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The potency of obtained clean water from rainwater Harvesting in Sikka District

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Abstrac. *Sikka District is one of the areas experiencing a clean water crisis because only 5.23% of people have access to clean water in 2020. Therefore, rainwater management will be carried out to obtain clean water using rooftop rainwater harvesting technology. This study aims to calculate the potency of clean water that can be obtained from rainwater harvesting. The comparative descriptive analysis method was used to compare the data on clean water potency that can be obtained from rainwater harvesting with the data on clean water needs from the people in Sikka District in 2020. The results show that the potency of clean water that can be obtained from rainwater harvesting is 3 593 961.6 m^3/year or 3 593 961 600 liters/year. This potency can only be distributed to 19.52% or 62 846 of the total people population in Sikka District. This shows that the use of rainwater cannot meet the clean water needs of all people in Sikka District. There is a need for other sources of clean water that are bigger and can be used to meet the needs of all people.*

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INTRODUCTION

Water is one of the most important elements to support the survival of all living things. Humans need clean water for various purposes such as household, industrial, sanitation, irrigation, and so on (Arnop *et al*., 2019). Clean water comes from various sources on the Earth's surface (rivers, lakes, seas), in the ground, and in the air (Amalia and Sugiri, 2014; Hudiyah and Saptomo, 2019; Ramadhayanti and Helda, 2021). The need for clean water is increasing due to an increase in population (Alihar, 2018). However, the available clean water is limited and even decreased due to reduced water sources and innovation in its management.

Sikka District is an area where the population suffers from a lack of access to clean water. The number of people who have access to clean water in 2020 is 16 823 people and smaller than 2019, which was 16 942 people (BPS of Sikka District, 2021). Based on information from the BPS of Sikka District (2021), the people population in 2020 was 321 953 people and an increase of 188 people compared to 2019. The percentage of people population who has access to clean water in 2020 is only 5.23%, and this shows that there are still many residents in Sikka District who do not have access to clean water.

Water sources in Sikka District come from the ground and are few in number, so not all residents have access to clean water. Another alternative source of water that can be utilized is from the air, namely rainwater. Rainwater can be harvested if managed by applying appropriate technology. Research conducted by Ramadhayanti and Helda (2021) regarding the potential that can be generated from rainwater harvesting in North Banjarbaru Sub-district shows that the potential for clean water obtained reaches 31.7% of the total clean water needs. This result can provide additional clean water for residents, especially during the dry season.

Sikka District can also gain additional access to clean water from rainwater harvesting activities. Rainwater harvesting can be carried out by applying a rooftop rainwater harvesting technology system. However, it is necessary to know the amount of clean water that will be produced from harvesting rainwater in Sikka District. Therefore, it is necessary to calculate and analyze the potential for clean water that can be obtained from rainwater harvesting.

METHOD

Research Location

This research was conducted in an area called Sikka District. Sikka District is located on the island of Flores, East Nusa Tenggara Province, Indonesia. The topography of Sikka District is 100-500 m above sea level. The capital city of Sikka District is Maumere. The area of Sikka District can be seen in Figure 1. Figure 1 shows there are 21 Sub-districts in Sikka District. Astronomically, the Sikka District is located at 08^{O} 22" to 08^{O}50" South Latitude and 121^{O}55'40" to 121^{O}41'30" East Longitude. Sikka District is bordered by East Flores District in the east. To the south it is bordered by the Sawu Sea. Ende District is in the west of Sikka District. The area to the north of Sikka District is the Flores Sea.

