UAV-Based Assessment of Rainwater Harvesting and Clean Water Management on a Small Island in Indonesia

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ABSTRACT: This study investigates the utilization of rainwater harvesting systems and their effectiveness in meeting domestic and educational water needs on Bonetambung Island. Using a mixed-method approach, data were collected through questionnaires and spatial analysis of high-resolution imagery obtained from unmanned aerial vehicles (UAVs) and processed via ArcGIS software. The findings reveal that 90% of the local population relies on boreholes and bottled water, while only 10% utilize rainwater harvesting, indicating a limited understanding of sustainable water management practices. Rainfall data analysis demonstrates a significant potential for rainwater collection, particularly in December, with an estimated collection capacity of 518,796 L for domestic use. However, a monthly deficit of 807,613 L indicates that rainwater alone cannot fully meet community needs. Additionally, educational facilities face similar challenges in water availability. The results highlight the need for improved water management strategies and the integration of rainwater harvesting systems to enhance water resilience for domestic and educational needs on Bonetambung Island.

1. INTRODUCTION

Clean water is a vital source of life essential for the normal functioning of the human body. However, its distribution is not evenly spread across all regions (Bidaisee, 2018). Small islands are among the areas facing limitations in clean water resources. Approximately 1,000 inhabited small islands in the Pacific Ocean, most of which are located in tropical and subtropical zones. Across these islands, clean water availability is a common issue with both quantity and quality constraints (White & Falkland, 2010). In Indonesia alone, 16,771 islands were officially reported to the United Nations during the UNGEGN session 2020.

Small islands face limitations in providing clean water resources due to their restricted storage capacities. Clean water sources on these islands generally rely on rainwater or meteoric water, as their catchment areas are limited, thus constraining their rainwater storage potential. Therefore, effectively managing clean water resources on Indonesia's small islands is essential (Marganingrum & Sudrajat, 2018).

To date, rainwater has not been optimally utilized as a natural resource. Much of it flows into drainage channels, ultimately reaching rivers and the sea. However, with proper collection and management, rainwater can offer numerous benefits, particularly in providing clean water for communities. Rainwater has substantial potential for various human needs, such as bathing, washing, and drinking. Collecting and utilizing rainwater can reduce dependence on other water sources, such as wells or surface water (PUPR, 2022).

The situation on Bonetambung Island is similar to that of other small islands, which face significant water availability challenges. The limited supply of clean water in Bonetambung has become a serious issue. A key factor contributing to this problem is the suboptimal use of rainwater on the island. Insufficient infrastructure and a lack of awareness and understanding among the community about the potential of rainwater utilization are major obstacles to optimizing rainwater as a sustainable source of clean water. The shortage of clean water directly impacts various aspects, including the economy, food security, and public health (Forde M.S et al., 2024; Rumihin O.F, 2024; Birawida A.B et al., 2021; Prüss-Ustün et al., 2014).

This study introduces an innovative approach by integrating high-resolution UAV imagery, spatial analysis, and direct surveys to assess the effectiveness of rainwater harvesting (RWH) systems on Bonetambung Island. This method accurately maps rainwater collection potential while providing insights into community water usage patterns. Consequently, the study not only evaluates the capacity of RWH systems but also identifies social and technical challenges in their implementation.

The availability of clean water remains a significant challenge for communities living on small islands, including Bonetambung Island. Boreholes and bottled water remain the primary water sources, while using rainwater harvesting (RWH) systems remains suboptimal. However, RWH has significant potential to enhance water resilience, particularly in areas with limited access to freshwater sources.

Previous studies have explored the use of rainwater to improve community quality of life, particularly with attention to regional topography. However, these studies have generally focused on clean water needs within urban areas. This research advances these efforts by quantifying the potential water availability using rainfall data, specifically within small island clusters. The issue of clean water availability on small islands is critical to address due to the growing population each year, which drives an increasing demand for water resources.

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2. MATERIAL AND METHODS

2.1 Study Area

This study was conducted on Bonetambung Island, located in Makassar City, one of the 114 small islands in the Spermonde Archipelago, Makassar Strait. Administratively, the island falls within the Barrang Caddi Subdistrict, Sangkarang Islands District, Makassar City. Astronomically, Bonetambung Island is situated at the coordinates 5°2′11.800″ S and 119°16′38.900″ E (Figure 1).

