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RELIABILITY OF TROPICAL RAINFALL MEASURING MISSION FOR RAINFALL ESTIMATION IN BRANTAS SUB-WATERSHEDS

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ABSTRACT: Rainfall data is pivotal for hydrological studies, water resource management, and climate analysis. However, regions like Indonesia face challenges due to uneven rainfall station distribution. This study explores the potential of Tropical Rainfall Measuring Mission (TRMM) 3B42RT Daily V7 satellite data for rainfall estimation in such areas, focusing on the Brantas sub-watersheds: Kedak, Ngampel, and Kresek. Multiple TRMM scenarios are assessed for reliability and accuracy against ground-based rainfall station data. In monthly rainfall analysis, TRMM exhibits stronger correlations with average ground station data (coefficients of determination ranging from 0.62 to 0.74 for individual stations and 0.76 to 0.79 for averages) with an average PBIAS of 35.07%. The TRMM data exhibited weak performance on daily rainfall records, as evidenced by the low coefficient of determination (R^2) values ranging from 0.04 to 0.21. TRMM proves sufficiently reliable for areas with limited rainfall records, particularly for cumulative monthly rainfall assessment. A comparative analysis of rainfall values for different return periods reveals that TRMM tends to provide lower values compared to single-station ground-based estimates. However, nearly similar values were obtained for area-averaged ground-based stations. Combining area-averaged TRMM data with cumulative ground-based rainfall data reduces variability in values for diverse return periods (3-8%), enhancing data accuracy. In conclusion, TRMM 3B42RT Daily V7 data integration enhances rainfall estimation accuracy in regions with limited data availability.

Keywords: TRMM 3B42RT Daily V7, Brantas sub-watershed, Rainfall estimation

1. INTRODUCTION

The Hydrological Model represents an alternative method for simplifying the complexities of real-world systems in water resources management, particularly in hydrology analysis [1]. Hydrological models, such as rainfall analysis, water availability assessment, and flood forecasting, are valuable tools for policy evaluation, early warning systems, and predicting future hydrological phenomena amidst the current challenges posed by climate change [2]. However, the development of hydrological models in Indonesia is hindered by the limited availability of accessible data for the entire country.

For instance, data collection agencies are required to continuously improve their performance to enhance the ground-based data network in order to meet the demand for hydrological data, especially rainfall and discharge data [3]. Consequently, remote sensing technology emerges as a promising alternative solution, with satellite-derived rainfall data being one of the potential sources of information [4, 5, 6, 7].

Precise rainfall estimation is vital for numerous applications in hydrology, climate studies, and water resource management [8]. However, the uneven distribution of rainfall stations in certain regions, such as remote areas in Indonesia, presents challenges in accurately capturing precipitation patterns. For example, in several hydrological analyses in remote areas in eastern Indonesia, namely the Maluku and Papua Islands, the nearest rain gauge is located quite far from the study location, and the utilized rain gauge is not situated within the watershed. Hence this research addresses the issue by exploring the potential use of precipitation data observed by the TRMM satellite as an alternative to surface rainfall stations.

The rainfall in Indonesia is observed and measured at rainfall stations using both manual and automatic rain gauges. The placement of manual rain gauges is currently hindered in remote locations, while automatic rain gauges are constrained by power sources and communication networks. As a result, the distribution of rainfall stations is uneven across the entire watershed. The uneven distribution of rainfall station positions can affect rainfall calculations for specific areas. One opportunity to address the issue of non-uniform rainfall data is to utilize precipitation data observed by the Tropical Rainfall Measuring Mission (TRMM) satellite data [9][10]. TRMM is a satellite owned by the United States National Aeronautics and Space Administration (NASA) in collaboration with the Japan Aerospace Exploration Agency (JAXA). TRMM serves the purpose of recording rainfall data in tropical regions, including Indonesia. Therefore, rainfall data from the TRMM satellite can be used as an alternative when the distribution of rainfall stations is uneven. However, the accuracy of TRMM rainfall data needs to be reevaluated since TRMM is part of remote sensing, and its precipitation measurement/scanning is based on atmospheric climate components [11]. Hence, research is needed to assess the reliability of TRMM rainfall data as an alternative to replace station data due to the uneven distribution of rainfall stations (including areas without any rainfall stations).

