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Research Article

Rainwater Harvesting-Based Water Resources Conservation

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Abstract
Denpasar City has an index of population increase worth 2.07% every year. It is feared that this will become a new problem in terms of environmental sustainability, such as the overexploitation of groundwater to meet the community's water needs. This study aims to support the sustainability of water resources by using Rainwater Harvesting (RWH) as a form of green building planning. The method used in this study is a quantitative descriptive method, which is an analysis method carried out to calculate and describe the scale of RWH in the focus of the system's effectiveness with the study location in the campus environment of the Ngurah Rai University Denpasar. The results of the study stated that 11 roofs of capture buildings produced rainwater of 1,783,350 litres/year. Another analysis said that this RWH method could cover all water needs, especially water used for flushing toilets. It is stated that the total water deficit of -703,734 litres/year can be subsidized from the entire remaining rainwater harvesting water of 879,624 litres/year. In addition, rainwater harvesting also plays a role as a form of effort to maintain the conservation of water resources and the application of green buildings that are energy efficient and environmentally friendly.

Keywords: Rainwater harvesting; water needs; conservation

1. Introduction

Water covering about 70% of the earth's surface is an essential substance for nature and the world's ecosystems. Water has unique chemical and physical properties that make it indispensable for life. About 97.5% of all water on earth is salt water, leaving only 2.5% as freshwater, which can be found in various forms such as glaciers or permafrost, groundwater, and surface water. This proves that renewable fresh water is a limited resource (Biswas & Mandal, 2014). The availability of limited water resources is in line with the increasing demand for housing facilities, which will change the land function of areas that were initially forests or gardens turned into residential areas, thus impacting the availability of water resources (Pratiwi & Permana, 2016). This causes concentrated population density in many areas, resulting in scarcity of surface water and uneven drying of groundwater. This then results in drought and drying of riverbeds in areas with high industrial and domestic water consumption (Mishra* et al., 2020).

Denpasar City has an area of 127.78 km^2, 63.57% of which is the land use of yards and settlements. In addition, Denpasar City also felt a shortage and decrease in water discharge, where the most considerable water use was from the source of drilled wells, with the highest increase in 2013, around 8.34%. With a population of 880,600 people and an annual increase index of approximately 2.07%, it is feared that it will become a new problem in terms of environmental sustainability, such as with the overexploitation of groundwater to meet the water needs of the community. Therefore, there is a need for prevention as an effort to support the sustainability of water resources using rainwater harvesting measures as a form of water resource conservation in green infrastructure planning (Pamungkas, 2022).

The positive impact of rain is that humans can use it for agriculture and other consumer needs. Negative impacts, excessive rain can also cause disasters such as floods and inundation. To avoid these events, it is necessary to have rainwater harvesting technology which is an effort to anticipate climate change (Jayanti et al., 2012). Rainwater harvesting is a series of activities in collecting, using and absorbing rainwater into the soil. Rainwater is one of the directly accessible water sources that can be used for various purposes, including adding other water supply sources in urban areas. Rainwater harvesting does not require special training because it is easy to implement and has relatively low implementation and maintenance costs (Maryono, 2016). Its implementation by the Indonesia strongly supports the method of harvesting rainwater to conserve water resources. This is based on the issuance of the Regulation of the State Minister of the Environment Number 12 of 2009 concerning Rainwater Utilization. The regulation explains that the basic principle of water conservation is to store as much water as possible in the surface flow into the earth's body to minimize the occurrence of water loss in the future. Based on this principle, excessive rainfall is not allowed to flow into rivers during the rainy season. Still, it is accommodated in a container that allows water to seep back into the soil through rainwater (Menteri Negara Lingkungan Hidup, 2009).

