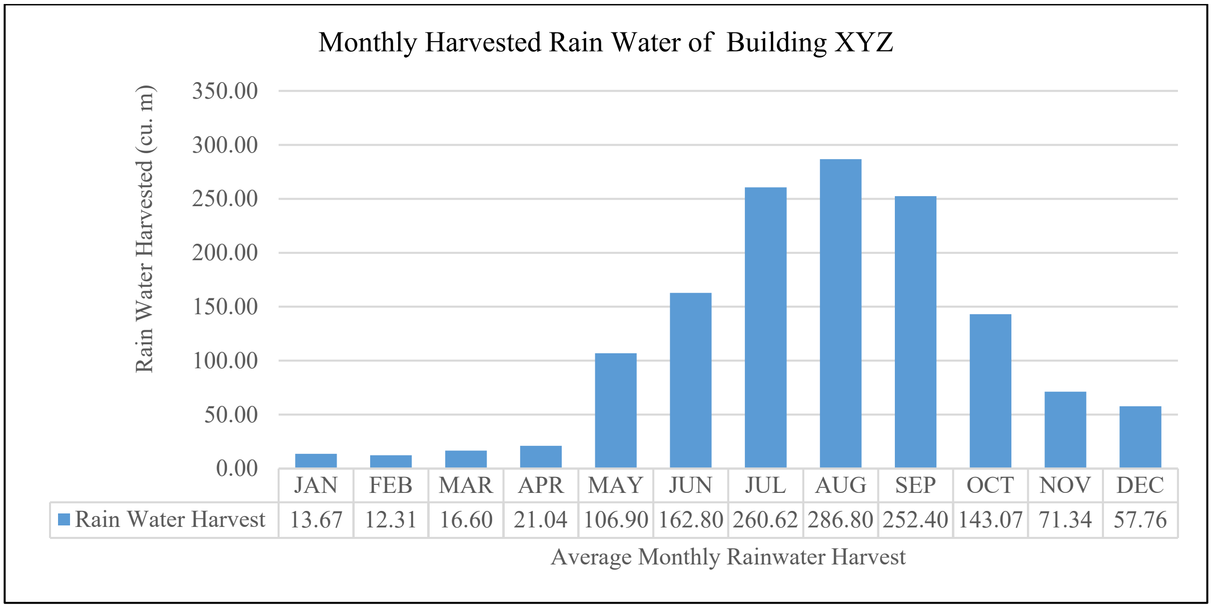

Figure 3. Average Monthly Rainwater Harvest

4.4 Building XYZ water demand

The naïve Forecasting method is used in the study, a time series technique for short-term forecasting where the current period is used for the next period forecast. Data from January 2021 to December 2022 were used to predict the water consumption of Building XYZ. The data in the year 2021 were used because it is the period where full occupancy of units is achieved and shows the maximum water consumption of the 5-story building. Figure 6 shows the demand forecast for building XYZ the accuracy of the forecasts shows a mean forecast error of -5.45, and a mean absolute percentage error of 16.23%

The potential rainwater harvest of building XYZ is not sufficient for the monthly water consumption of residents. The building consumed 13,773 cu m of water in 2021 and is forecasted to have almost the same consumption for the year 2022. The potential rainwater harvest is 1,405.31 cu m which accounts for only 10.20% of the 2021 water consumption of the building.