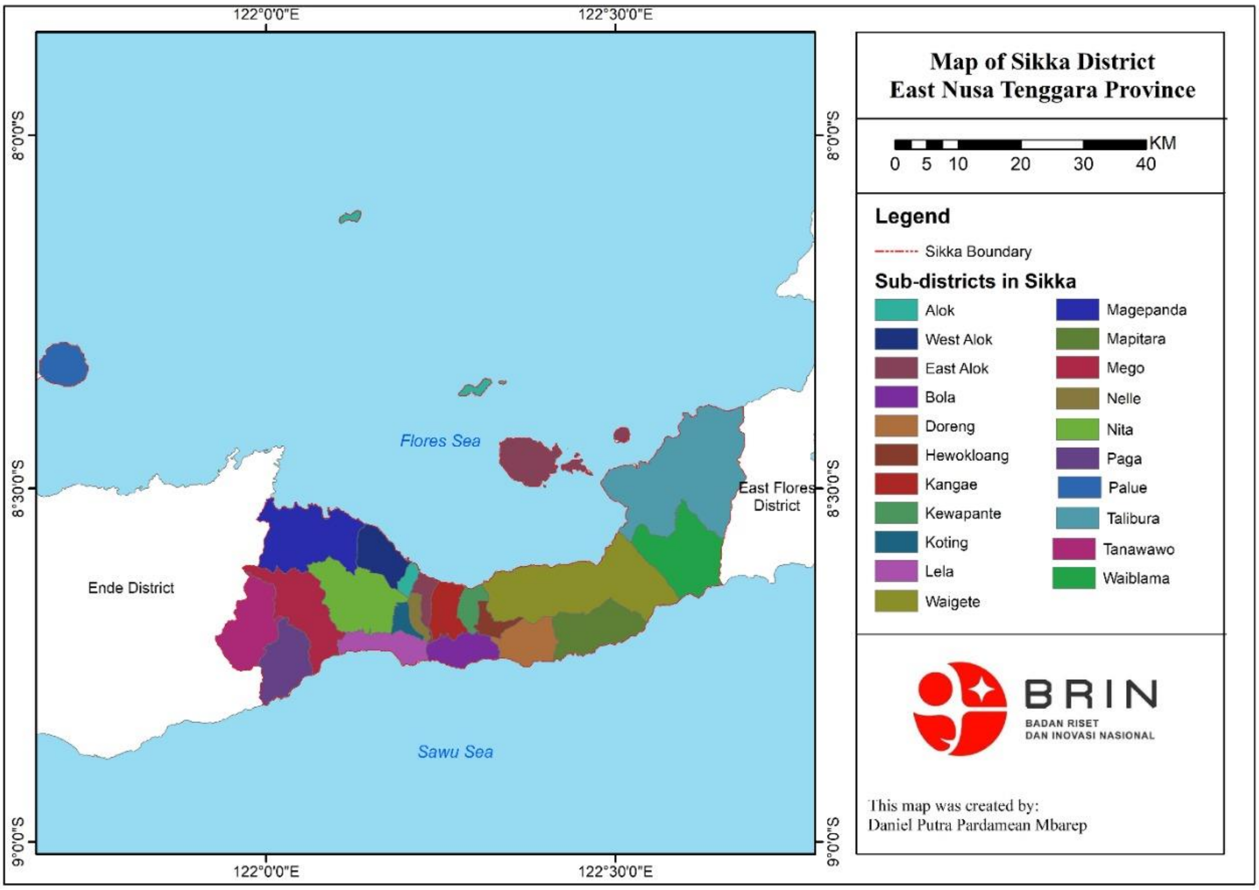

Figure 1 A map of Sikka District

Data Collection and Processing

The data about the clean water potency from rainwater harvesting is the data of total of harvested rainwater that obtained by calculating data on the rooftop area of the houses and buildings and daily rainfall. According to Maryono (2017), the formula for calculating the total of rainwater harvested is:

$$\sum Q = \alpha \; x \; R \; x \; A \tag{1}$$

Information:
∑Q : Total of harvested rainwater (m^3/day)
α : Runoff coefficient (0.8)
R : Daily rainfall (m/day)
A : Rooftop area (m^2)

The data of the rooftop area is the data regarding entire rooftops from houses and other buildings in the Sikka District area. The initial step taken to obtain this data is to digitize the rooftops of houses and buildings that appear on the Google Earth 2020 base map image. The next step is to enter the digitized data into the Arcmap 10.1 software. The last step is to calculate the rooftops area of houses and buildings from the results of digitizing the image in Google Earth.