The catchment field is the part of the RWH system in charge of capturing rainwater, and it can be a roof or other waterproof layer. Rainwater from the catchment field further flows through the pipe to the storage tank (reservoir). Considering atmospheric wash as a source of contamination, the best rainwater quality for urban areas is after the first roof cleaning (the beginning of rain), thus minimizing the effects of particles on the roof surface. This method will improve the quality of rainwater harvested (Yushananta, 2021). Roofing material is also an important consideration when designing a rainwater harvesting system. This is because it affects the quality of rainwater harvested (Olaoye, R.A, Olaniyan, 2019). Harvested rainwater can also be used for cooking, washing, and bathing. The main limitation of this choice is the inability to use rainwater all year round. However, it can be widely used as an additional source if rainwater is correctly stored in the rainy season (Biswas & Mandal, 2014).

The method that will be applied based on the conditions of densely populated areas such as Denpasar City is to apply the rainwater harvesting system method by using the roof of the building as a rain collection medium. The selection of the Rainwater Harvesting method is based on a reference from the Denpasar mayor's regulation no.18 of 2010, which confirms the use of rainwater (Walikota Denpasar, 2010). The case study that will be the place of planning in this study is the Ngurah Rai University Campus. This campus was chosen because it is considered very practical to be a pilot location for implementing sustainable green infrastructure. At least it can introduce rainwater harvesting to the entire academic community and residents in the Ngurah Rai University Campus environment, where the thing that is of note is related to the condition of the Ngurah Rai University Campus. The Ngurah Rai University campus has a water supply system in the form of drilled wells or underground water, if not accompanied by replenishment of groundwater again. There will be a vacuum of groundwater which in the long term can have an impact on soil subsidence that is not simultaneous, so it must be anticipated by rainwater capture to replenish groundwater and, at the same time, reduce the use of groundwater (Marni, 2019). It is clarified again that the drilled well uses a pump system without a reservoir. It is undeniable that the life of the water pump periodically causes a large enough flow of electrical energy. Therefore, it is necessary to consider implementing green construction/buildings in one way by harvesting rainwater. Green construction/buildings have three main aspects that need to be considered: materials, energy, and water. One of the efforts to make it happen is to save energy and reduce the problems that will arise in the environment (Tanubrata & Gunawan, 2016).

This study aims to find out how effective the Rainwater Harvesting method is as a water conservation measure in the context of being one way to reduce the use of groundwater and excessive. It uses electrical energy and understands the role of Rainwater Harvesting in supporting the development and innovation of green infrastructure.

2. Methods

The method used in this study is a quantitative descriptive method. The analysis was carried out to calculate and describe the scale of rainwater harvesting, focusing on the system's effectiveness in the campus environment of Ngurah Rai University. To carry out the analysis stage in this study, it is necessary to go through several steps, including identifying rainfall. The calculation of rain that can be harvested, the analysis of the reservoir, then the study of the effectiveness to be measured in terms of additional water supply volume and duration of conservation.

The availability of adequate data sources supports the smooth running of this study. Therefore, data collection activities consisting of secondary data are needed. Secondary data collection in this study was carried out within six months. Secondary data in this study were obtained from the Bali-Penida River Basin Center, Satellite Imagery, and the PDDIKTI website, including research location data, rainfall data, student number data, and lecturer number data. Furthermore, the secondary data obtained are recorded and collected for further analysis to get correct calculations when processing the data to minimize errors that occur.

2.1. Research Location

The research location for planning the application of rainwater harvesting is Ngurah Rai University. Ngurah Rai University was chosen because of its location in Denpasar City. Besides that, the reason for selecting Ngurah Rai University is because it is considered very practical to be a pilot location for implementing a rainwater harvesting system. At least later, it can introduce rainwater harvesting to the entire academic community and residents in the Ngurah Rai University Campus environment as a form of support in building sustainable green infrastructure.

