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THE IMPACT OF ROOF SIZE ON THE DIMENSIONS AND EFFICIENCY OF RAINWATER COLLECTION TANKS USING TANGKI NAHRIM 2.0

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Abstract

The phenomenon of global warming, coupled with the growing global population, has a direct and significant influence on the demand for water worldwide. In Malaysia, the use of drinkable water is significantly higher compared to other nations, and the primary supply of drinkable water is predominantly surface water. Rainwater harvesting is a widely adopted alternative for water resources globally. Despite Malaysia's copious rainfall, rainwater collection remains unpopular in the country. Houses of varying sizes have corresponding variations in roof sizes, which in turn necessitate variable sizes of rainwater tanks. This study employed the use of Tangki NAHRIM 2.0 (TN2), a web tool, to calculate the most suitable tank capacity for a rainwater collecting system. The analysis was conducted for five distinct roof sizes, with the focus on meeting non-potable water requirements. The TN2 simulation employs a daily water balance model that utilizes rainfall data from an integrated database, following the yield-after-spillage (YAS) protocol. The ideal capacities for rainwater tanks for five distinct roof sizes range from 2.6 m³ to 3.8 m³. These tanks exhibit water-saving efficiency values ranging from 59% to 76.2% and storage efficiency values ranging from 30.9% to 53.9%. A larger tank capacity provides greater water-saving efficiency, but at the expense of reduced storage efficiency. The product will be valuable for the implementation of RWHS in residential buildings.

Keywords: Rainwater harvesting, Water, Storage, Efficiency, Residential

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INTRODUCTION

The global population growth has led to a rise in the demand for water across all areas of production. Furthermore, climate change is amplifying the occurrence and severity of both droughts and storms worldwide. Currently, the increasing problem of river contamination is causing disruptions to water supplies in Malaysia, as the country relies on rivers as a primary source of water. The pollution of rivers poses a significant threat to the long-term viability of water resources. Malaysia's per capita household water usage is from 209 to 228 liters per day, which is considered excessive when compared to the World Health Organization's recommended level of only 165 liters per day (Zabidi et al., 2020). Moreover, Stec et al. (2019) found that more than 50% of water used in households is for non-potable purposes (Stec & Zeleňáková, 2019). One method to attain a sustainable infrastructure is by implementing Rainwater Harvesting Systems (RWHS). RWHS, or Rainwater Harvesting Systems, enhance the water supply and mitigate flooding by reducing the amount of surface runoff that enters drains and rivers. They also assist alleviate combined sewer overflows (CSOs) and minimize the long-term withdrawal of water from surface sources (Gold et al., 2010).

Rainwater harvesting is a widely adopted alternative for water resources globally. Malaysia is a nation that experiences a significant amount of precipitation. Nevertheless, the utilization of rainwater harvesting in Malaysia remains rather limited. The research, analysis, and implementation of Rainwater Harvesting Systems (RWHS) for residential residences are currently not as extensive as those for government buildings (Lani et al., 2018). For instance, Hashim et al. (2013) conducted a simulation of a model representing a large-scale Rainwater Harvesting System (RWHS) (Hashim et al., 2013). Their findings indicate that the ideal capacity for the storage tank is 160 m³ with a dependability of 60%, given a roof area of 20,000 m². In their study, Hamid et al. (2011) discovered that by using a storage tank with dimensions of 40m × 35m and a depth of 5m, a student hostel with a roof area of 3000m² could save 6500m³ of treated water annually (Abd Hamid & Nordin, 2011). This leads to a yearly reduction in water expenses of around RM10460. A study on RWHS for institutional application at the Infrastructure University Kuala Lumpur (IUKL) Bangi Campus (Al-Saffar et al., 2016). They used Tangki Nahrin 1.0 (TN) for their research. The chosen tank sizes for the two academic blocks are 75 m³. These tanks provide water saving efficiencies of 81% and 93% respectively. In a study conducted by Kuok Kuok et al. (2020), it was determined that Rainwater Harvesting Systems (RWHS) can be used for non-potable purposes in residential buildings in Kuching, Sarawak (Kuok Kuok et al., 2020). The study found that the ideal size for the RWHS tank in double-story residences in Kuching is 2m³. In a recent study conducted by Goh et al. (2021), it was shown that the ideal size

for a rainwater harvesting system (RWHS) tank for a 100m² roof area in Kuala Lumpur is 3m³ (Goh & Ideris, 2021). This tank size is capable of meeting 90% of the non-potable water demand using rainwater.