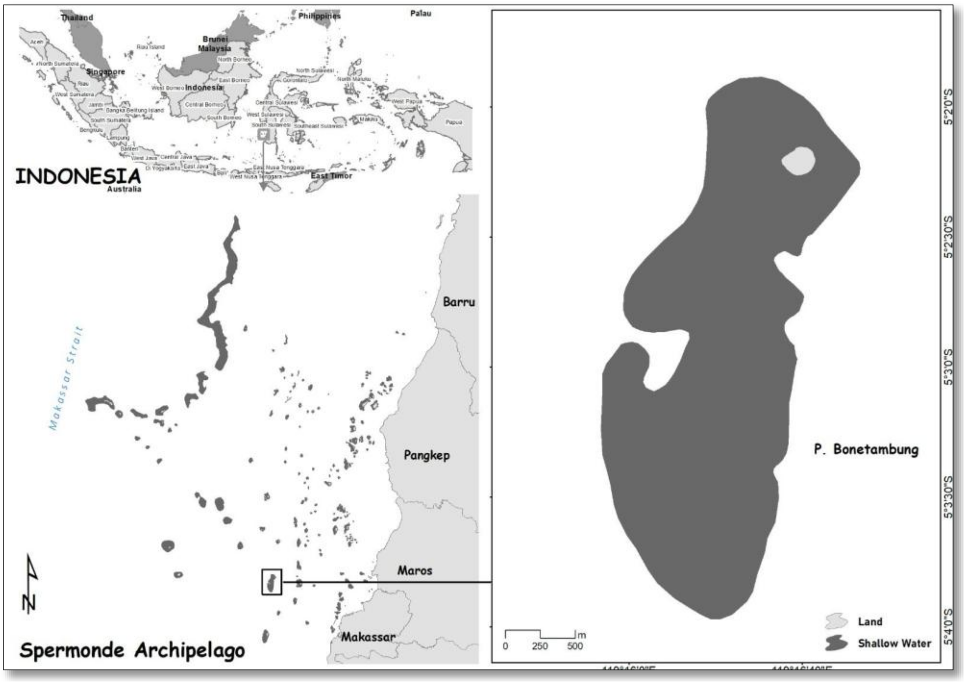

Figure 1. The research location on Bonetambung Island is one of the small island that forms the Spermonde Archipelago, located off the southwestern coast of Sulawesi, Indonesia

This study employs a descriptive quantitative approach aimed at providing a factual depiction of variables supported by numerical data, allowing for comprehensive, valid, reliable, and objective data collection (Creswell, 2014:5). The purpose of this study is to understand the current state of clean water availability on small island Bonetambung and to identify the potential for rainwater harvesting as an alternative source of clean water for the local community. Additionally, this study seeks to offer guidance and recommendations on using and managing rainwater as a clean water source on Bonetambung Island.

2.2 Data

2.2.1 Data Requirements

This study requires two types of data: primary and secondary data. Primary data were obtained through field surveys, observations, and questionnaires involving respondents on Bonetambung Island. This data was gathered directly from sources. Meanwhile, secondary data comprises pre-existing information that is accessible through government agencies or relevant prior research. This secondary data serves to support and supplement the collected primary data. Both types of data are essential to enriching and strengthening this study. Table 1 presents the specific data requirements for this research.

Table 1. Types of Data Requirements

No	Data Type	Source	Output
1	Latest High-Resolution Imagery	UAV (Unmanned Aerial Vehicle), observation	Area of community water catchment
2	Community Water Demand	Interviews, observation, and literature review,	Water demand of Bonetambung Island
3	Rainfall Data for the Last 13 Years	BMKG website	Monthly average rainfall

The secondary data included information on the population of Bonetambung Island in 2023, water demand standards outlined in Indonesia’s Ministry of Environment Regulation No. 17, water planning criteria from the Ministry of Public Works and Housing (2000), and historical rainfall data from the BMKG Paotere Station for the 2010–2022 period. This rainfall data was used to analyze annual rainfall patterns and calculate the potential volume of rainwater that could be harvested as a clean water source.