Ngurah Rai University is located on Jalan Padma Penatih, Denpasar Bali, and was founded by the Jagadhita Denpasar Foundation. The Tri Hita Karana concept is the basic foundation of the vision and mission of Ngurah Rai University, which is used as a fundamental concept in the application of a conservation system in supporting green infrastructure. Etymologically Tri Hita Karana consists of 3 words: 'Tri,' 'Hita,' and 'Karana.' According to the Sanskrit dictionary: Tri means three; Hita means broad, can mean encouraged, moved, benefited, profitable, and well-being; and Karana refers to the meaning of produced by or coming (Idedhyana et al., 2021). Thus Tri Hita Karana can be summed up. Its purpose is "three that bring well-being," which can also be interpreted as "the three causes of happiness." Three sources that can bring well-being are three harmonious, vertical, and horizontal relationships. The vertical relationship is the harmony of the relationship between man and God. Horizontal relations are the harmony of human relations with humans and the harmony of human relations with the natural environment (Idedhyana et al., 2021).

In this study, the third point of Tri Hita Karana was discussed, namely, love and respect for nature. About this research topic, there is support for the development of infrastructure planning which is realized by implementing a rainwater harvesting system. This shows that it can be a way to implement love and respect by preserving and utilizing nature by implementing green infrastructure planning. The following is the top view of the Ngurah Rai University research site from the 2022 satellite imagery.

Figure 1. Ngurah Rai University campus plan
(Satellite Imagery, 2022)

2.2. Calculation of the Amount of Water that can be Harvested

Critical data must be understood in knowing the amount of water harvested through the Rainwater Harvesting system. The maximum monthly average rain of the study site and the size of each roof of the building will be used as a rainwater collection medium. In general, the maximum monthly average rain of the study site is expressed in units of "mm" and the roof area of the building is expressed in units of "m²" so that later it can produce a volume of catchment water in "liters."

Here are the calculation steps used (Setyawaty & Aggraini, 2014):

Average rainfall data of the study site = (a) mm
Building roof area = (b) m^2
Rainwater harvesting results = a x b =... liter (1)

2.3. Calculation of Water Requirements

Water needs must be calculated to determine how effectively the Rainwater Harvesting system will be applied. Of course, the water needs are for domestic purposes, especially flushing toilets. Water users for light needs in this study are assumed to be 25% of the number of people in the building; this is also adjusted to the still restrictions due to the Covid19 pandemic (Menteri Dalam Negeri, 2021).

The simple calculation steps are:

Assumption of water requirement per person per day = (a) liters/person/day
Number of people = (b) people
Water needs = a x b =... liter/day (2)

3. Result and Discussion

3.1. Building Roof Analysis

Rainwater harvesting is the process of capturing and storing rainwater for various purposes. One of them in this study is an additional water source for toilet flushing needs. In small-scale applications, rainwater harvesting can be made simple by channelling rainwater from roofs that do not use gutters directly to the landscaping area by utilizing the contours of the landscaping area. A more complex system includes gutters, first rain pouring channels, pipes, reservoirs, filters, pumps, and water treatment units if they are to be used as raw water. The essential components of this system depend on the complexity of the system. However, in this study, the planned rainwater harvesting system generally has six primary parts: the surface of the catchment area, gutters, downspout pipes, leaf filters, and reservoirs (Pamungkas, 2022).

The primary and essential fundamental component in rainwater harvesting is the surface of the catchment area, where in this case, the roof of the building plays a critical role in the function. The amount of water collected from a roof depends on how wide the catchment area is(Pamungkas, 2022).

In this study, the analysis of building roof calculations is based on the area of the roof area of each building at the study site. The roof area will be known by utilizing data from 2022 satellite imagery which is then analyzed using software based on a geographic information system. The results obtained are as follows.

Figure 2. Analysis of roof area in study site building

Based on the results of mapping the roof of the building above, it can be known that there are 11 types of buildings that have different exteriors. The roof area on each building is presented in Table 1, which will further become a preliminary parameter for the analysis of the RWH.