The size of the roof or catchment area is a crucial element of RWHS. However, the varying sizes of houses necessitate different roof sizes, which in turn require variable quantities of rainwater tanks. Gurung (2012) found that tanks make up 30% of the total expenses over the lifespan of the RWHS and are the most expensive individual component (Gurung & Sharma, 2012). Therefore, choosing the wrong size of rainwater tank will result in resource wastage if it is too large, and poor system efficiency if it is too small. Therefore, this study aims to identify the most suitable rainwater harvesting tank capacities for different sizes of residential roofs. The output will be valuable for the implementation of Residential Water Harvesting Systems (RWHS) in residential.

RESEARCH METHODOLOGY

TN2.0 is an enhanced iteration of a web application created by the National Hydraulic Research Institute of Malaysia (NAHRIM). The system is specifically created and developed to determine the most suitable tank capacity for Rainwater Harvesting Systems (RWHS) in Malaysia, taking into account the available rainfall data. TN2.0 utilizes an R-based water balance model. There are two categories of water balance models, namely Yield Before Storage (YBS) and Yield After Storage (YAS). The YBS model employs a strategic methodology, wherein the collected rainwater is utilized for daily purposes, while the remaining amount is kept in a reservoir for future usage. The YAS concept follows a conservative strategy by initially collecting rainwater and directing it to the tank, while any surplus rainfall is then discharged through overflow. The tank will be utilized to measure the daily usage.

YAS and YBS were two models created by Jenkins et al. (1978) to analyze the temporal and volumetric performance (Jenkins & Pearson, 1978). YAS stands for the utilization of rainwater that occurs after the release of excess rainwater, whereas YBS refers to the utilization of rainwater that occurs before the release of excess rainwater. According to Fewkes et al., YAS was determined to offer a cautious estimation, whereas YBS yielded the opposite result. Therefore, YAS was suggested as a better choice compared to YBS (Fewkes&dagger et al., n.d.).

Study Area

The study situated in Putrajaya, Malaysia. This study examined five distinct categories of houses. The dimensions of the houses range from 6m by 21m, 7m by 21m, 9m by 21m, 10m by 21m, to 13m by 21m. The sizes of the houses are deemed equivalent to the sizes of the roofs. The closest rainfall station is station

ID: 2916001 Puncak Niaga Putrajaya, situated approximately 10km radius from the research area.



Figure 1: Study area rainfall station is station ID: 2916001 Puncak Niaga Putrajaya

Figure 2 illustrates the annual variations of rainfall from 1997 to 2017, with an average rainfall amount of 2067 mm. Figure 3 illustrates the monthly variation in rainfall. The biggest quantity of rainfall occurs in November due to the North-East Monsoon, while there is a smaller peak in June during the inter-monsoon season. The significant annual and monthly precipitation levels indicate that the region is suitable for rainwater harvesting (Goh & Ideris, 2021). Therefore, the effectiveness of the rainwater harvesting tank is directly influenced by the intensity of rainfall in the area.

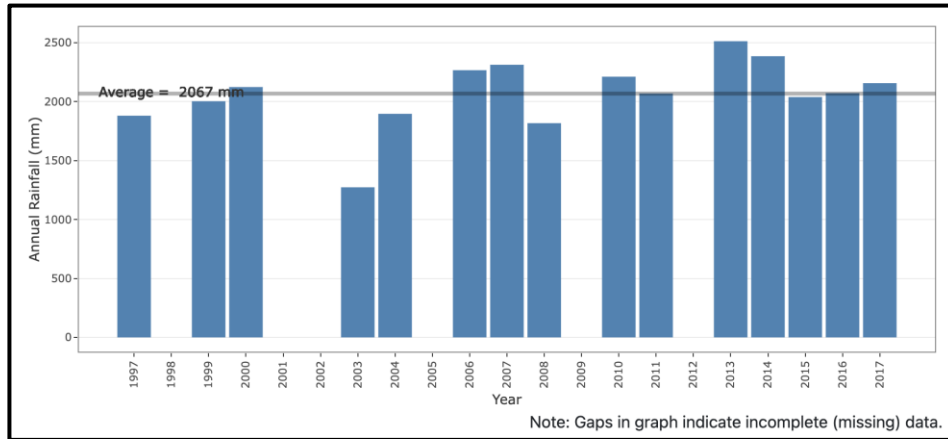


Figure 2: Annual rainfall pattern at Putrajaya Station from 1997 until 2017 with an average of 2067mm