Daily rainfall data is obtained from the calculation of the average rainfall intensity in one year (365 days). The time (years) used for calculating daily rainfall data is determined by calculating the mainstay rainfall. The mainstay rainfall is rainfall that has the highest probability of occurring, approaching or reaching 80% in a certain period (Ramadhayanti and Helda, 2021). The calculation of the probability of each year in a certain period using the formula below:

$$P\ (\%) = \left(\frac{m}{n+1}\right) x\ 100\ \% \tag{2}$$

Information:
P (%) : Probability of rainfall (%)
m : Rainfall data ranking
n : Amoun of rainfall data

The amount of rainfall data in Sikka District is data from 2010 to 2020. The rainfall data comes from Frans Seda monitoring station, the BMKG in Maumere City. The ranking of rainfall data in the last ten years is determined based on the highest amount (rank 1) to the least amount (rank 10).

Data Analysis Method

The method used to analyze the data in this study is comparative descriptive analysis. Comparative descriptive analysis is a research method used to provide an overview of a phenomenon under study by comparing facts from one or two different objects or samples (Sugiyono, 2017). The purpose of the comparative descriptive analysis is to compare the data on clean water potency that can be obtained from harvesting rainwater with the data on clean water needs from the people in Sikka District in 2020. The results of the analysis can provide an overview and conclusions regarding the fulfillment of clean water needs of all the people if rainwater management is carried out.

RESULTS AND DISCUSSION

Results

The Daily Rainfall

Data on rainfall in Sikka District from 2010 to 2020 were obtained, then ranking was carried out to determine the mainstay rainfall. The mainstay rainfall is determined based on the time (year) where the calculation of rainfall approaches or reaches 80%. This information can be seen in Table 1. The information in Table 1 shows that 2015 is the period of time with the closest 80% rainfall and is referred as the mainstay rainfall. The rainfall data in 2015, was then calculated to find out the daily rainfall data. The calculation results show that the daily rainfall data in 2015 is 1.85 mm/day or 0.00185 m/day. This daily rainfall data will be used to calculate the total of harvested rainwater.

Table 1 Probability of rainfall data based on ranking

Year	Annual Rainfall Data (mm/year)	Rainfall Data Ranking	Probability (%)
2013	1 360.3	1	8.3
2012	1 133.7	2	16.7
2010	1 014.3	3	25.0
2017	920.2	4	33.3
2016	917.2	5	41.7
2011	875.2	6	50,0
2018	856.3	7	58.3
2019	856.0	8	66.7
2020	799.2	9	75.0
2015	676.1	10	83.3
2014	665.9	11	91.7

The Rooftops Area of Houses and Buildings

Based on the digitization of the results of satellite imagery, it is known the number of all houses and buildings in Sikka District. All of the houses and buildings have rooftops made of clay tiles and asbestos. The rooftop area of all houses and buildings is calculated, and the results can be seen in Table 2. Table 2 shows that East Alok is the sub-district that has the largest rooftop area and is one of the three Sub-districts in Maumere City, the capital city of Sikka District. This is because the number of houses and buildings is also higher than in the other Sub-districts. Based on the data in Table 2, the rooftop area of houses and buildings throughout Sikka District is 6 673 036.3 m^2. Similar to daily rainfall data, data from the rooftops area of houses and buildings are also used to calculate the total of harvested rainwater.

Table 2 The rooftop area of all houses and buildings.

No.	Sub-districts in Sikka	Amount of Houses and Buildings (units)	Rooftop Area (m^2)
1	Paga	4 399	350 496.67
2	Mego	1 740	137 590.27
3	Tanawawo	1 979	123 613.40
4	Lela	4 043	344 130.80
5	Bola	3 214	248 133.04
6	Doreng	1 333	113 335.21
7	Mapitara	1 090	74 671.95

No.	Sub-districts in Sikka	Amount of Houses and Buildings (units)	Rooftop Area (m^2)
8	Talibura	5 498	494 525.94
9	Waigete	5 504	422 685.41
10	Waiblama	1 422	115 614.14
11	Kewapante	4 531	338 393.08
12	Hewokloang	364	37 058.48
13	Kangae	6 813	533 541.04
14	Palue	3 228	168 850.71
15	Koting	2 118	182 955.13
16	Nelle	2 235	212 678.50
17	Nita	6 489	535 776.55
18	Magepanda	1 147	95 797.30
19	Alok	7 904	902 798.95
20	West Alok	3 627	307 154.33
21	East Alok	9 654	913 235.35

The Obtained Clean Water Potency from Rainwater Harvesting

The total rainwater that can be harvested in Sikka District is obtained from the calculation of daily rainfall data, the rooftop area of houses and buildings, as well as a runoff coefficient of 0.8. The runoff coefficient is an estimate that every one millimeter of rainwater that falls on a 1 m^2 rooftop will produce 0.8 liters of water that can be accommodated. Information on the total harvested rainwater can be seen in Table 3.