A range of studies have investigated the reliability of TRMM satellite rainfall data, with some specifically focusing on its suitability for addressing non-uniform rainfall station distribution. Chen et al., [12] conducted a study using different rainfall accuracy estimation indexes to estimate the precision of real-time precipitation data gained from TRMM satellite in Dongjiang River Basin of south China according to the station gauging data. The results revealed a strong correlation between the TRMM data and the observed data at both the basin and individual station levels. This indicates that TRMM rainfall data is reliable and can be used for hydrologic simulation and water resources studies after systematic calibration. Jin et al., [13] Evaluate the precipitation climatology derived from TRMM Multi-Satellite Precipitation Analysis (TMPA) monthly product over land with two gauge-based products. This research contributes to improving the understanding of precipitation patterns and enhances the reliability of TMPA data for various hydrological and climate-related studies. In a study conducted in Indonesia, Senjaya et al., [3] explored the use of Tropical Rainfall Measuring Mission (TRMM) data for hydrological analysis in the Upper Bengawan Solo River Basin. The study highlighted the value of correcting TRMM data using ground station data to enhance accuracy and reliability in hydrological modeling applications. The corrected TRMM data proved to be beneficial for dependable flow analysis and design storm assessments, providing robust information for water resource management and flood prediction. Suroso et al., [14] evaluates the suitability and accuracy of Tropical Rainfall Measuring Mission (TRMM) rainfall data for flood modeling in three different catchments located in Java, Indonesia and the study contributes to enhancing flood forecasting and water management strategies in Java, Indonesia. Suryaningtyas et al., [15] conducted the TRMM research in Lesti Watershed, shows that TRMM data can serve as an alternative for estimating flow discharge, but using rainfall data from the rain station post yields more accurate results for flow discharge analysis. Ansori et al., [16] conducted rainfall-runoff model using TRMM satellite data in Keser watershed and obtained good result of daily and monthly predictions compared with observed data.

This study focuses on several sub-watershed locations within the Brantas sub-watersheds located in Kediri, East Java (Kedak sub-watershed, Ngampel sub-watershed, and Kresek sub-watershed) and various TRMM data scenarios. Through this research, it is expected to obtain results in line with the research objectives, which are to determine the accuracy level of each location and identify the most optimal TRMM rainfall data scenario for each sub-watershed location. This study aims to determine the performance of the Tropical Rainfall Measuring Mission (TRMM) in analyzing point and average rainfall compared to ground-based stations. The findings will serve as a reference for estimating rainfall data in Indonesia.

2. RESEARCH SIGNIFICANCE

This study will focus on the reliability of TRMM satellite data compared to ground station rainfall data. Within the analysis of TRMM data, it will be possible to ascertain the correlation between TRMM data with point rainfall data or average ground rainfall data for both daily and cumulative monthly data sets. Additionally, this study will present predictions of TRMM data when utilized for calculating rainfall for return period analysis, as well as the biased error concerning ground rainfall data.

3. MATERIALS AND METHODS

3.1 Study Area

The Brantas River basin is one of the largest river basins in East Java, encompassing multiple sub-watersheds that contribute to the overall flow of the Brantas River. The Brantas sub-watershed plays a crucial role in the overall hydrological system of the Brantas River basin. It receives rainfall and runoff from the surrounding land, including hills, mountains, plateaus, and plains. The water flows through streams, rivers, and channels, eventually converging into the main stem of the Brantas River. The management and conservation of the Brantas sub-watershed are crucial for various reasons. It affects water availability for domestic, agricultural, and industrial purposes, as well as the overall ecological balance of the region.

The sub-watershed of Kediri is characterized by its diverse topography, including hills, mountains, and plains. It encompasses a range of land uses, including agricultural areas, residential zones, industrial areas, and natural landscapes. The Brantas River, along with its tributaries, flows through the sub-watershed, providing water resources for irrigation, domestic use, and industrial purposes.

The study was focused on the sub-watersheds of the Brantas River in the Kediri region, including the

Ngampel sub-watershed (9.9 km^2), Kedak sub-watershed (52 km^2), and Kesek sub-watershed (102 km^2). These sub-watersheds vary in size from small to large (Fig. 1). The selected sub-watersheds are of significant importance in the Kediri region, where extreme conditions often lead to flooding, especially for the Kedak and Ngampel rivers.

The observed rainfall data utilized consists of daily point rainfall (R_{24}) from the Brantas River Basin Agency over a period of ten years (2010-2019). The selection of the three sub-watersheds for this study is based on the variation size of watershed area and the number of rainfall stations. Ngampel sub-watershed, being the smallest in size (9.9 km^2) with two rainfall gauge stations. Kedak sub-watershed (52 km^2) is characterized by three rainfall gauge stations, while Kresek sub-watershed, being the largest in size (102 km^2), is associated with eight influential rainfall gauge stations. The average rainfall in each watershed is calculated with a Thiessen polygon. The list of influential rainfall stations in the three sub-watershed locations of the study is presented in Table 1.

