Development of Community Rainwater Harvesting Technology for Drought Mitigation in Gunung Kidul District, Indonesia

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Abstract

Drought is a natural disaster often found in various countries, including Indonesia. Rainwater harvesting can reduce the impact of drought by providing an alternative water source for daily needs. This research aims to determine the effectiveness of rainwater harvesting using rainwater harvesting installations to meet community water needs and reduce surface runoff which causes soil erosion. The potential for rainwater harvesting is calculated as adequate rain, where evapotranspiration is calculated using the Penman-Monteith Method in CROPWAT 8.0 for nine research location points. Surface runoff is calculated using the SCS Curve Number (CN) method. The research results show that the rain harvesting can help meet an average of 11-41% of water needs per capita and reduce around 0.71% of surface runoff generated from each resident's house. The results of this research can be a reference in developing the rain harvesting technology for soil and water conservation.

Keywords: Community water needs, rainwater harvesting, surface runoff, SCS-CN, water conservation

1. INTRODUCTION

Drought is a condition in which the amount of available water is so limited that it cannot meet daily needs, including those for agriculture. Water conservation is one effort to prevent drought. Water conservation efforts can be carried out on a sizeable environmental scale and a small scale at the household level. One form of small-scale water conservation uses Rainwater Harvesting Installation (IPAH) technology. Rainwater harvesting significantly reduces drought's impact (Rahim et al., 2018).

Rainwater harvesting is also important in areas prone to flooding because it can help reduce the risk of flooding in several ways. Through rainwater harvesting, the amount of water that flows directly into waterways and rivers can be reduced so that pressure on the drainage system and the risk of surface runoff can be reduced (Singarimbun, 2022). In addition, by utilizing captured rainwater, the need for water from other sources can be reduced, maintaining the balance of water flows and reducing the risk of flooding. Thus, rainwater harvesting is an essential step in managing water flow more efficiently and reducing pressure on the drainage system, thereby helping to reduce the risk of frequent flooding in areas prone to flooding (Embongbulan et al., 2021). Many types of IPAH technology are used to harvest rainwater, and several studies have examined their potential in capturing rainwater. This research focuses on assessing the potential for water harvesting using IPAH and its potential to reduce surface runoff.

2. METHODS

Study Site

This study was conducted at the Banyumanik research site, which has a 50-ha coverage area and is administratively located in Pacarejo Village, Semanu District of Gunung Kidul Regency, Yogyakarta Special Province, Indonesia (Figure 1). Nine observation points were located in residents' homes at the study site.

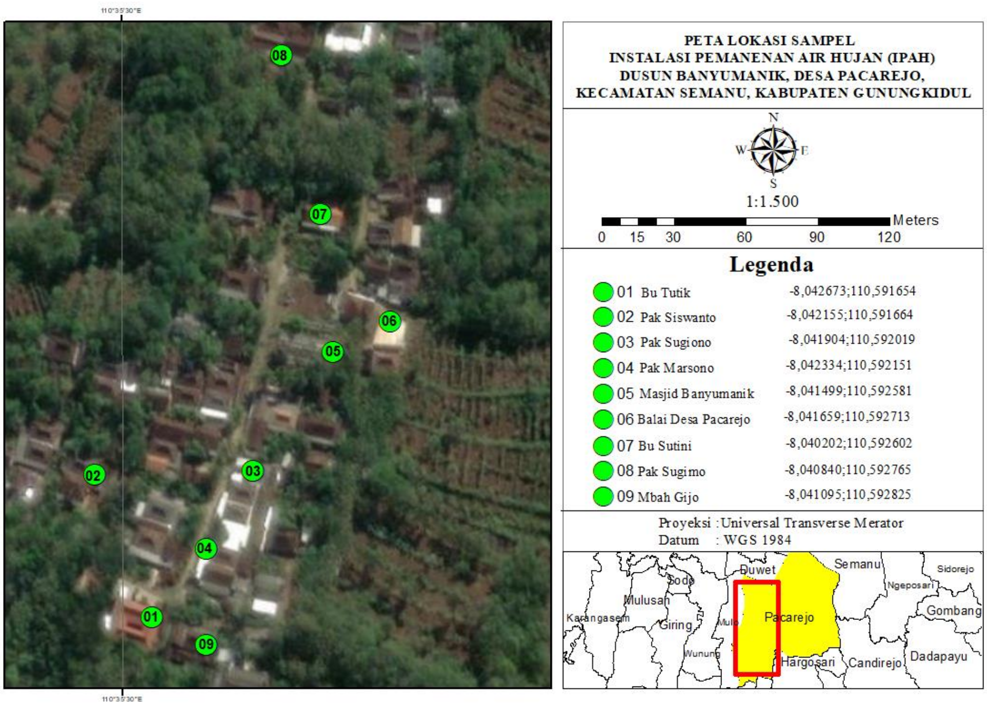


Figure 1. Map of Study Site

Data observation

The research was conducted at nine observation points in residents' houses at the study location (Figure 1). Climate data at the study location was obtained from the Indonesian