Table 3 Total of harvested rainwater

No.	Sub-districts in Sikka	Daily Rainfall (m/day)	Rooftop Area (m^2)	Runoff Coefficient	Harvested Rainwater (m^3/day)
1	Paga	0.00185	350 496.67	0.8	518.74
2	Mego	0.00185	137 590.27	0.8	203.63
3	Tanawawo	0.00185	123 613.40	0.8	182.95
4	Lela	0.00185	344 130.80	0.8	509.32
5	Bola	0.00185	248 133.04	0.8	367.24
6	Doreng	0.00185	113 335.21	0.8	167.74
7	Mapitara	0.00185	74 671.95	0.8	110.52
8	Talibura	0.00185	494 525.94	0.8	731.89
9	Waigete	0.00185	422 685.41	0.8	625.57
10	Waiblama	0.00185	115 614.14	0.8	171.11
11	Kewapante	0.00185	338 393.08	0.8	500.82
12	Hewokloang	0.00185	37 058.48	0.8	54.85
13	Kangae	0.00185	533 541.04	0.8	789.64
14	Palue	0.00185	168 850.71	0.8	249.89
15	Koting	0.00185	182 955.13	0.8	270.77
16	Nelle	0.00185	212 678.50	0.8	314.76
17	Nita	0.00185	535 776.55	0.8	792.95
18	Magepanda	0.00185	95 797.30	0.8	141.78
19	Alok	0.00185	902 798.95	0.8	1 336.14

No.	Sub-districts in Sikka	Daily Rainfall (m/day)	Rooftop Area (m^2)	Runoff Coefficient	Harvested Rainwater (m^3/day)
20	West Alok	0.00185	307 154.33	0.8	454.58
21	East Alok	0.00185	913 235.35	0.8	1 351.58

Based on the data in Table 3 above, the total amount of rainwater that can be harvested is 9 846.47 m^3/day. If calculated in 1 year, the rainwater that can be harvested is 3 593 961.6 m^3 or 3 593 961 600 liters. This data is the potential of clean water that can be obtained to be used by the people in Sikka District. The number of people in Sikka District in 2020 is 321 953 People (BPS of Sikka District, 2021). This number is between 100 000 to 500 000 people, so the predicted need for clean water per individual per day is 150 liters (SNI, 2002). Based on this information, the total need for clean water for all people in Sikka District in 2020 is 17 385 462 m^3 or 17 385 462 000 liters. The percentage of clean water fulfillment for the people from the rainwater harvesting results can be seen in Table 4. Table 4 shows that the potential of clean water that can be obtained from rainwater harvesting has not met the water needs of all people in Sikka District. The overall percentage of obtained clean water from harvesting rainwater that can be distributed to the people is 19.52%. This shows that the total of people population in Sikka District who get clean water from rainwater harvesting is 62 846 people.

Table 4 Percentage of clean water fulfillment in Sikka District

No.	Sub-districts in Sikka	*People Population	Total of Clean Water Needs (m^3/year)	Total of Harvested Rainwater (m^3/year)	The Percentage of People who Get Clean Water (%)
1	Paga	16 399	885 546	189 340.10	21.38
2	Mego	12 939	698 706	74 324.95	10.64
3	Tanawawo	8 926	482 004	66 776.75	13.85
4	Lela	11 596	626 184	185 901.80	29.69
5	Bola	10 797	583 038	134 042.60	22.99
6	Doreng	12 002	648 108	61 225.10	9.45
7	Mapitara	6 672	360 288	40 339.80	11.20
8	Talibura	22 424	1 210 896	267 139.85	22.06
9	Waigete	24 931	1 346 274	228 333.05	16.96
10	Waiblama	8 074	435 996	62 455.15	14.33
11	Kewapante	14 775	797 850	182 799.30	22.91
12	Hewokloang	8 998	485 892	20 020.25	4.12
13	Kangae	18 055	974 970	288 218.60	29.56
14	Palue	9 497	512 838	91 209.85	17.78
15	Koting	6 526	352 404	98 831.05	28.06
16	Nelle	6 147	331 938	114 887.40	34.62
17	Nita	22 748	1 228 392	289 426.75	23.55
18	Magepanda	12 727	687 258	51 749.70	7.52
19	Alok	32 629	1 761 966	487 691.10	27.68
20	West Alok	22 294	1 203 876	165 921.70	13.78
21	East Alok	32 797	1 771 038	493 326.70	27.85