Table 1 Rainfall gauge stations in the watershed

Sub-Watershed	Area (km^2)	Number of Rainfall Stations
Ngampel	9.96	2 (Mrican, Kediri)
Kedak	52	3 (Kediri, Kanyoran, Besuki)
Kresek	102	8 (Gurah, Brenggolo, Sidomulyo, Simbar, Kalasan, Wates, Bakung, Jengkol)

3.2 The Tropical Rainfall Measuring Mission (TRMM) Satellite Data

The Tropical Rainfall Measuring Mission (TRMM) satellite data has revolutionized our understanding of global precipitation patterns and their impacts on weather, climate, and the environment [9]. The Tropical Rainfall Measuring Mission (TRMM) was a joint initiative by NASA and the Japan Aerospace Exploration Agency (JAXA) launched in 1997 [10]. Its primary objective was to provide accurate and comprehensive measurements of tropical rainfall and related meteorological parameters. TRMM operated for 23 years, providing critical precipitation measurements in the tropical and subtropical regions.

The TRMM grid size refers to the spatial resolution of the data obtained by the TRMM satellite instruments. The grid size is estimated to be 0.25º x 0.25º, which is equivalent to approximately 28 kilometers by 28 kilometers at the equator. This means that each grid cell in the TRMM data represents an area of approximately 28 km x 28 km on the Earth's surface [9].

The fine spatial resolution of the TRMM data allows for detailed analysis of precipitation patterns and distribution over a wide range of geographical regions. However, it's essential to note that this spatial resolution may vary as the latitude changes, as the Earth's surface is not perfectly flat. In higher latitudes, the grid size will appear smaller due to the convergence of longitude lines towards the poles [9].

The 0.25º x 0.25º grid size is a valuable feature of TRMM data, enabling researchers and hydrologists to study and understand rainfall variability and its impact on various environmental processes, including hydrological modeling, flood prediction, and water resource management.

TRMM carried a suite of sensors onboard its satellite, including the Precipitation Radar (PR), the TRMM Microwave Imager (TMI), and the Visible and Infrared Scanner (VIRS) [9]. These instruments worked in tandem to capture rainfall and cloud data, providing a unique perspective on precipitation patterns in the tropics. The TRMM data products encompass a range of variables, including rainfall rates, storm heights, cloud properties, and rainfall-derived parameters such as latent heating and vertical motion. The raw satellite measurements undergo rigorous processing and calibration to derive the final data products, which are made available to the scientific community. TRMM data has significantly improved the accuracy of weather forecasts, particularly in regions where ground-based observations are limited. By providing detailed information on precipitation patterns, TRMM enables meteorologists to track and predict severe weather events such as tropical cyclones, thunderstorms, and heavy rainfall.

TRMM data has been instrumental in advancing the understanding of climate dynamics, including the water and energy cycles in the tropics. By providing long-term precipitation measurements, TRMM helps identify climate trends, variability, and the impacts of climate change on regional and global scales. The availability of timely and accurate rainfall data from TRMM enables improved disaster management and mitigation strategies. By monitoring rainfall intensities and identifying potential flood-prone areas, TRMM data assists in early warning systems and emergency response planning. The quality of TRMM rainfall data has been assessed in various studies, with findings indicating its performance in different regions and its potential for hydrological modeling and other applications It is expected that TRMM will serve as an alternative source of rainfall data for estimating rainfall in Indonesia, particularly in remote areas with limited rainfall data.