2.2.2 High-Resolution Imagery Data

Data collection of high-resolution imagery on Bonetambung Island was conducted using an Unmanned Aerial Vehicle (UAV), or drone, capable of producing high-resolution images essential for detailed spatial analysis. This phase began with meticulous flight planning to ensure the UAV's flight path entirely covered the research area. The flight route was designed to ensure overlap between the captured images, typically around 60-80%, to

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facilitate the alignment of images into an orthomosaic. Additionally, the UAV's flying altitude was adjusted according to the required resolution, which in this study ranged from 5 to 10 cm per pixel, to ensure the accuracy needed for detecting land features. By employing this UAV data collection approach, the study produced accurate high-resolution maps, which were then used to identify potential rainwater storage areas and assess clean water needs based on the distribution of public facilities. These results are crucial for supporting further analysis of rainwater utilization's effectiveness in meeting Bonetambung Island's water demands. The Orthophoto Digital Surface Model (DSM) results are utilized for further spatial analysis in the form of land cover analysis on Bonetambung Island, conducted using on-screen digitizing techniques. The information related to land use is then used to determine the water needs of the Bonetambung community by integrating observational data with relevant literature findings.

2.2.3 Roof Area Measurement Using Drone Technology and Photogrammetric Processing

To efficiently and accurately calculate the roof area of residential houses, the method employed involves utilizing drone technology for aerial imagery acquisition, which is then processed using photogrammetry software and Geographic Information Systems (GIS). Initially, flight paths are meticulously planned to ensure optimal survey area coverage. Ground Control Points (GCPs) are established to enhance georeferencing accuracy. Drones equipped with high-resolution cameras capture overlapping aerial photographs, facilitating comprehensive data collection. Subsequently, these images undergo photogrammetric processing to generate a georeferenced orthomosaic and a detailed 3D model of the surveyed area. Within the GIS environment, the boundaries of each house's roof are digitized based on the orthomosaic. The software then calculates the area of each digitized roof polygon, providing precise measurements. To ensure data accuracy, field checks are conducted by comparing a sample of the digitized roofs with actual on-site conditions. This validation step confirms the reliability of the digitization and area calculations. By following this methodology, the process of determining the roof areas of residential houses becomes more efficient and accurate compared to traditional methods. The integration of drone technology enables rapid and safe data collection, while the use of photogrammetry and GIS ensures precise and dependable results.

2.2.4 Population Water Demand Data

Data collection regarding the water needs of the community on Bonetambung Island was conducted using a comprehensive approach to gather information about clean water consumption patterns on the island. This data is crucial for identifying the extent of clean water needs for various activities, both domestic and non-domestic, amidst the existing limitations of water resources. The data collection involved direct field surveys and the distribution of questionnaires filled out by local residents. The questionnaires were designed to collect data related to daily clean water needs, the primary water sources utilized, and the level of rainwater usage by the community.

The data collection process began by identifying the target population, which included households and various public facilities on the island, such as schools, healthcare facilities, and places of worship. Sampling was conducted using Slovin's formula; from a total population of 642 individuals, a sample size of 87 individuals was determined to be necessary. The collected data included the average per capita water consumption for household needs, covering water for drinking, cooking, washing, and bathing. Additionally, for the non-domestic category, the data encompassed water usage in educational, healthcare, and worship facilities.

The method for measuring the population's water needs was also adapted to the types of facilities present. For instance, water needs were calculated in the education category based on the school's number of students and teachers. Water needs in healthcare facilities were assessed by considering the number of medical staff and patients served daily. In this case, the calculation of standard water needs was performed based on two categories, domestic and non-domestic needs, in accordance with the regulations outlined in PERMEN LH No. 17 of 2009 and Ditjen Cipta Karya 2000. To calculate domestic water needs, the formula used is as follows;

$$D_A = N \times K \quad (1)$$

Dimana: DA = Total Water Needs (L/day)
N = Population (individuals)
K = Water Needs (L/person/day)

This data is subsequently used to compare with the potential rainwater that can be utilized, providing an overview of the gap between the demand for and the availability of clean water on the island.

2.2.5 Rainfall Data for the Last 13 Years

The collection of rainfall data over the past 13 years on Bonetambung Island was conducted to analyze the potential utilization of rainwater as a primary source of clean water. Monthly average rainfall data was obtained by analyzing secondary data records from relevant rainfall stations. In this study, the reliable rainfall calculation utilized the basic month method. The probability of occurrence was calculated using the probability formula from the Weibull equation (Equation 2). This method is commonly used because the reliability of the flow is calculated from January to December.

$$P = \left(\frac{m}{N+1}\right) * 100\% \quad (2)$$

Where: P = Probability
m = Rainfall Data Serial Number
n = Data Quantity

The analysis of reliable rainfall was conducted using the planning month method, with a reliability level of 80%. The following formula is used to determine the reliable rainfall year in this context:

$$R80 = \left(\frac{N}{5}\right) + 1 \quad (3)$$

Once the three variables are obtained, the calculation of the amount of rainwater that can be harvested is carried out. The guidelines used for calculating the amount of harvestable rainfall are as follows::

$$\sum Q = a \times R \times A \quad (4)$$

Dimana: $\sum Q$ = Harvestable Water Volume (L/month)
A = Roof Area of the Building (m²)