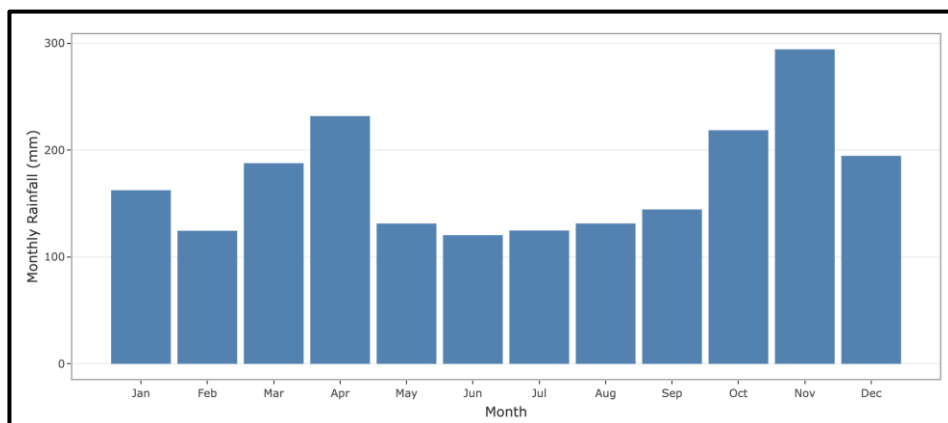


Figure 3: Average monthly rainfall pattern at Putrajaya Station

RESULT AND DISCUSSION

The simulation results for the five different sizes of housing are depicted in Figures 4 to Figure 7. These figures display the curves representing water-saving and storage efficiency in relation to the range of tank capacities, supposing a consistent daily non-potable demand. The graph exhibits a linear growth pattern, indicating that as the size of the tank increases, the amount of water that may be collected also increases, contingent upon the desired level of water conservation.