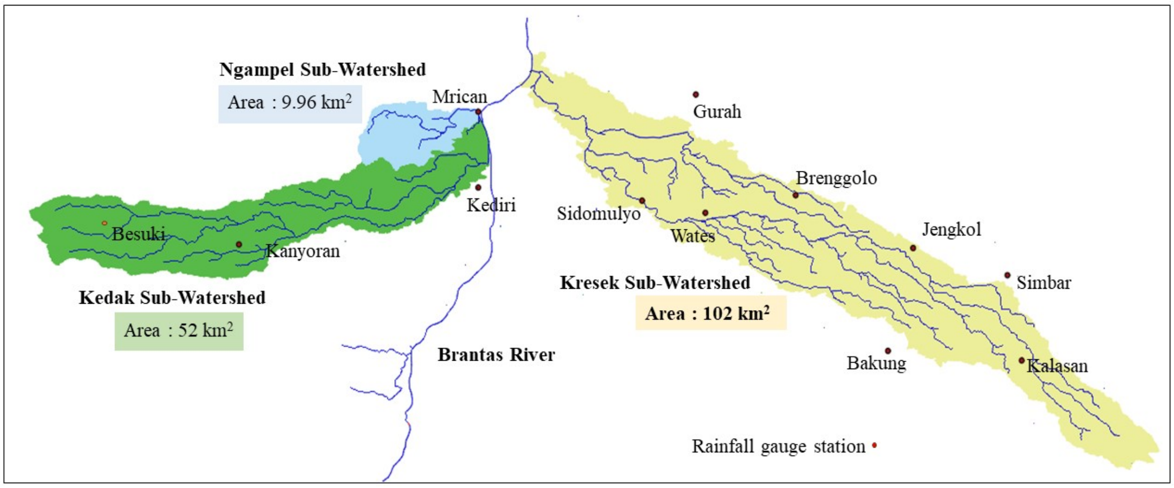

Fig 1. Study area: Ngampel, Kedak, and Kresek sub-watersheds of the Brantas river basin

The TRMM data employed in this study consists of the TRMM 3B42RT Daily V7 near-real-time precipitation rate data. The TRMM 3B42RT Daily V7 rainfall data is a specialized dataset derived from the TRMM satellite mission [9]. It provides daily estimates of precipitation accumulation, which is essential for understanding and analyzing tropical and subtropical rainfall patterns, climate variations, and their broader implications for the environment and society. The "3B42RT" designation indicates the type of data product within the TRMM dataset series. The "3B42" product is specifically focused on providing precipitation estimates, and the "RT" indicates that the data has undergone real-time processing. This real-time processing is essential for time-sensitive applications like weather forecasting and disaster monitoring. The "Daily V7" refers to the temporal resolution and version of the dataset. It provides daily aggregated rainfall estimates, making it suitable for analyzing precipitation patterns over longer time scales. These estimates are provided with minimal delay after the data is collected and are generated as part of the TRMM mission's Multi-Satellite Precipitation Analysis project. This kind of data is valuable for monitoring weather patterns, predicting and responding to extreme weather events/heavy rainfall [17], and understanding precipitation variations over time. The result study Zhao et al., [18] of TRMM multi-satellite precipitation analysis (TMPA) daily accumulated precipitation products (3B42RTV7 and 3B42V7) were evaluated for a small basin, the Nanliu river basin, against gauge observations from a period of 9 years (2000-2009) at temporal and spatial scales and the study show that the temporal-spatial precipitation characteristics of the Nanliu river basin are highly consistent.

3.3 Model Evaluation Statistics of TRMM Satellite Data

The evaluation of TRMM satellite rainfall data reliability often involves comparisons with ground-based observations. The TRMM satellite, launched in 1997, carries instruments capable of measuring precipitation using active and passive remote sensing techniques. Ground-based rainfall station data, collected from meteorological networks and rain gauge measurements, serve as reference datasets for validation and comparison purposes.

Regression analysis is a statistical method employed to ascertain the relationship between variables in a correlated dataset with a cause-and-effect connection [19]. It utilizes a regression equation to express the association between independent variables or predictors and the dependent variable (response) [20]. Two common types of regression analysis techniques are simple linear regression and multiple linear regression. The term "linear" can be understood in two ways: linear in variables and linear in parameters [21]. Although linear regression is generally interpreted as being linear in parameters (β), its linearity in variables may vary.

The Pearson correlation coefficient, also known as the linear correlation coefficient (R), quantifies the relationship between independent and dependent variables, representing a quantitative association between two variables measured on an ordinal or interval scale [20]. Correlation analysis is employed to gauge the strength or degree of linear association between two variables, as indicated by the correlation coefficient (R). The correlation coefficient, ranging from 0 to 1, signifies the magnitude of the linear relationship between the variables. The calculation of the correlation coefficient is based on the equation provided below.

$$R_{xy} = \frac{n\sum_{i=1}^{n} x_i y_i - \sum_{i=1}^{n} y_i}{\sqrt{[n\sum_{i=1}^{n} x_i^2 - (\sum_{i=1}^{n} x_i)^2].[\sum_{i=1}^{n} y_i^2 - (\sum_{i=1}^{n} y_i)^2]}} \tag{1}$$

$$R^2 = \left(\frac{n\sum_{i=1}^{n} x_i y_i - \sum_{i=1}^{n} y_i}{\sqrt{[n\sum_{i=1}^{n} x_i^2 - (\sum_{i=1}^{n} x_i)^2].[\sum_{i=1}^{n} y_i^2 - (\sum_{i=1}^{n} y_i)^2]}}\right)^2 \tag{2}$$

Where R_{xy} represents the correlation coefficient between variables x and y. Additionally, 'x_i' denotes the observed data, which corresponds to the actual data collected during the study, while 'y_i' refers to the estimated data resulting from the applied estimation methods. Furthermore, 'n' represents the total number of data points in the dataset R^2 represent the coefficient of determination.