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a = Roof Runoff Coefficient (0.95)
R = Reliable Rainfall (mm/month)

The runoff coefficient used is 0.95 as an estimate, where each millimeter of rainfall that falls on one square meter of roof will yield 0.95 millimeters of collected water. This accounts for water loss due to evaporation and leakage (Cahyani & Helda, 2022). Subsequently, the average daily rainfall is calculated based on the maximum monthly rainfall average over a 10-year period. This data is obtained from secondary hydrological data collected from relevant rainfall stations. Based on these variables, the comparison between the amount of harvestable rainwater and the clean water needs of the residents of Bonetambung Island is then calculated. After performing the calculations, the average maximum monthly rainfall (R) over the 10 years was obtained, which was then divided by the number of days in a month (30) to determine the average maximum daily rainfall.

The data analysis results from the first and second research questions were processed using quantitative descriptive analysis to identify the effectiveness of rainwater utilization in enhancing the availability of clean water on Bonetambung Island. This analysis aims to determine the extent of the potential and effectiveness of rainwater in meeting the water needs of the residents of Bonetambung Island.

Subsequently, the data obtained from this analysis were processed using a surplus-deficit balance calculation. This surplus-deficit balance is calculated using the following equation (Hatmoko, 2012):

$$\text{Balance} = \text{Rainwater (Q)} - \text{Water Needs (Q)} \tag{5}$$

Where: *Balance* = Balance
Rainwater (Q) = Availability of Rainwater
Water Needs (Q) = Water Needs

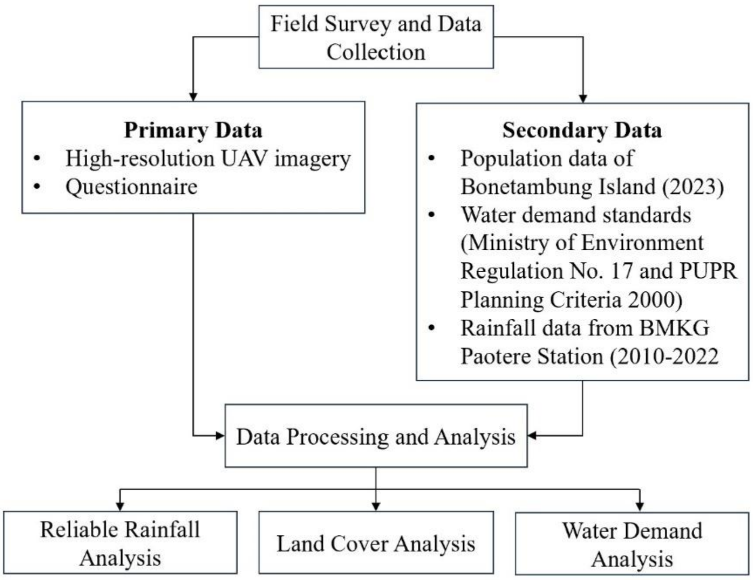

Figure 2. Research Flow Diagram

3. RESULT AND DISCUSSION

3.1 Calculation of Water Needs

3.1.1 Calculation of Domestic Water Needs

The calculation of clean water needs can be determined based on the population size and the daily clean water requirement per person. This information is necessary to calculate the comparison between the clean water needs of the population and the potential harvestable rainwater. According to the Planning Criteria from the Directorate General of Human Settlements, Ministry of Public Works in 2000, the daily clean water requirement is 60 L per person per day, with a total population of 642 individuals. The calculation is performed using Equation (1) as follows:

$$
\begin{aligned}
D_A &= N \times K \qquad (1)\\
&= 642 \times 60 \text{ L/day}\\
&= 38520 \text{ L/day, to L/month}\\
&= 1194120 \text{ L/month}
\end{aligned}
$$

Based on the data from 2023, the population of Bonetambung Island is 642 individuals, with a standard water requirement of 60 L per person per day. Therefore, the total daily water need to meet the domestic requirements of the residents of Bonetambung Island amounts to 38,520 L per day, which translates to 1,194,120 L for the month of January (Table 2)

Table 2. Recapitulation of Domestic Water Needs for the Population of Bonetambung Island