Table 1. The roof area of the study site building

Code	Building	Roof Area (m^2)
FST	Faculty of Science and Technology (classroom)	716.827
FST	Faculty of Science and Technology (office)	250.528
FEB	Faculty of Economics and Business	434.877
FL	Faculty of Law	410.216
FSH	Faculty of Social Sciences and Humanities (classroom)	123.627
FSH	Faculty of Social Sciences and Humanities (office)	369.675

Code	Building	Roof Area (m²)
CO	Cooperation	71.468
PM	Postgraduate and Master	474.559
LI	Library	151.260
RE	Rectorate	819.716
CA	Canteen	315.144

3.2. Maximum Rainfall Analysis

Two essential data must be known to find out the amount of water that can be harvested through the rainwater harvesting process. Namely the average rain at the study site and the size of the catchment area (in this case, the roof of the building as a rainwater collector). The calculation, in general, the average rain of the study site is expressed in units of "mm" and the roof area of the building is expressed in units of "m^2" so that later it can produce the volume of catchment water in "liters" (Pamungkas, 2022).

The analysis of maximum monthly rainfall was taken based on rain data at the Penatih Rain Station, right at the study location, the Ngurah Rai University Campus. The data analyzed are rain data from 2013-to 2019. The results of the calculation analysis are presented in the table below.

Table 2. Average monthly maximum rainfall at Penatih Rain Station

Year	Month											
	Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Agt**	**Sep**	**Okt**	**Nov**	**Dec**
2013	97.000	67.200	50.000	18.300	41.800	115.600	42.100	4.000	3.700	10.200	31.100	59.800
2014	114.400	43.300	64.600	117.900	22.700	3.900	19.000	0.000	0.000	2.500	23.300	0.000
2015	47.800	46.040	43.500	35.700	21.300	58.000	0.000	2.500	0.000	0.000	19.800	67.320
2016	0.000	0.000	12.100	15.100	24.300	44.100	32.600	6.200	27.200	42.300	129.500	60.500
2017	0.000	120.900	29.800	32.400	41.400	43.400	17.600	11.600	3.200	81.400	74.800	102.400
2018	115.200	76.400	42.600	0.000	7.600	28.300	4.300	31.200	5.700	1.300	49.200	94.200
2019	69.400	49.200	55.800	44.400	9.100	1.300	2.100	1.300	0.000	0.000	10.500	70.600
average	**63.400**	**57.577**	**42.629**	**37.686**	**24.029**	**42.086**	**16.814**	**8.114**	**5.686**	**19.671**	**48.314**	**64.974**

3.3. Water Needs Analysis

The water need analysis will initially display data on the number of students and lecturers at each faculty at the study site. This data is intended to obtain the percentage of water use needed. In this study, due to the limited conditions of face-to-face meetings (Menteri Dalam Negeri, 2021), it is assumed that 25% of the students and the number of lecturers in each faculty use water for flushing toilets. So that the results of the analysis are obtained as follows:

Table 3. Average monthly maximum rainfall at Penatih Rain Station

Description	Number of Lecturers	Number of Students	Sum	Percentage of water users (25% x Sum)
Faculty of Science and Technology	22	396	418	105
Faculty of Economics and Business	26	1,019	1,045	262
Faculty of Social Sciences and Humanities	16	950	966	242
Faculty of Law	14	247	261	66
Postgraduate and Master	17	218	235	59

The assumption of water needs for flushing toilets is based on the standard storage capacity of the toilet for 2 flushes, which is 6 liters/person/day (TOTO Indonesia, 2021). So that the water needs of each faculty are obtained, namely:

Faculty of Science and Technology	= 6 x 105 = 630 liters/day
Faculty of Economics and Business	= 6 x 262 = 1,572 liters/day
Faculty of Social Sciences and Humanities	= 6 x 242 = 1,452 liters/day
Faculty of Law	= 6 x 66 = 396 liters/day
Postgraduate and Master's Programs	= 6 x 59 = 354 liters/day

The calculation above shows the daily water needs to be used as flushing toilets in each faculty, which will later become the basis for obtaining the analysis results of calculating the monthly water needs needed.