The coefficient of determination is defined as the proportion of variance in the dependent variable that can be explained by the regression equation, expressed by the coefficient of determination [22]. This method represents one of the approaches to assess the extent to which a mathematical regression model can depict the available data.

In this study, the evaluation of the model will also be conducted through the analysis of PBIAS. PBIAS (Percent Bias) is a statistical measure used for model evaluation and is one of the recommended statistics for systematic quantification of accuracy in watershed simulations [23]. PBIAS measures the average tendency of the simulated values to be larger or smaller than the observed values, expressed as a percentage of the observed values [21]. A smaller absolute PBIAS indicates better model fit to observed data [24]. The optimal value of PBIAS is 0.0, with low-magnitude values indicating accurate model simulation. Positive values indicate overestimation bias, whereas negative values indicate model underestimation bias. The PBIAS values vary depending on the calibration and validation periods, the watershed, and the rainfall events [23][24] calculated using the following equation:

$$\text{PBIAS} = \frac{\sum_{i=1}^{n} \text{Yi obs} - \text{Yi sim}}{\sum_{i=1}^{n} \text{Yi obs}} * 100 \tag{3}$$

Where Yi sim represents the simulated value (TRMM data), while Yi obs indicates the observed value as a ground rainfall data, and n denotes the total number of observations.

The model evaluation results from PBIAS and correlation coefficients serve as a reference in determining whether the TRMM satellite data is being either overestimated or underestimated. PBIAS and correlation coefficients should be utilized in conjunction to comprehensively assess model performance. Additionally, model performance can be inferred from the analysis of PBIAS and correlation coefficients.

The Goodness-of-fit indicators and model performance evaluation criteria for the hydrological models of PBIAS and correlation coefficients shown in table 2.

Table 2 Goodness-of-fit indicators and model performance evaluation criteria for the hydrological models [24]

Performance Rating	PBIAS	Correlation Coefficients
Very Good	│PBIAS│≤ 25	0.8 < R ≤ 1
Good	25 <│PBIAS│ ≤ 50	0.7 < R ≤ 0.8
Satisfactory	50 <│PBIAS│ ≤ 70	0.3 < R ≤ 0.6
Unsatisfactory	│PBIAS│ > 70	R ≤ 0.3

4. RESULT AND DISCUSSION

This research involves assessing the reliability of TRMM data across various watershed sizes to establish correlations between TRMM and ground station data. The TRMM data used consists of daily rainfall data (R_{24}) in the form of area-averaged near real-time precipitation rates (TRMM 3B42RT Daily V7). Subsequently, this TRMM 3B42RT daily V7 data is compared with the area-averaged rainfall from all ground-based rainfall stations, each affecting respective sub-watersheds, where the average rainfall is calculated using the Thiessen polygon method with rainfall heights averaged for the same day.

In the first scenario, where TRMM 3B42RT daily V7 data is compared with a single rainfall station in the Ngampel, Kedak, and Kresek sub-watersheds, the following values were obtained. The ground rainfall stations are: Mrican, and Kediri station for the Ngampel sub-watershed, Kanyoran, Kediri, and Besuki station for the Kedak sub-watershed, and Sidomulyo, Wates, Brenggolo, Simbar, Bakung, Kalasan, and Jengkol station for the Kresek sub-watershed. The correlation values for the comparison of daily rainfall correlations yielded coefficient of determination (R^2) values ranging only from 0.04 to 0.18 for single station, and 0.09-0.21 for average rainfall ground station (Table 3), indicating low correlation. The low correlation values for the comparison of daily rainfall correlations could be due to several factors, such as natural variability, local factors, and missing data. In addition, the low correlation values could also be due to the fact that the R^2 values are generally low for daily rainfall data, as daily rainfall is highly variable and subject to noise and uncertainty. Therefore, to comprehensively evaluate model performance, analysis of PBIAS will also be conducted.

