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Sustainable water management: roof as a rainwater catchment area

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Abstract. This paper studies on the application of the theory of rainwater harvesting, particularly on the roof as a catchment area. The background of this study is that the implementation of sustainable architecture in design should not have negative consequences for future generations. Awareness of energy conservation by avoiding depletion of resources including energy and water, preventing environmental degradation and creating a comfortable, safe and liveable environment that needs to be considered. The water management is essential for any country in the world, but the unconsciousness in the concept of rainwater management systems makes people not interested in adopting this system. So, promoting the rainwater harvesting system and utilization that system as sustainable rainwater management becomes an important issue and it must be remembered that every drop of the water must be stored and used for mankind. The collection of rainwater in this study is focused on a roof as a catchment areaand to accommodate these objectives, a brief calculation of the roof area is 64m^{2}and the result showed that it can be provide and full fill 100% of the water needs for the latrines flushing and cleaning the house for 19 months.

Keywords: catchment area, sustainable water management, toilet flushing, cleaning the house.

1. Introduction

Ensuring that an architectural design does not have negative consequences for future generations need to be our concern. Therefore, the implementation of sustainable architecture is one of the goals that need to be considered. Awareness of energy conservation by avoiding depletion of resources including energy and water, preventing environmental degradation and creating a comfortable, safe and liveable environment are important.

Conserving the environment and resources for the long term and trying to preserve the environment is a new challenge for actors involved ecological development. The future of our cities and landscapes depends on the extent to which climate change and its environmental impacts can be managed with appropriate measures. Due to population growth and rising demand for food and water and climate change causes water resources to shrink every year and begin to lead to water scarcity. So, a sustainable approach to water resources needs to be taken into consideration because water is a non-renewable natural resource. Rainwater management, water treatment and reuse, protection and enhancement of groundwater quality and creating water-saving landscapes become one of the options for sustainable water management approaches.

Although the average rainfall for each year is not the same, Indonesia is one of the countries with a considerable amount of rainfall that is average about 2000 – 3000 mm/year.Jakarta is the capital city of Indonesia, which has a high frequency in activities, so that the water need become essential to support these activities. In 2013, the need of the clean water increased to around 23.3 m^3/s but the local government water supply (PDAM) can only provide about 18.025 m^3/s. Therefore, there is a shortage of water supply of around 5.3 m^3/s. Furthermore, currently, most people use ground water compared that water supply from PDAM as their water source. Therefore, water conservation needs to be done, rainwater harvesting is one of many methods to conserve the water [1].

Rainwater is a free source of nearly pure water and rainwater harvesting refers to activities that collect rainfall locally and store it through various technologies, it uses for the future and meet the demands of human consumption or human activities [2]. According to the regulation of the Indonesia State Minister of Environment number 12 of 2009 in clause 3 mentioned, that rainwater collection ponds can used to hold rainwater that falls on the roof of the building (house, office building or industry) which channelled through the gutters [3].

2. Literature Review

2.1. Data Rainfall

The United Nations estimates that the world's current population nearly 7.6 billion and will be increasing to 8.6 billion by 2030, it causes water consumption increased fourfold in the 20th century and the population suffering from water scarcity rose from 0.24 billion (14% of the world population) in the 1900s to 3.8 billion (58%) in the 2000s and almost 80% of the world population is exposed to high levels of threat to water safety. In country with high rainfall in almost all areas, rainwater can be considered as a water source that ensures to supply the water needs. Potentiality rainfall in each area varies, due to the rainfall pattern changes in the quality and quantity [4]. Based on data from Meteorology Climatology and Geophysics Council (BMKG) from 2000 - 2015 that has been analysed and found that the average annual rainfall in Indonesia, especially in Jakarta is about 1,739.65 mm. But the utilization of rainwater use is small compared to its potential, although the rainwater harvesting system technology has been applied but still has not been done optimally. From this perspective, there is a need to seek for calculation of the amount of potential water that can be accommodated by the roof area as a rainwater catchment area.