Month	Population	average water consumption	Water needs	
	(Person)	(L/person/day)	L/day	(L/month)
Jan	642	60	38520	1194120
Feb	642	60	38520	1078560
Mar	642	60	38520	1194120
Apr	642	60	38520	1155600
May	642	60	38520	1194120
Jun	642	60	38520	1155600
July	642	60	38520	1194120
Aug	642	60	38520	1194120
Sep	642	60	38520	1155600
Oct	642	60	38520	1194120
Nov	642	60	38520	1155600
Dec	642	60	38520	1194120

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3.1.2 Calculation of Water Requirements for Educational Facilities

In 2023, there were 78 students attending elementary school (SD), accompanied by 6 teachers, and 29 students at the junior high school level (SMP), guided by 7 teachers. Based on this data, the total number of individuals involved in educational facilities reached 113 people. With a standard water requirement for educational facilities in category V (village) set at 5 L per person per day, the calculation for total daily water needs is as follows Table 3.

Table 3. Number of Students and Teachers in Educational Facilities on Bonetambung Island

Years	Elementary schools		Junior High Schools	
	students	teachers	students	teachers
2024	78	6	29	7

This data then serves as the basis for calculating the water requirements for educational facilities using the following equation:

$$Ks = d\,x \sum n \quad (4)$$

Where: Ks = 5 L/person/day x ∑ (78+6+29+7)
= 5 L/person/day x 113 person
= 600 L/person/day to L/month
Ks = 18600 L/month

Thus, the total daily water requirement for educational facilities is 565 L per day or approximately 16,950 L per month. Table (4) summarizes the monthly water needs for educational facilities

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Table 4. Calculation of Water Needs for Educational Facilities on Bonetambung Island

Month	Number of students and teachers		Average Water Consumption	Water Consumption	
	SD	SMP	(lt/person/day)	lt/day	(lt/month)
Jan	84	36	5	600	18600
Feb	84	36	5	600	16800
Mar	84	36	5	600	18600
Apr	84	36	5	600	18000
Mei	84	36	5	600	18600
Jun	84	36	5	600	18000
Jul	84	36	5	600	18600
Agt	84	36	5	600	18600
Sep	84	36	5	600	18000
Okt	84	36	5	600	18600
Nop	84	36	5	600	18000
Des	84	36	5	600	18600

Figure 3. Land use of Bonetambung Island and digitization of residential houses used as a basis for calculating the roof area of residents' houses

3.2 Potential Rainwater Harvesting

3.2.1 Land Cover Analysis

The interpretation of digital imagery was conducted to identify land use classification in the research area. This classification follows the system established by the Geospatial Information Agency (BIG) and includes various categories such as residential areas, fields, vacant land, cemeteries, beach sand, and roads. Using digitization techniques, the boundaries of these areas were accurately defined to map the rainwater catchment areas. The results indicate that the total area of residential land is 12,582.99 m², with details on the area for each type of land use as follows Table 5.

Table 5. Area and Classification of Land Use in Bonetambung Island

No	Land Use Type	Area (m^2)
1	Road	1817,02
2	Field	2915,15
3	Mosque	263,82
4	Yard	5633,02
5	Cemetery	188,04
6	Residential Area	12582,99
7	Coastal Area	7520,98
8	Community Health Center (Puskesmas)	109,60
9	Elementary School	301,29
10	Junior High School	358,47

Figure 3 represents a visual representation of the land use classification results in the study area. This land cover map illustrates the distribution of various types of land use, providing important information regarding the rainwater catchment areas and the potential for water collection on Bonetambung Island.

3.2.2 Average Monthly Rainfall

Algebraic methods were employed to calculate the average maximum rainfall, particularly suited for flat topographies and areas with limited measurement stations. This method allows for efficient calculations even when the number of measurement stations is restricted. By allocating the area to each station, the algebraic approach yields an average maximum rainfall based on the distribution of these areas. The resulting data enhances understanding of rainfall distribution, thereby supporting development planning, resource management, and disaster mitigation efforts in the region. The implementation of this method provides a solid foundation for decision-making at both local and regional levels.

Rainfall data in the study area were collected from the Paotere Rain Gauge Station during the period from 2010 to 2022, aiming to assess the available rainwater potential and reliable storage capacity. The average monthly rainfall over the 13-year period was utilized to calculate the dependable rainfall, defined as the amount of rainfall with an 80% probability of occurrence, which can be relied upon for water management planning.