Table 3 Determination coefficient of TRMM 3B42RT daily V7 and ground based stations for daily and monthly data

No	Sub-Watershed	Rainfall Station	PBIAS (%)	Correlation Coeff (R)		Determination Coeff (R^2)	
			Daily and MonthlyRainfall Data	Daily Rainfall Data	Monthly Rainfall Data	Daily Rainfall Data	Monthly Rainfall Data
1	Ngampel	Mrican	34.98	0.42	0.86	0.18	0.74
		Kediri	57.29	0.29	0.80	0.09	0.64
		Average	43.10	0.46	0.88	0.21	0.77
2	Kedak	Kanyoran	40.30	0.24	0.85	0.06	0.72
		Kediri	54.53	0.29	0.80	0.09	0.64
		Besuki	-23.11	0.25	0.84	0.06	0.71
		Average	4.70	0.32	0.88	0.10	0.77
3	Kresek	Brenggolo	28.92	0.24	0.85	0.06	0.72
		Sidomulyo	40.74	0.25	0.84	0.07	0.71
		Wates	41.82	0.20	0.82	0.04	0.67
		Simbar	45.50	0.25	0.78	0.06	0.62
		Kalasan	59.85	0.24	0.84	0.06	0.71
		Bakung	48.71	0.27	0.84	0.08	0.71
		Jengkol	10.88	0.24	0.83	0.06	0.69
		Average	37.81	0.31	0.89	0.09	0.80

The results of the model evaluation using PBIAS indicate that the percent PBIAS for daily and monthly data over a period of 10 years varied from 4.70% to 59.85%, with an average PBIAS of 35.07% for TRMM 3B42RT data (as shown in Table 3). Based on these results, the goodness-of-fit indicators, as per the model performance table from the study of [23] in Table 2, indicate that the model is a good fit ($25 < |PBIAS| \leq 50$).

In the context of monthly rainfall analysis, the coefficients of determination between Tropical Rainfall Measuring Mission (TRMM) 3B42RT daily V7 data and the specifically chosen ground station data, within the three delineated sub-watersheds of the study area, ranged from 0.62 to 0.74 for individual station results.

However, when considering the average rainfall data obtained from multiple ground stations, these coefficients ranged between 0.76 and 0.79 (Fig. 2). This disparity suggests that the correlation between TRMM 3B42RT daily V7 data and average rainfall data from multiple ground stations is notably stronger compared to the correlation observed when utilizing data from a single rainfall station. This study suggests that TRMM 3B42RT daily V7 data can be considered sufficiently reliable for utilization in areas where there is a lack of available rainfall records, particularly for analyzing cumulative monthly rainfall patterns in Indonesia.

The model evaluation of monthly rainfall data for average rainfall using PBIAS yielded very good results for the Kedak watershed, with a value of 4.7%. However, for the Ngampel and Kresek watersheds, the results were 43.2% and 37.8%, respectively. Nevertheless, according to the study by [23], the model showed good performance. The coefficient of determination (R^2) for the average rainfall data, which is between 0.77-0.8, indicates a strong positive linear relationship between the dependent and independent variables. The consistency in these determination coefficients is further supported by the pattern of monthly rainfall distribution, which proves to be quite satisfactory for water balance modeling in Indonesia.

In the comparative assessment of rainfall values for various return periods between TRMM and a singular ground station, as calculated using the Gumbel distribution, the findings revealed that most of the computed rainfall values for return periods (2 - 1000 years) were higher than the estimations derived from TRMM data (Fig. 3). Nonetheless, there were a few rainfall stations that exhibited proximity to TRMM data. The variability in the divergence of estimated rainfall values for different return periods from the data of a single ground station in comparison to TRMM data reached up to 40% for the Kediri station (Ngampel sub-watershed), 30% for the Wates station (Kresek sub-watershed), and a substantial 60% for the Besuki station (Kedak sub-watershed).

In the second scenario, a calculation is conducted for the area-averaged rainfall data obtained from TRMM (Tropical Rainfall Measuring Mission) and the cumulative influential rainfall derived from ground-based precipitation records. The area-averaged rainfall is computed using the Thiessen polygon method. The evaluation demonstrates that the variability in the values of rainfall for various return periods is notably smaller when comparing the area-averaged data with the cumulative influential rainfall from multiple ground-based stations, as opposed to the data obtained from a single station. The differences in the values of rainfall for different return periods between the TRMM and the cumulative influential rainfall from ground-based stations were quantified at 8% for the Kedak sub-watershed, and 12% for the Ngampel and Kresek sub-watersheds, respectively.

Hence, it is evident that the area-averaged data derived from both TRMM and ground-based stations exhibit a reduced margin of error in comparison to the data from a single ground-based station. In this analysis, the use of only one rain station for a large area is suspected to result in overestimating the return period calculations. Therefore, the calculation results using TRMM area average data are expected to provide estimates of rainfall that are closer to ground-based stations.