3.4. Calculation of the Volume of Water that can be Harvested

The volume of water that can be harvested begins with an analysis of the maximum monthly rainfall each year which is averaged based on rain data for 2013-2019. The volume of water that can be harvested is based on the maximum monthly rainfall yield and the size of the cover or roof of the building used as a harvesting medium. Then much water that can be poured will be analyzed for each building. Based on these data, the result of the volume of water that can be stored is presented in the table below.

Table 4. The volume of rainwater that can be harvested in the Faculty of Science and Technology Building

Month	**Number of days**	**Rainfall average (mm)**	**Roof area (m^2)**	**The amount of rainwater that can be harvested (liter)**
a	**b**	**c**	**d**	**e**
January	31	63.400	967.355	61,330
February	28	57.577	967.355	55,698
march	31	42.629	967.355	41,237
April	30	37.686	967.355	36,455
may	31	24.029	967.355	23,244
June	30	42.086	967.355	40,712
July	31	16.814	967.355	16,265
August	31	8.114	967.355	7,849
September	30	5.686	967.355	5,500
October	31	19.671	967.355	19,029
November	30	48.314	967.355	46,737
December	31	64.974	967.355	62,853

Using the same analysis steps, the following is presented an analysis of rainwater that can be harvested in each building at Ngurah Rai University.

Table 5. The volume of rainwater that can be harvested in each Building at Ngurah Rai University

Code	**Description**	**The amount of rainwater that can be harvested (liter)**
FST	Faculty of Science and Technology	416,911
FEB	Faculty of Economics and Business	187,423
FSH	Faculty of Social Sciences and Humanities	212,603
FL	Faculty of Law	176,795
PM	Postgraduate and Master	204,525
CO	Cooperation	30,801
LI	Library	65,190
RE	Rectorate	353,281
CA	Canteen	135,821

3.5. Rainwater Harvesting Capacity Analysis

This analysis explains the RWH capacity for water deficit moon conditions by explaining in detail the Capacity of RWH that must be provided, the amount of water that can be harvested, and excess and/or lack of water. Here are the results of the RWH capacity analysis.

Table 6. Calculation of RWH capacity in the Faculty of Science and Technology Building

Month	number of days	Rainfall average (mm)	Roof area (m^2)	The amount of rainwater that can be harvested (liter)	The abundance of water requirements (liter)	Lack of water (liter)	Excess water (liter)
a	**b**	**c**	**d**	**e**	**f**	**g**	**h**
January	31	63.400	967.355	61,330	19,530		41,800
February	28	57.577	967.355	55,698	17,640		38,058
march	31	42.629	967.355	41,237	19,530		21,707
April	30	37.686	967.355	36,455	18,900		17,555
may	31	24.029	967.355	23,244	19,530		3,714
June	30	42.086	967.355	40,712	18,900		21,812
July	31	16.814	967.355	16,265	19,530	3,265	
august	31	8.114	967.355	7,849	19,530	11,681	
September	30	5.686	967.355	5,500	18,900	13,400	
October	31	19.671	967.355	19,029	19,530	501	
November	30	48.314	967.355	46,737	18,900		27,837
December	31	64.974	967.355	62,853	19,530		43,323
Sum	**365**			**416,911**	**229,950**	**28,846**	**215,807**

From the results of the calculations above, the following information was obtained:

1. RWH storage capacity for water deficit conditions for four months requires a reservoir with a total of 28.84 = 29 m3
2. Examination of the calculation results:
   1. Amount of water that can be elucidated = 416,911 liters /year
      Water requirement = 229,950 liters /year
      Remaining water = 416,911 -229,950 = 186,961 liters /year
   2. Excess water = 215,807 liters /year
      Lack of water = 28,846 liters /year
      Remaining water = 215,807 -28,846 = 186,961 liters /year

From the results of the analysis above, it can be seen that the capacity of the RWH reservoir for conditions of a 4-month water deficit, namely in July, August, September, and October, is worth 28.84 = 29 m3. The calculation examination can also explain that the results of the RWH system in the Faculty of Science and Technology Building in one year still obtained the remaining water from rainwater harvesting of 186,961 liters/year. With details of water that can be harvested as much as 416,911 liters/year minus the total needs of 229,950 liters/year.