The dependable rainfall probability was calculated using the Weibull equation (Equation 2) and the Basic Years method (Equation 3). Rainfall is considered dependable if it meets a probability threshold of 28.57%. Based on the summary table, the dependable rainfall for each month was identified in specific years: January in 2010, February in 2022, March in 2021, April in 2014, May in 2012, June in 2019, July in 2010, August in 2021, September in 2017, October in 2010, November in 2022, and December in 2022. The following graph illustrates the dependable rainfall, summarizing the results of these calculations.

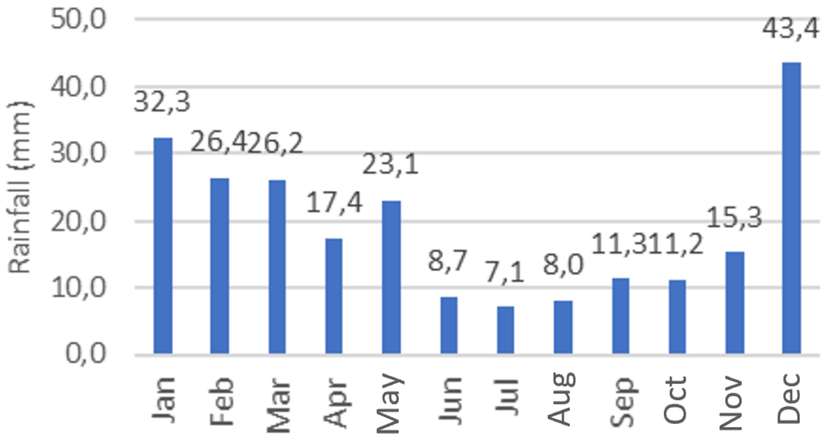

Figure 4. Monthly rainfall reference chart

3.2.3 Calculation of Harvestable Rainwater

The runoff coefficient used in this study is 0.95, indicating that for every millimeter of rainfall falling on one square meter of roof, 0.95 L of water can be harvested after accounting for losses due to evaporation and leakage. To calculate the amount of rainwater that can be harvested, Equation (4) was employed. In the context of these calculations, the catchment area for various types of settlements is as follows: the catchment area for residential settlements is 12,583 m², while that for educational facilities is 659.75 m²

The average dependable rainfall utilized is 32.3 mm per month, equivalent to 0.032 m per month. By applying these values into the equation, the total amount of rainwater that can be harvested in January can be determined. The following are the calculations for each type of catchment area.

Harvestable Domestic Rainwater

From the calculation of harvestable domestic rainwater in January using Equation (4), the study area has the potential to collect approximately 386,507 L of rainwater. Table 6 illustrates a summary of the potential harvestable rainwater for domestic needs.

This contribution has been peer-reviewed. The double-blind peer-review was conducted on the basis of the full paper.
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Table 6. Recapitulation of Harvestable Rainwater Potential for Domestic Needs

Month	Rainfall		Roof Area	Runoff Coefficient	Water Availability	
	mm	m	m^2	c	m^3	liter
Jan	32,3	0,032	12583	0,95	387	386507
Feb	26,4	0,026	12583	0,95	316	315725
Mar	26,2	0,026	12583	0,95	313	312593
Apr	17,4	0,017	12583	0,95	208	207698
May	23,1	0,023	12583	0,95	276	276266
Jun	8,7	0,009	12583	0,95	104	103657
July	7,1	0,007	12583	0,95	85	85385
Aug	8,0	0,008	12583	0,95	96	95631
Sep	11,3	0,011	12583	0,95	135	135477
Oct	11,2	0,011	12583	0,95	133	133285
Nov	15,3	0,015	12583	0,95	183	183165
Dec	43,4	0,043	12583	0,95	519	518796

Harvestable Rainwater from Educational Facilities

Based on the calculations of harvestable rainwater for educational facilities in January using Equation (2), where aaa is the runoff coefficient (0.95), RRR is the average daily rainfall (0.032 m/month), and AAA is the catchment area (659.75 m²), the result obtained for harvestable rainwater is 20.3 m³/month. When converted to L, the total amount of rainwater that can be collected for educational facilities is approximately 20,265.4 L/month.