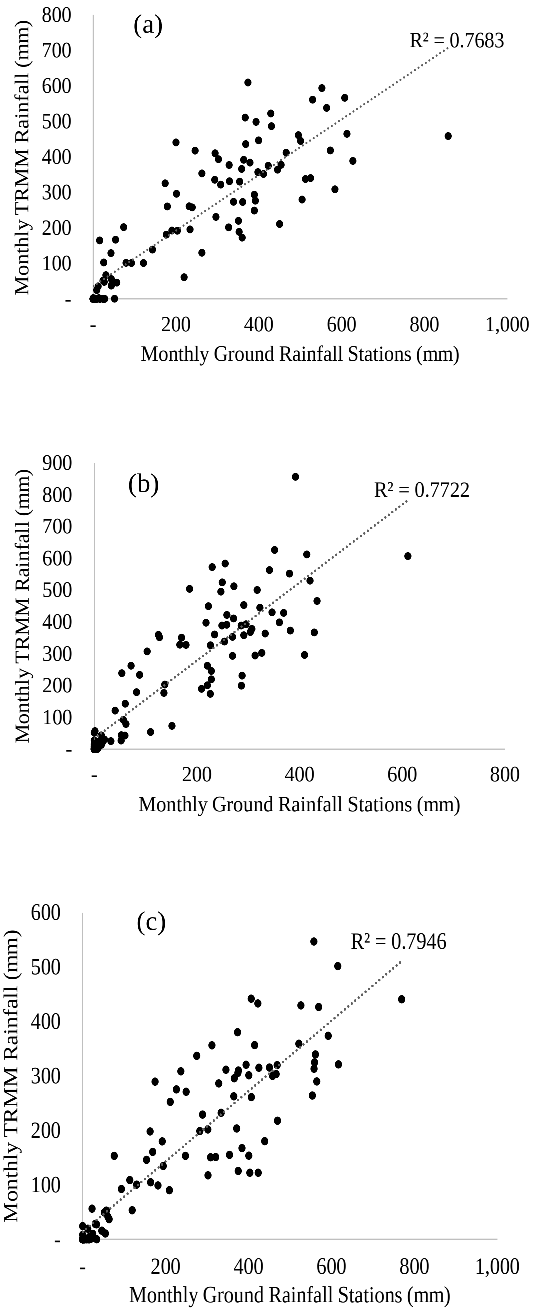

Fig. 2. Monthly rainfall correlation of TRMM 3B42RT and ground based stations (a) Kedak (b) Ngampel (c) Kresek sub-watershed

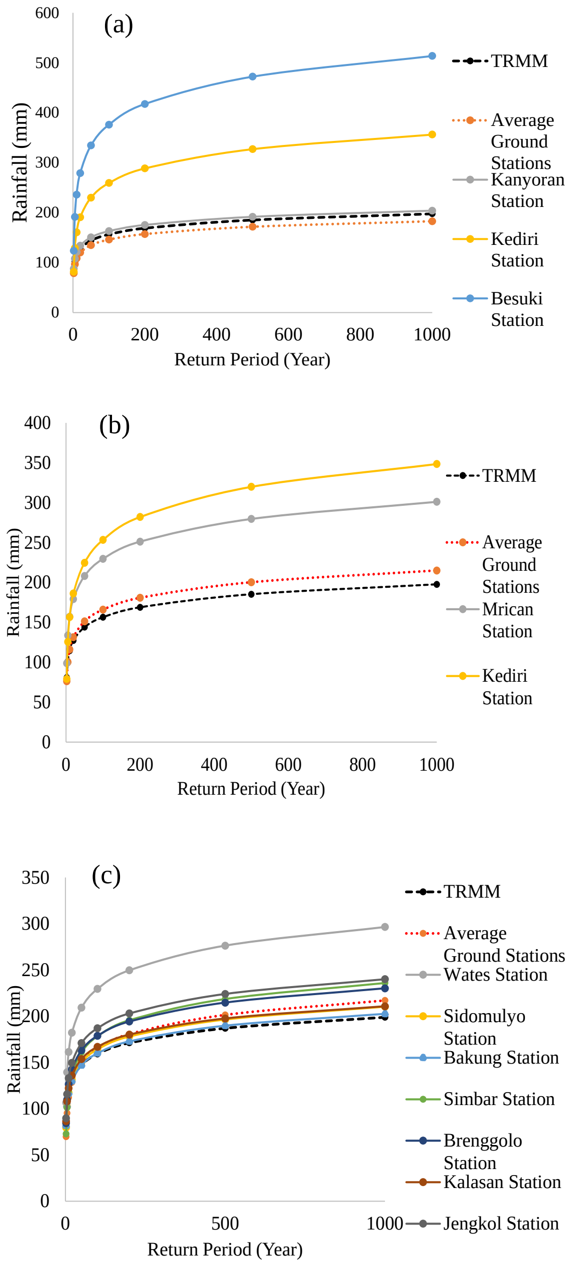

Fig. 3. Comparative analysis of rainfall values for different return periods between TRMM (3B42RT daily V7) and ground stations (point rainfall and average data) (a) Kedak (b) Ngampel (c) Kresek sub-watershed

The details of the comparison values between the rainfall calculations for the return period estimation of TRMM data and the average ground station data are presented in Table 4-6 below. The disparities between the TRMM estimates and the average ground station data are reasonably close, ranging between 5-8 percent. Based on the calculations presented in Table 4-6, the TRMM estimates are slightly larger compared to the average ground station data, except for Kedak sub-watershed, where the TRMM estimate is slightly greater.