2.2. Rainwater Harvesting

If we are prepared and have the necessary equipment, rainwater harvesting from the roof, building or other sources is easy. Rainwater harvesting is defined as a way of collecting rain water or surface runoff during high rainfall for subsequent use during low rainfall times. Viewed from the scope, rainwater harvesting divided into two categories [5]:

2.2.1. Roof top as a rainwater harvesting. This system collects rainwater when it falls and the roof as a catchment area. This can be stored in a tank or transferred to an artificial recharge system. This method is cheaper and very effective and if implemented properly can help in augmenting the groundwater level in the area. This system is usually used in residential buildings or urban areas.

2.2.2. Surface Runoff in rainwater harvesting. In urban areas, rainwater flows away as surface runoff and it can be captured and reused by adopting the appropriate methods. This system is usually used on a wide scale such as agricultural land or watersheds.

2.3. Runoff Coefficient

The runoff coefficient factor is an essential issue to determine the potential of rainwater harvesting, which not all the rainfall falling on the catchment area can be collected. Some rainwater will be lost due to evaporation and retention factors from the surface itself. This can decide how much water you can harvested [6]. The runoff coefficient for tile roof is between 0.8 - 0.9.

2.4. Catchment Area
The roof as a catchment area is the first layer that directly contact with rainfall. In most tank-based rainwater harvesting systems, the roof becomes a catchment area for rainwater. There are several important factors about roofs that need to be considered when planning rainwater harvesting systems:

2.4.1. Roof material made of metal is recommended because it easily releases contaminants that are attached to the roof and must avoid the roof made of wood shingle (because it is difficult to remove dirt) or flashing metal that containing lead.
2.4.2. The slope of the roof can affect the speed of runoff water when the rain falls. Steep roofs can cause runoff water to flow faster and easier to clean the roof from contaminants, while the less of steep roof causes runoff water to flow more slowly.
2.4.3. *The size of catchment area* will determine how much rainwater that you can harvested.

3. Methodology
The method that use to obtaining data in this study was literature review. The data needed are as follows: (1) the catchment area; (2) the runoff coefficient and (3) the annual rainfall. The next step is the water potential obtained from the rainfall by multiplying the average rainfall with runoff coefficient and catchment area. The formula for getting the clean water supply is as follows [1]:

Water Potential = R x A x RC

R = Rainfall
A = Catchment Area
RC = Runoff Coefficient

4. Result and Discussion
4.1. Rainfall intensity
Based on data from Meteorology Climatology and Geophysics Council (BMKG) from 2000-2015 that has been analyzed and found that the average annual rainfall in Indonesia, especially in Jakarta is about 1,739.65 mm. (Table 1)

Table 1. Average annual rainfall (2000-2015) in Jakarta

Province	*Year*	*Precipitation (mm)*
DKI Jakarta	2000	871.40
	2001	1 750.30
	2002	1 911.10
	2003	1 644.30
	2005	433.50
	2006	527.10
	2007	2 353.90
	2008	1 779.10
	2009	1 973.00
	2010	2 405.00
	2011	1 274.00
	2012	1 570.00
	2013	2 524.60
	2014	2 908.00
	2015	2 169.50
Average rainfall (mm)		1 739.65

The table above shows the result of average rainfall per year based on rainfall data from 2000-2015, and the results obtained that the average yearly precipitation is 1739.65 mm.