With the same analysis process by adjusting the needs of students and lecturers, the RWH results are obtained in the table below.

Table 7. Calculation of RWH capacity in the Faculty of Science and Technology Building

Description	The amount of rainwater that can be harvested (liter)	The abundance of water requirements (liter)	Lack of water (liter)	Excess water (liter)	Remaining water (liter)	Deficit month
Faculty of Science and Technology	416,911	229,950	28,846	215,807	186,961	4
Faculty of Economics and Business	187,423	573,780	386,357	0	-386,357	12
Faculty of Social Sciences and Humanities	212,603	529,980	317,377	0	-317,377	12
Faculty of Law	176,795	144,540	30,499	62,754	32,255	5
Postgraduate and Master	204,525	129,210	18,040	93,355	75,315	3
Cooperation	30,801	0	0	30,801	30,801	0
Library	65,190	0	0	65,190	65,190	0
Rectorate	353,281	0	0	353,281	353,281	0
Canteen	135,821	0	0	135,821	135,821	0

Based on the table above, the highest deficit month was for 12 months, with a total of -703,734 liters obtained from the results of the calculation of RWH capacity in the Faculty of Economics and Business Building and the Faculty of Social Sciences and Humanities. However, on the other hand, the results of the RWH capacity analysis showed that the amount of RWH remaining water from other buildings was 879,624 liters. Excess RWH water residue in the analysis results can be a solution as an additional water source for facilities that experience a water deficit.

Based on the results of the analysis, it is stated that there is an additional RWH water supply that plays a role in reducing the amount of groundwater used continuously and simultaneously can also reduce the electrical energy used by the good pump. Like previous research at Semarang State University, rainwater harvesting has excellent benefits in increasing water availability so that there is no water shortage during the dry season. During the rainy season, water can be accommodated and absorbed. It is also mentioned in the survey results that almost 70% of campus residents said that rainwater harvesting is a form of conservation support (Jayanti et al., 2012). On the other hand, with almost the same method and application, it is stated that research conducted at Ekasakti universities produces the potential for rainwater harvesting to supply overall water needs so that it does not require groundwater extraction (Marni, 2019).

From this explanation, it can be concluded that rainwater harvesting is not only an alternative water source for meeting water needs (Nurrohman & Waskita Eka, 2015). Especially in the Ngurah Rai University environment but also as an effort to maintain water resource conservation and can create sustainability for water management (Kharisma et al., 2016) and can meet the aspects of implementing green building management in terms of energy-saving and environmentally friendly concepts (Tanubrata & Gunawan, 2016).

4. Conclusions

The rainwater harvesting analysis conducted at the Ngurah Rai University study site showed that 11 rainwater catchment buildings produce water reservoirs from 1,783,350 liters/year crops. There is a total water deficit of -703,734 liters/year, while the remaining water is 879,624 liters/year. This indicates that this rainwater harvesting method can cover all water needs in Ngurah Rai University, especially water used for flushing toilets. In addition, rainwater harvesting also plays a role as a form of effort to maintain the conservation of water resources and the application of green buildings that are energy efficient and environmentally friendly. Applying a rainwater harvesting system, as described earlier, certainly has many benefits. However, there have been no studies on the quality of the rainwater produced in this study. Therefore, it is hoped that in the following research, there will be an analysis related to rainwater quality to increase the usefulness of potential rainwater harvesting results.

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