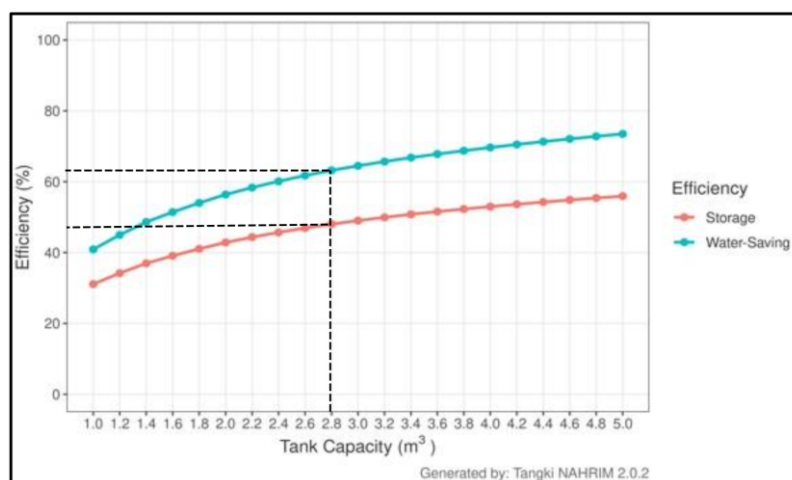


Figure 4: Roof size area 156m²

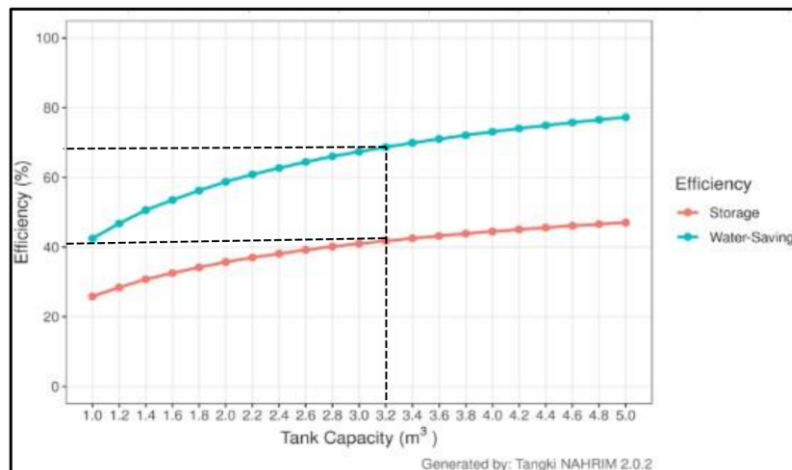


Figure 5: Roof size area 195m²

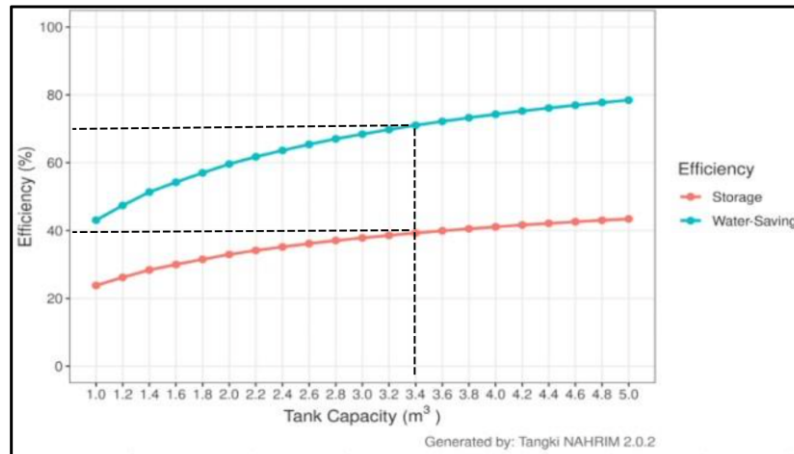


Figure 6: Roof size area 215m²

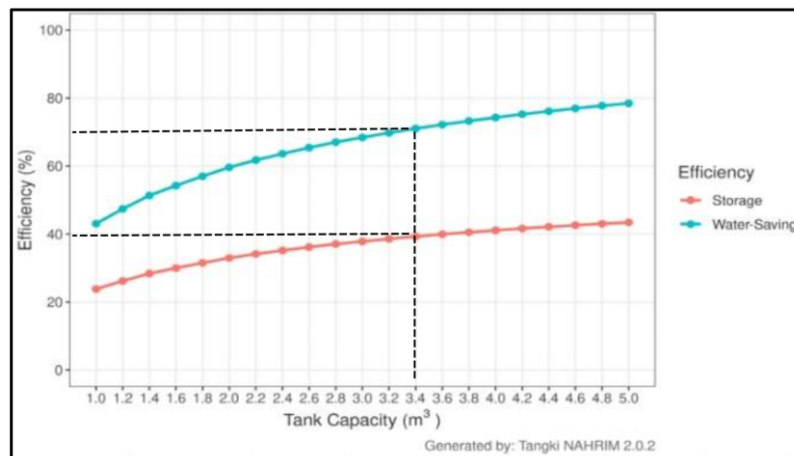


Figure 7: Roof size area 292m²

Figure 4 to Figure 7 show the comparing water-saving and storage efficiency for different roof sizes: a) 130m², b) 156m², c) 195m², d) 215m², and e) 292m².

The determination of the ideal tank size for each housing mostly relied on the analysis of water-saving and storage-efficiency curves. An increase in tank sizes leads to an improvement in efficiencies until the percentage of efficiency gains becomes less significant as the tank size increases (Goh & Ideris, 2021). The point at when the graphs began to level out is observable. Through careful

observation, it was determined that the ideal tank sizes for each dwelling are 2.6m^3 , 2.8m^3 , 3.2m^3 , 3.4m^3 , and 3.8m^3 . These tanks have water-saving efficiency values ranging from 59% to 76.2% and storage efficiency values ranging from 30.9% to 53.9%. A water-saving efficiency of 59% means that 390.8 litres of rainwater can be used out of a total daily non-potable demand of 662.3 litres.