Meteorological, Climatological, and Geophysical Agency (BMKG) during 2009-2022. Climate data calculates evapotranspiration and adequate rainfall (rainwater harvesting potential).

Effective rain and evapotranspiration calculation

$$Effective\ rainfall\ = CH_{monthly} - ETo_{monthly}$$

Keterangan:

CH $_{monthly}$:	Average monthly rainfall obtained by processing rainfall data for 2009-2022
ET0 $_{monthly}$:	Evapotranspiration is obtained by processing data on minimum temperature, maximum temperature, humidity, wind speed, and duration of sunlight using the Penman-Monteith method via the CROPWAT 8.0 application

Total water needs of the community per family

One family is assumed to consist of three (3) to four (4) family members. The calculation of water needs per family can be considered as follows:

$$KA = \frac{(1A + 2B) + (3B)+)1B + 2C) + (2A + 2B) + (4B) + (2B + 2C)}{6}$$

Note:

KA : Community water needs per family.

A : Community group aged 0-15 years.

B : Community group aged 16-65 years.

C : Community group aged 0-15 years.

Amount of roof rainwater

$$V\ = A\ x\ h\ x\ \alpha\ x\ \beta$$

Note:

V : Volume.

A : Roof area (m^2).

h : Rainfall (mm).

α : Runoff coefficient (0.9).

β : Distribution coefficient (1).

Surface runoff SCS-CN method

The SCS-CN (*Soil Conservation Service-Curve Number*) method was applied (Asdak, 2010):

$$Q = \frac{(P-0,2S)^2}{P+0,8S}$$

$$S = \frac{25400}{CN} - 254$$

Note:

Q : Effective rainfall (mm)

P : Rain depth (mm)

S : Soil water storage (mm)

CN : Curve number

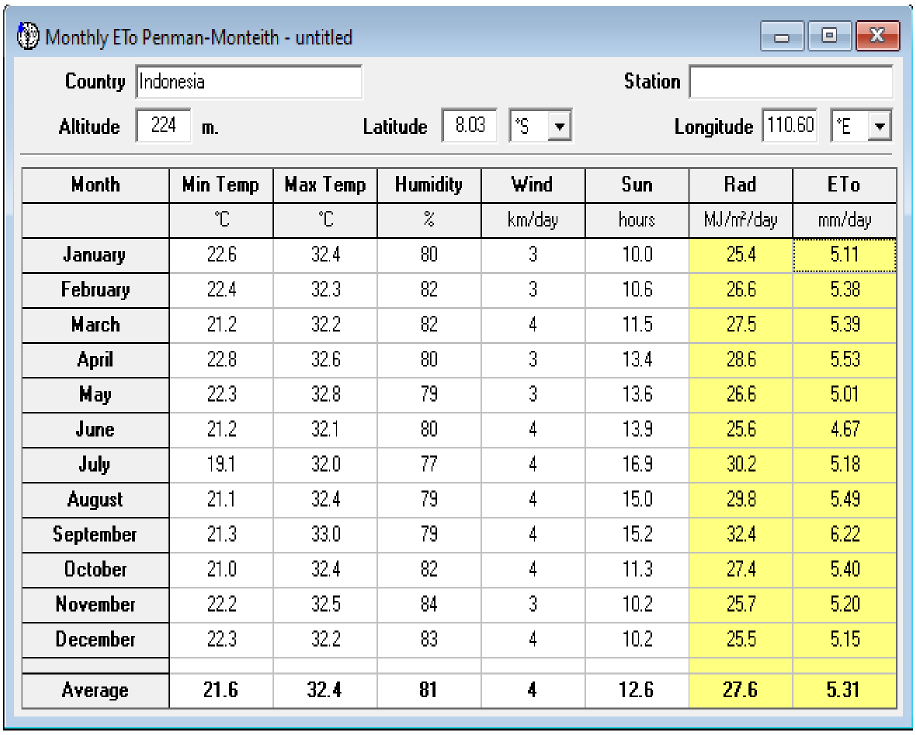
3. RESULTS AND DISCUSSIONS

Rainfall and Evapotranspiration

The average annual rainfall is more than 2000 mm. Other climate data, such as temperature, humidity, wind speed, and sunlight duration (Table 1), are used to calculate evapotranspiration using the CROPWAT 8.0 application, as in Figure 1.