For Ngampel and Kresek sub-watersheds, there are significant differences in the estimates for shorter repeat periods (2 years), however for longer return periods, the estimated values approach each other with discrepancies of less than 10%. Similarly, for Kedak sub-watershed, the difference values range from 3-8% for the rainfall values in return periods estimation between TRMM 3B42RT daily V7 and average ground stations.

Table 4 Comparison of rainfall return period estimations between TRMM 3B42RT d and average ground stations data for Kedak sub-watershed

Return Period	TRMM 3B42RT	Average Ground Stations	Difference (%)
2	80.86	78.42	3.12
5	101.10	96.49	4.78
10	114.50	108.45	5.58
20	127.36	119.92	6.20
50	143.99	134.77	6.84
100	156.46	145.90	7.24
500	185.27	171.62	7.57
1000	197.66	182.68	7.95

Table 5 Comparison of rainfall return period estimations between TRMM 3B42RT and average ground stations data for Ngampel sub-watershed

Return Period	TRMM 3B42RT	Average Ground Stations	Difference (%)
2	88.14	76.19	15.69
5	106.88	100.25	6.61
10	119.29	116.18	2.67
20	131.19	131.46	-0.21
50	146.59	151.24	-3.07
100	158.14	166.07	-4.78
500	184.81	200.32	-6.19
1000	196.28	215.05	-7.74

Table 6 Comparison of rainfall return period estimations between TRMM 3B42RT and average ground stations data for Kresek sub-watershed

Return Period	TRMM 3B42RT	Average Ground Stations	Difference (%)
2	86.57	69.83	23.97
5	106.03	95.34	11.22
10	118.93	112.23	5.97
20	131.29	128.43	2.23
50	147.30	149.40	-1.41
100	159.29	165.11	-3.53
500	187.00	201.42	-5.27
1000	198.92	217.03	-7.16

5. CONCLUSION

This research explores the reliability of Tropical Rainfall Measuring Mission (TRMM) 3B42RT daily V7 near real-time precipitation rates in addressing hydrological data limitations within the Brantas Watershed, Indonesia. The study evaluates TRMM data against ground rainfall station data across various watershed sizes to establish correlations. Daily rainfall data from TRMM 3B42RT is analyzed using a resolution of 0.25° x 0.25° and compared to both single rainfall station scenarios and area-averaged ground station data obtained through the Thiessen polygon method.

- The comparison with a single rainfall station within the Ngampel, Kedak, and Kresek sub-watersheds reveals weak daily rainfall correlations, with coefficient of determination (R^2) values ranging from 0.04 to 0.18 for single stations and 0.09 to 0.21 for average ground station rainfall.
- In monthly rainfall analysis, TRMM 3B42RT daily V7 data shows stronger correlations with average rainfall data from multiple ground stations, exhibiting coefficients of determination (R^2) between 0.62 and 0.74 for individual station results and 0.76 to 0.79 for averages. The study concludes that TRMM 3B42RT daily V7 data can be considered sufficiently reliable for regions with limited historical rainfall records, particularly when analyzing cumulative monthly rainfall patterns.
- The model evaluation using PBIAS reveals a range of 4.70% to 59.85% in percent PBIAS for both daily and monthly data over a ten-year period, with an average of 35.07%. These results suggest that the TRMM data demonstrate a good fit based on the goodness-of-fit indicators.
- A comparative evaluation of rainfall values across different return periods indicates that TRMM 3B42RT daily V7 data tends to indicate lower values compared to single-station ground-based estimates. Furthermore, when comparing area-averaged data from TRMM 3B42RT daily V7 and cumulative influential rainfall from multiple ground-based stations, the variability in values for various return periods is notably smaller compared to data from a single ground-based station.

Overall, this research highlights TRMM 3B42RT daily V7 potential utility for improving rainfall data accuracy in hydrological studies, particularly in regions with limited data availability for monthly rainfall and rainfall return period analysis. The calculation results using TRMM area average data provide a good comparison with area average ground-based stations

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