The water-saving efficiency is directly proportional to the increase in roof area. The water-saving effectiveness of a tank with a size of 2.6m^3 is just 59%, which is the lowest among all options. The largest roof size provides a greater water-saving efficiency of 76.2% for the same daily water demand. Figure 8 shows the relationship between tank size and water-saving and storage efficiencies.

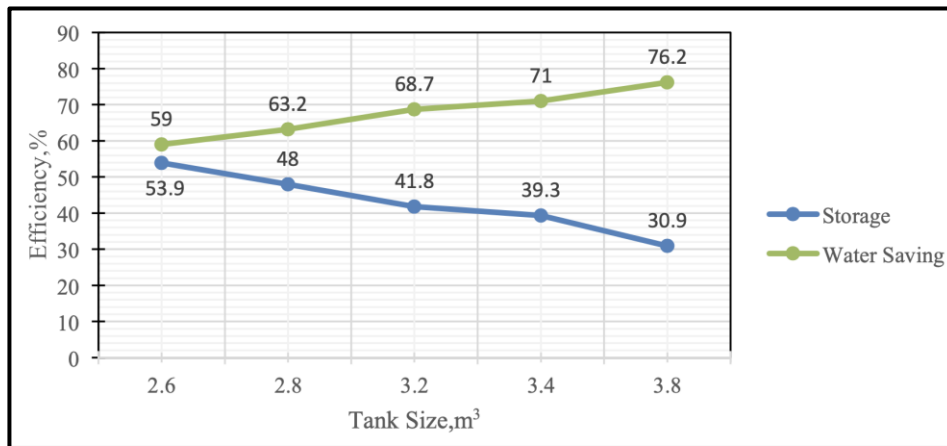


Figure 8: Comparison of tank sizes in relation to storage capacity and water-saving effectiveness

A reduced roof surface area can only collect a limited amount of rainwater. By expanding the roof area, the inflow of water into the tank will rise, hence enhancing the tank's volume reliability. According to reference (Khan et al., 2017), the reliability of a tank increases as the catchment area increases, given a specific tank size. However, the efficiency of storage has an inverse correlation with the efficiency of water conservation. Using a larger rainwater tank will result in decreased storage efficiency. The storage efficiency declined from 53.9% to 30.9% with an increase in tank size from 2.6m^3 to 3.8m^3 . Storage efficiency is determined by the combined factors of spillage and roof runoff volume. When the spillage volume decreases, the storage efficiency improves. Low storage efficiency indicates that a significant proportion of the rainfall collected by the roof is lost through drainage. Due to the low water demand and high rainfall volume, there will be an increase in spillage, resulting in a decrease in storage

efficiency (Goh & Ideris, 2021). This aligns with the precipitation pattern in the western region of Peninsular Malaysia, which is impacted by the inter-monsoon periods and marked by intense convective storms.

CONCLUSION

This study utilized TN2.0, a web-based application, to calculate the ideal tank capacity for five distinct roof sizes of a residential dwelling in Selangor, while maintaining consistent daily water consumption. TN2.0 utilizes a decade's worth of daily precipitation data for its simulation. The ideal sizes for rainwater (RW) tanks for non-potable use in residences with roof sizes of 130m², 156m², 195m², 215m², and 292m² are determined to be 2.6m³, 2.8m³, 3.2m³, 3.4m³, and 3.8m³, respectively. A larger roof size necessitates a larger optimal tank size. The ideal capacities for rainwater tanks for five distinct roof sizes range from 2.6m³ to 3.8m³. These tanks exhibit water-saving efficiencies ranging from 59% to 76.2% and storage efficiencies ranging from 30.9% to 53.9%. As the capacity of the tank increases, the water-saving efficiency will also improve for the same level of demand. However, when faced with similar demand, the storage efficiency of a larger rainwater tank decreases.

This study specifically examines the implementation of TN2.0 in residential dwellings. However, it is recommended that TN2.0 be extended to include commercial and industrial structures in future applications. It is advisable to further investigate the impact of geographical rainfall patterns on the size and performance of rainwater tanks. Subsequent studies might examine the impact of different roof technologies on the efficiency of tanks. Elevated temperatures on the rooftop will inevitably impact the gathering of rainfall. Another aspect that should be investigated is how the tank performs when there are changes in water demand. The demand fluctuation can occur on a daily, weekly, or user count basis.

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