Table 7. Recapitulation of Harvestable Rainwater Potential for Educational Facilities

Bulan	Rainfall		Roof Area	Runoff Coefficient	Water Availability	
	mm	M	m^2	c	m^3	liter
Jan	32,3	0,032	660	0,95	20,3	20265,4
Feb	26,4	0,026	660	0,95	16,6	16554,1
Mar	26,2	0,026	660	0,95	16,4	16389,9
Apr	17,4	0,017	660	0,95	10,9	10890,1
May	23,1	0,023	660	0,95	14,5	14485,3
Jun	8,7	0,009	660	0,95	5,4	5435,0
Jul	7,1	0,007	660	0,95	4,5	4476,9
Aug	8,0	0,008	660	0,95	5,0	5014,1
Sep	11,3	0,011	660	0,95	7,1	7103,3
Oct	11,2	0,011	660	0,95	7,0	6988,4
Nov	15,3	0,015	660	0,95	9,6	9603,8
Dec	43,4	0,043	660	0,95	27,2	27201,6

Based on the data above, several conclusions can be drawn regarding water needs for various purposes. Domestic water requirements are substantial, with a catchment area of 12,582.99 m², yielding a total harvestable water amount of 38,520 m³/month or 1,194,120 L/month. On the other hand, the water requirements for educational facilities are significantly lower. For instance, an educational facility with a catchment area of 659.75 m² yields a total harvestable water amount of 600 m³/month or 18,600 L/month.

3.2.4 Rainwater Potential for Domestic and Non-Domestic Water Needs

Domestic Rainwater Availability Balance

Understanding the amount of harvestable rainwater and calculating the water needs for both domestic and non-domestic purposes allow for an analysis of the potential to meet household water demands. The surplus or deficit balance can be determined using Equation (5). The calculations indicate that the domestic rainwater balance experiences a deficit of -807,613 L per month. This demonstrates that the available rainwater is insufficient to meet the domestic needs, which amount to 1,194,120 L per month. Therefore, additional or alternative water sources are necessary to address this shortfall. Effective planning and management of water resources are crucial to mitigate the imbalance between water availability and demand.

Table 8. Recapitulation of Domestic Water Surplus and Deficit Balance

Month	Water Availability		Water Demand		Balance	Description
	L/month	m3/month	L/month	m3/month		
Jan	386507	386,5	1194120	1194,1	-807613	defisit
Feb	315725	315,7	1078560	1078,6	-762835	defisit
Mar	312593	312,6	1194120	1194,1	-881527	defisit
Apr	207698	207,7	1155600	1155,6	-947902	defisit
May	276266	276,3	1194120	1194,1	-917854	defisit
Jun	103657	103,7	1155600	1155,6	-1051943	defisit
July	85385	85,4	1194120	1194,1	-1108735	defisit
Aug	95631	95,6	1194120	1194,1	-1098489	defisit
Sept	135477	135,5	1155600	1155,6	-1020123	defisit
Oct	133285	133,3	1194120	1194,1	-1060835	defisit
Nov	183165	183,2	1155600	1155,6	-972435	defisit
Dec	518796	518,8	1194120	1194,1	-675324	defisit

Based on the results of the recapitulation of the domestic water surplus and deficit balance shown in Table 8, a comparative graph between the potential utilization of rainwater and the water requirements for domestic activities can be seen in Figure 6.

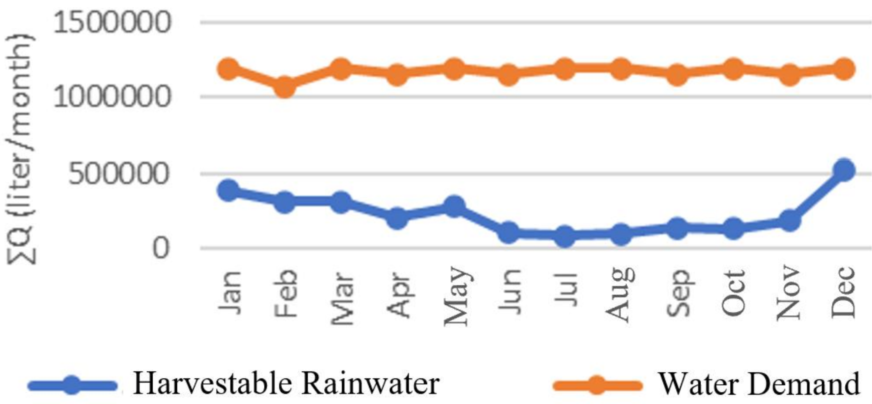

Figure 5. Comparison Graph of Domestic Water Supply and Demand

Rainwater Availability Balance for Educational Facilities

Based on the calculations of the rainwater availability balance for educational facilities using Equation (5), it is found that there is a surplus of 1,665 L/month. This indicates that the availability of rainwater for educational purposes in a given location exceeds the necessary requirements, resulting in a positive surplus of that amount.