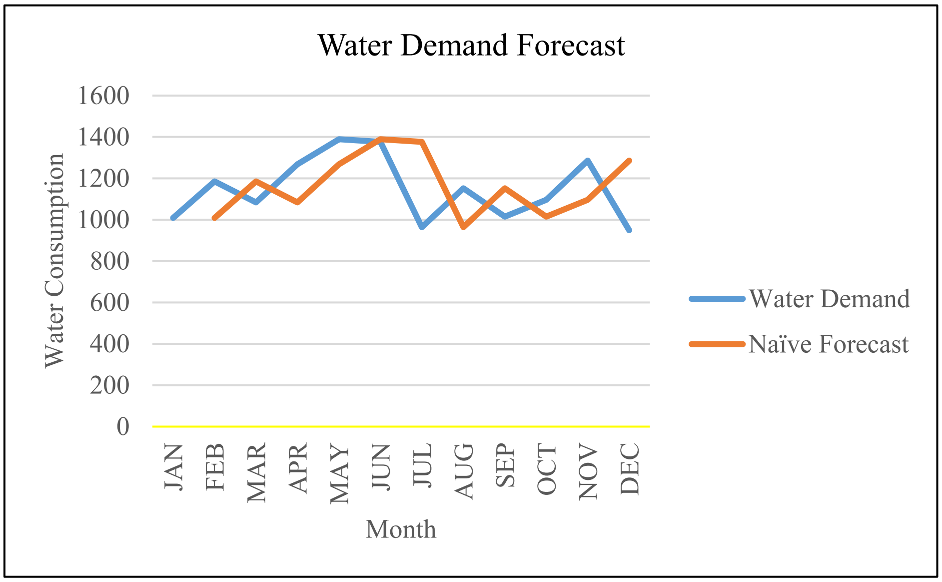

Figure 4. Naive Forecast*ing*

4.5 Potential Use of Rainwater

Building XYZ is an 84-unit residential building, and each has 5 water fixtures and 4 water fixtures provided for watering the landscape outside the building. All of the units have identical water fixtures each is designed to have one water closet with 10 liters (0.01 cu m) of flushing, two wall faucets, one showerhead, one lavatory faucet, and one kitchen countertop faucet.

The rainwater harvested is considered for non-potable water use as it can be contaminated because it may absorb air pollutants and contaminants from the roof area or storage posing general hazards to be found in the rainwater (Struck,2011). The non-potable water can be used for water flushing, and landscape watering of building XYZ. Rainwater harvesting is more beneficial in cities that highly consume potable water as it will generate savings in the water bills of the residents (Ghisi et al 2015). The month of February has the lowest average monthly rainwater harvest of 12.31 cu m where each unit can save almost 15 toilet flushes per month while in the month of August the rainwater harvest of 286.80 cu m can save 320 toilet flushes per month or 10 flushes per day. The building XYZ has 87.3 square meters of the landscaped garden, and the area is covered with bermudagrass and several types of plants. According to Microdips (2019), plants need 2.5 cm of water per week making 2.18 cu m of water needed to water the gardens of building XYZ. Harvested rainwater in the month of February would be sufficient for watering the landscaped garden.

5. Conclusion

The rooftop rainwater harvesting in building XYZ show very good potential in relation to the average rate of precipitation in Metro Manila. Approximately 1405.31 cubic meters of water can be harvested in building XYZ with its 593.52 square meters of roof area. The month of February shows the lowest rainwater harvest as expected because of the summer season in the Philippines while the month of October has the highest rainwater harvest because it is in the middle of the rainy season. The rainwater harvest for building XYZ is considered to be a non-potable type of water that can be used for toilet flushing and landscape irrigation of building XYZ.

The water demand of building XYZ was forecasted by utilizing a naïve forecasting method that resulted in an absolute percentage error of 16.23%. The forecasted water demand was compared to the average monthly rainwater harvested and evidently, it cannot wholly support the water demand of the building rather it could complement the needs that could involve non-potable water. The rainwater harvest could provide 15 toilet flushes during the driest season and 320 toilet flushes during the rainy season in each unit of building XYZ. Also, the harvest would be sufficient if used as garden irrigation for building XYZ.

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Biography

Engr. Rombert Brian B. Malate is a Registered Electrical Engineer (REE) in the Philippines. He finished his bachelor's degree in Electrical Engineering at Adamson University located at Manila, Philippines in May 2018. He was a Junior Design Engineer of automotive wiring harness for three years in Yazaki Philippine EDS Techno-Service Inc. The company provides automotive design services operating in computer system design and related services. He made a career change as a Property Engineer of GD Prime Property Management Corporation providing augmentation to the managed properties ensuring proper, orderly, cost-effective, and timely execution of the operation and maintenance of the building systems and facilities. He is currently a master's student in engineering management at Mapua University since November 2

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