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4.2 Rooftop as A Catchment Area

Corrugated metal sheet was selected as a material for catchment area because it has runoff coefficient between 0.7 – 0.9 and they easily shed the contaminants. The catchment area on the footprint of the roof, that calculated by finding the building area. The image below shows that the difference in the slope roof turned out do not change the area of rainwater catchment. (see Fig. 1)

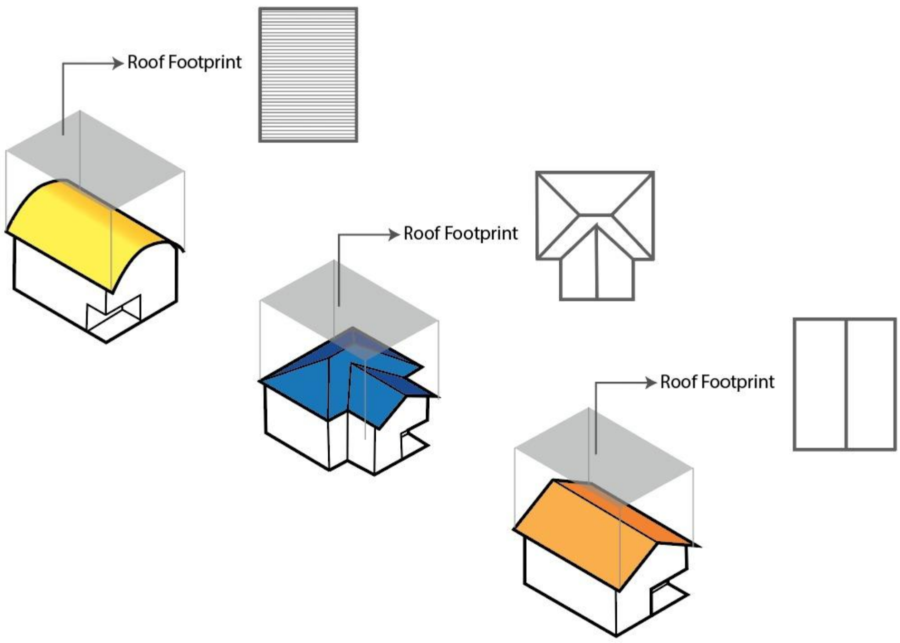

Figure 1. The footprint of the roof as a catchment area

So, to calculate rainwater harvesting needed data about the number of average rainfalls, runoff coefficient and the area of the rooftop.

To calculate the potential of the rainwater in the catchment area, it is assumed that the roof area of a common residential area is 64 m^2 and the calculation is as follows:

The annual precipitation = 1739.65 mm = 17.3965 dm
Runoff Coefficient = 0.8
The catchment area = 64 m^2 = 6,400 dm^2

Water Potential = 17.3965 dm x 6,400 dm^2 x 0.8 = 89,070.08 litres.

From the result above, the building with the variation of size of the catchment areas can offer different volume of rainwater harvesting results, so it is necessary to calculate the ideal size of the catchment area to meet the required water needs. Water requirements for different determination according to the Centre for Science and the Environment (CSE) for cleaning the house is 10 litres/person/day and for flushing of latrines is 30 litres/person/day.

In the residential building consists of 4 people, then the volume of water that used for cleaning the house and flushing of latrines, they need about= 40 litres x 4 persons x 365 days = 58,400 litres/year.

And if assumed that the catchment area is 64 m^2, the volume of the potential rainwater can meet their water needs is:

$$= \frac{89{,}070.08 \text{ litres}}{58{,}400 \text{ litres/year}} \times 365 = \pm 556 \text{ days (about 19 months)}$$

Total water consumption for cleaning house and flushing toilet 58,400 litres/year, and it can be served and fulfill for a building for about 19 months.

5. Conclusion

Preserving the environment and resources for the long term is a new challenge for actors involved in ecological development. The future of our cities and landscapes depends on the extent to which climate change and its environmental impacts can be managed with the right steps. Jakarta as one of the capitals that has the highest level of human population in Indonesia, must be able to utilize the potential of rainwater as an alternative use of water sourced from PDAMs. By utilizing rainwater harvesting, the lack of water supply from PDAMs can be minimized.

Rainwater collection in this study focused on the roof as a catchment area. In general, the potential of water captured on a roof of 64 m2 can provide and fill up the water needs. This rainwater can be used every day to water the latrines and clean the house for about 19 months. The use of this rainwater is one of the contributions to the application of sustainable architecture in the awareness of energy conservation, in this case is water.

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