Table 9. Recapitulation of Surplus and Deficit Water Balance for Educational Facilities

Month	Water Availability		Water Demand		Balance	Description
	literr/month	m3/month	L/month	m3/month		
Jan	20265,4	20,3	18600	18,6	-807613	defisit
Feb	16554,1	16,6	16800	16,8	-762835	defisit
Mar	16389,9	16,4	18600	18,6	-881527	defisit
Apr	10890,1	10,9	18000	18,0	-947902	defisit
Mei	14485,3	14,5	18600	18,6	-917854	defisit
Jun	5435	5,4	18000	18,0	-1051943	defisit
Jul	4476,9	4,5	18600	18,6	-1108735	defisit
Agt	5014,1	5,0	18600	18,6	-1098489	defisit
Sep	7103,3	7,1	18000	18,0	-1020123	defisit

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Month	Water Availability		Water Demand		Balance	Description
	literr/month	m3/month	L/month	m3/month		
Okt	6988,4	7,0	18600	18,6	-1060835	defisit
Nop	9603,8	9,6	18000	18,0	-972435	defisit
Des	27201,6	27,2	18600	18,6	-675324	defisit

Based on the results of the recapitulation of the domestic water surplus and deficit balance shown in Table 9, a comparative graph between the potential utilization of rainwater and the water requirements for educational activities can be seen in Figure 6.

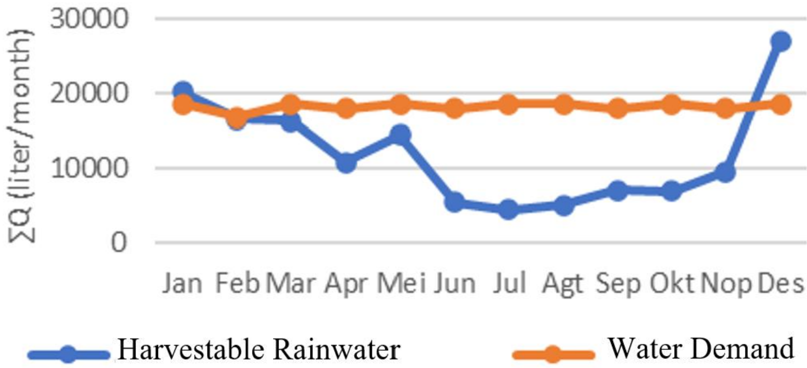

Figure 6. Comparison Graph of Educational Facilities Water Supply and Demand

This study indicates that Bonetambung Island has significant potential for rainwater collection, especially in December, with a reliable rainfall of 43.4 mm. The estimated potential for domestic use in December is substantial, reaching 518,796 liters, suggesting that this resource has not been optimally utilized and could enhance water availability across various sectors, including domestic and educational needs. However, when compared to domestic water requirements, there is a deficit of 807,613 liters per month, highlighting that the available rainwater is insufficient to meet total domestic demands. These findings underscore the necessity for strategic planning and management of rainwater resources to bridge the gap between availability and demand. Implementing rainwater harvesting systems and improving existing infrastructure can enhance water conservation efforts, particularly in areas facing deficits. By leveraging the potential of harvested rainwater, communities can achieve greater resilience against water scarcity and ensure a sustainable supply for domestic and educational purposes. Continued research and investment in water resource management will be vital in addressing the challenges of fluctuating rainfall patterns and increasing water demand in the region. This study makes a significant scientific contribution by providing empirical data on the disparity between water availability from rainwater harvesting and actual water demand for both domestic and educational purposes. It demonstrates the potential of geospatial technologies in evaluating water resource management, offering a replicable model for similar small island environments.
Additionally, the study highlights the socio-behavioral aspect of water management by revealing the limited adoption of rainwater harvesting despite its potential, providing valuable insights for future water management policies and sustainable practices. Similarly, the balance analysis reveals a gap between the availability and demand for water in educational facilities. These findings emphasize the necessity for improved management strategies to optimize rainwater utilization, ensuring that both domestic and educational water needs are sustainably met on Bonetambung Island.

4. CONCLUSION

The findings underscore the necessity for enhanced management strategies to optimize rainwater utilization, ensuring the sustainable fulfillment of domestic and educational water needs on Bonetambung Island. This highlights the importance of increasing public awareness regarding rainwater harvesting and management, as well as the need for effective management strategies to optimize rainwater utilization on the island. Further research should focus on enhancing community engagement and exploring innovative approaches in sustainable water resource management.

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