(*BPS of Sikka District, 2021)

Discussion

Based on the criteria for rainfall in Estiningrum *et al*. (2015), the daily rainfall in Sikka District in 2015 was included in the very light category. Rainfall in this category does not have the potential to cause natural disasters such as floods because of the small amount. A little intensity of rainfall can cause soil and vegetation to dry out, which results in a decrease in food availability, an increase in temperature, and an increase in the thermal humidity index for the people (Mbarep and Herdiansyah, 2020; Mbarep *et al*., 2021a, 2021b). A little intensity of rainfall can also have an impact on reducing the potential for clean water available to the people. Availability of more resources can lead to more products, while fewer resources can lead to fewer products. This explains that the intensity of rainfall determines the amount of potential clean water harvested to meet people needs (Hanum, 2017).

The rooftop is one of the important elements and needs to be considered in the use of technology with a rooftop rainwater harvesting system. A large rooftop with a large number can catch and drain more rainwater into the reservoir. The increase in the amount of rooftops area for harvesting rainwater occurs due to an increase in the number of houses and buildings caused by an increase in people population. In addition to the positive impact that can be generated because the opportunity to harvest rainwater is getting bigger, this also has a negative impact, namely environmental degradation (Song *et al*., 2015; Miao *et al*., 2017; Ilyas *et al*., 2019). The rooftop materials also need to be considered apart from the number and extent because there are several houses and buildings in Sikka District whose rooftops are made of asbestos. Although asbestos does not dissolve in water, it has an impact on respiration if the fibers are released into the air and inhaled (Thamrin and Akhadi, 2004).

The rooftops of houses and buildings also need to be treated properly so that the quality of the clean water obtained is maintained from toxic particles due to cracking, deposition, animal feces, and other cases. Apart from that, environmental and climate conditions also affect the quality of the rainwater produced. Based on the aspects described previously, there are several parameters that determine the good or bad quality of clean water produced from rainwater harvesting, such as Color, Turbidity, TDS, pH, BOD_5, COD, Na, Fe, Mn, Pb, Cd, Total Coliforms, Fecal Coliforms (Anuar *et al*., 2015; Asnaning *et al*., 2018; Ranaee *et al*., 2021). In order to maintain and improve the quality of clean water, several activities were carried out, such as creating sewers for initial rainwater, which could potentially contain dirty and toxic particles (Ranaee *et al*., 2021). Filtration using activated sand and activated carbon media installed in rainwater harvesting technology is a useful activity to reduce levels of harmful substances such as heavy metals (Hedegaard and Albrechtsen, 2014). Then, the activities that are carried out to eliminate microorganisms (Total Coliforms and Fecal Coliforms) in water are chlorination or pasteurization using solar technology (McGuigan *et al*., 2012; Ranaee *et al*., 2021).

The potential of clean water obtained from harvesting rainwater that can be distributed to the people in Sikka District is very small. These results, when combined with 5.23% of the people who currently have access to clean water from PDAM, then there are 75.25% or 242 270 people who do not have access to clean water. Based on the national mid-term development plan from 2015 to 2019, 100% of the people must have access to clean water (Silangen *et al*., 2020). Clean water obtained from rainwater harvesting in Sikka District can only be used as an additional source that can be utilized during the dry season.

CONCLUSION

The potency of obtained clean water by applying technology with a rooftop rainwater harvesting system cannot meet the needs of all people in Sikka District. This is because the clean water that can be produced cannot be distributed to the whole people. Apart from rain water, other sources of clean water are needed to be managed so that it can be used by the people. Clean water produced from these other sources must be sustainable so that it can be utilized by the people regardless of season.

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