Table 1. Climate Parameters Calculation of Evapotranspiration

Month	Temperature (^{0}C)			RH (%)	Wind speed (m/s)	Sunshine duration (hour)
	Min.	Ave.	Max.			
Jan.	22,60	27,03	32,43	80,33	3,00	9,96
Feb.	22,40	26,87	32,33	81,67	3,33	10,56
March	22,17	26,97	32,20	82,33	3,67	11,52
April	21,77	27,20	32,63	80,00	3,33	13,44
May	22,33	27,60	32,80	79,33	3,33	13,56
Juny	21,23	26,77	32,10	80,33	3,67	13,92
July	19,07	26,40	32,00	77,33	3,67	16,92
Aug.	21,07	26,37	32,43	78,67	4,00	15,00
Sep.	21,33	26,97	32,97	78,67	4,33	15,24
Oct.	21,03	26,57	32,37	81,67	4,00	11,28
Nov.	22,23	26,43	32,53	83,67	3,00	10,20
Dec.	22,33	26,67	32,20	82,67	3,67	10,20



Monthly ETo Penman-Monteith - untitled

Country: Indonesia | Station:

Altitude: 224 m. | Latitude: 8.03 °S | Longitude: 110.60 °E

Month	Min Temp	Max Temp	Humidity	Wind	Sun	Rad	ETo
	°C	°C	%	km/day	hours	MJ/m²/day	mm/day
January	22.6	32.4	80	3	10.0	25.4	5.11
February	22.4	32.3	82	3	10.6	26.6	5.38
March	21.2	32.2	82	4	11.5	27.5	5.39
April	22.8	32.6	80	3	13.4	28.6	5.53
May	22.3	32.8	79	3	13.6	26.6	5.01
June	21.2	32.1	80	4	13.9	25.6	4.67
July	19.1	32.0	77	4	16.9	30.2	5.18
August	21.1	32.4	79	4	15.0	29.8	5.49
September	21.3	33.0	79	4	15.2	32.4	6.22
October	21.0	32.4	82	4	11.3	27.4	5.40
November	22.2	32.5	84	3	10.2	25.7	5.20
December	22.3	32.2	83	4	10.2	25.5	5.15
Average	21.6	32.4	81	4	12.6	27.6	5.31

Figure 2. Processing monthly evapotranspiration data using the Penman-Monteith method via CROPWAT 8.0 software

The potential evapotranspiration values obtained are converted into monthly values and adjusted for the number of days each month. Monthly rainfall and evapotranspiration data are then used to calculate adequate rainfall where other loss factors (other than evapotranspiration) are considered absent. Practical rain values can be seen in Table 2.

Table 2. Effective rainfall (CH-ETo)

Month	Rainfall (mm)	ETo (mm)	CH-ETo (mm)
Jan.	357,91	158,41	199,50
Feb.	300,76	150,64	150,12
March	301,85	167,09	134,76
April	217,55	165,90	51,65
May	109,61	155,31	0,00*
Juny	79,51	140,10	0,00*
July	27,59	160,58	0,00*
Aug.	26,61	170,19	0,00*
Sep.	56,64	186,60	0,00*
Oct.	107,65	167,40	0,00*

Nov.	291,14	156,00	135,14
Dec.	312,86	159,65	153,21

*Values below zero are not calculated because it is assumed that no water can be accommodated through the roof.

Community Water Needs per Family

Data on community water needs in Gunungkidul Regency was obtained through a journal compiled by (Astuti et al., 2018) regarding domestic and non-domestic water needs analysis. This data is processed and used as a reference for the amount of water the community needs per family. Based on the equation, the results show that the community's water requirement per family is 238.32 liters/day. Water needs are calculated per month by considering the number of days each month. The amount of water needed per month for each family can be seen in Table 3.

Table 3. Community water needs per month

Month	Water need (l)
Jan.	7387,90
Feb.	6672,94
March	7387,90
April	7149,58
May	7387,90
Juny	7149,58
July	7387,90
Aug.	7387,90
Sep.	7149,58
Oct.	7387,90
Nov.	7149,58
Dec.	7387,90

Various water demand standards are referenced for this journal, namely the Indonesian National Standards Agency (BSNI), UNESCO, and the Directorate General of Human Settlements, Department of Public Works. According to these three standards, the standard water needs of rural communities is 60 liters per capita per day. This standard value is similar to the journal results used. According to the journal, the value of community water needs is still used in the results because it is considered more appropriate to the reality in Banyumanik Hamlet. After all, the journal examines data on water needs in various villages in Gunungkidul Regency.

Percentage of community water needs

Based on the analyzed data, Table 4 shows the percentage of community water needs met annually at nine study points. Figure 3 shows the situation of IPAH's existence in community homes.

Table 4. Percentage of water fulfillment per year

No	Sample location	Rain harvesting (l)	Water need (l)	Fulfilment Percentage
1	Tutik house	27.246,270		31,322%
2	Siswanto house	9.607,500		11,045%
3	Sugiyanto house	36.028,126		41,418%
4	Marsono house	12.009,375		13,806%
5	Pacarejo house	25.219,688	86.986,575	28,993%
6	Banyumanik mosque	9.607,500		11,045%
7	Sutini house	18.239,239		20,968%
8	Sugimo house	19.752,420		22,707%
9	Gijo house	10.020,323		11,519%

Figure 3. Situation of IPAH Buildings owned by Residents at the Study Location

Surface runoff

The soil in Banyumanik Hamlet, Pacarejo Village, Semanu District, Gunungkidul Regency is sandy soil, which contains elements of dust and clay. It can be concluded that the soil type in Banyumanik Hamlet, according to the SCS-CN method, is included in soil group A. Based on the residential area in the IPAH installation area used as a sample, which is 30,000 m^2, and the existing soil type, the value obtained curve number is 51 (Triatmodjo, 2009). The S value is 244.04, while the surface runoff discharge value is calculated using the equation, which can be seen in Table 5.

Table 5. Monthly average surface runoff in Banyumanik Hamlet

Month	Rainfall intensity (mm)	S Value (mm)	Surface runoff (mm)
Jan.	357,91		172,73
Feb.	300,76		127,99
March	301,85		128,81
April	217,55		68,98
May	109,61		12,13
Juny	79,51	244,04	3,43
July	27,59		2,02
Aug.	26,61		2,22
Sep.	56,64		0,24
Oct.	107,65		11,43
Nov.	291,14		120,74
Dec.	312,86		137,23

Surface runoff per month is converted into liters/second by multiplying surface runoff (mm) by the residential area (mm^2), which then results in the form of mm^3/month and converted to (dm^3/month or liters/month) so that it can be compared with rainwater harvesting using a roof with IPAH. The comparison results of water that can be harvested with surface runoff in residential areas are presented in Table 6. This data illustrates the effectiveness of IPAH in reducing surface runoff where the value is relatively small. Other conservation technologies are still needed to reduce surface runoff effectively.

Table 6. IPAH Efficiency in Reducing Runoff

Month	Total of Rain harvesting (l)	Runoff Discharge (l)	IPAH efficiency
Jan	42.235,679	5.181.890,712	0,82%
Feb.	30.662,774	3.839.566,584	0,80%
March	27.102,563	3.864.367,676	0,70%
April	9.739,387	2.069.411,643	0,47%
May	0,000	363.816,325	
Juny	0,000	102.927,052	
July	0,000	60.613,879	
Aug.	0,000	66.635,426	
Sep.	0,000	7.306,118	
Oct.	0,000	342.943,552	
Nov.	26.694,637	3.622.214,985	0,74%
Dec.	31.295,402	4.116.781,530	0,76%

4. CONCLUSION

Installing IPAHs in nine sample locations of houses or public facilities can help provide water for the community. Based on the analysis results, the percentage of community water supply ranges from 11-41%. It can be concluded that rainwater harvesting using IPAH can help meet community water needs, but it still needs to be used as the primary option. Apart from that, the percentage efficiency of IPAH in reducing surface runoff is only 0.71% in the measured residential area, so the installation of IPAH is less than optimal and not the best option for reducing surface runoff that occurs. Optimizing rainwater harvesting is needed by increasing the roof area as a water harvesting area so that more water is harvested, as well as by integrating it with other conservation technologies such as *rorak* on agricultural land.

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None

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