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Validation of Satellite-Based Precipitation Products TRMM using Ground-Based Measurements

Feri Fadlin^{1,2,a)}, Muhammad Arsyad Thaha^{1,b)}, Farouk Maricar^{1,c)}, and Mukhsan Putra Hatta^{1,d)}

¹Civil Engineering Department, Engineering Faculty, Hasanuddin University, Makassar, Indonesia

²Geomatic Engineering, State Agriculture Polytechnic of Samarinda, Indonesia

^{a)}Corresponding author: ferifadlin@gmail.com

^{b)}athaha@unhas.ac.id

^{c)}fkmaricar@yahoo.com

^{d)}mukhsan_hatta@yahoo.co.id

Abstract. Hydrological analysis in an area requires rainfall data. The problem is that the availability of rainfall data is very limited due to the lack of rainfall measuring stations in an area. One solution to overcome this problem is by utilizing daily rainfall products from the Tropical Rainfall Measuring Mission (TRMM 3B42) satellite. To support the use of these products in an area, it is necessary to test the accuracy of the data to determine the characteristics of the resulting error. The purpose of this study is to evaluate and validate TRMM satellite-based precipitation products using the extreme rainfall data measured in the field at two rainfall stations of the Kendari Meteorological, Climatological, and Geophysics Agency. Data validation for satellite-based precipitation products TRMM was performed using the coefficient of determination (R^2) and Root Mean Square Error (RMSE). The results of this study indicate that the TRMM satellite-based precipitation products have good accuracy and can be used to estimate rainfall in areas not covered by ground gauged stations.

INTRODUCTION

Rainfall data is a very vital data component in any hydrological analysis. In general, the rain data used in the hydrological analysis is rainfall data from direct observations in the field through rain stations managed by certain agencies. Available rain data are usually sourced from manual and automatic rain gauges or often called Automatic Rainfall Recorder (ARR). The main difference between the two devices is that the rain data generated by the manual type is daily rainfall data, while the ARR can generate hourly rainfall data. In a hydrological analysis, especially in the calculation of design flood, complete daily rainfall data with long periods are needed. Meanwhile, in the analysis of early warning systems or to predict floods, hourly rain data is needed.

A common problem that often occurs in the field is that in some areas, tools to measure rainfall are sometimes not available. A remote sensing approach with satellite is an alternative that can solve the problem of rain data availability. To support the use of satellite rainfall data, evaluation and validation are needed to determine the accuracy of rainfall data.

Most satellite precipitation data products have a temporal resolution of a day and a spatial resolution of 0.250. This resolution includes the resolution required in hydrological analysis, especially in analyzes that require daily rainfall data [1]. In 2018 [2] Research was conducted to assess the adequacy or reliability of TRMM data in SWAT modeling. The results of this study indicate that the TRMM data has good reliability so that it can be used in hydrological modeling, water balance analysis, and water resource management in the watershed. Research related to the validation of TRMM data was also carried out in Peru [3]. The results of the research conducted indicated that the TRMM product data was statistically well correlated with the measurement data in the field.

Kendari city is one of the cities that is prone to hydrological disasters such as floods. One of the problems faced is the lack of data and information related to rainfall that is continuous and covers all areas, especially in river basins (DAS) included in the administrative area of Kendari. A method or approach is needed to estimate rainfall in areas without a rainfall measuring station. One approach that can be used is by utilizing the TRMM satellite-based precipitation data. To support this, it is necessary to conduct a study regarding the accuracy of the TRMM precipitation data before it is used in the hydrological analysis.

RESEARCH METHOD

Study Area

This research was conducted in the administrative area of Kendari. The distribution of field rainfall measuring stations and TRMM data can be seen in the following figure.

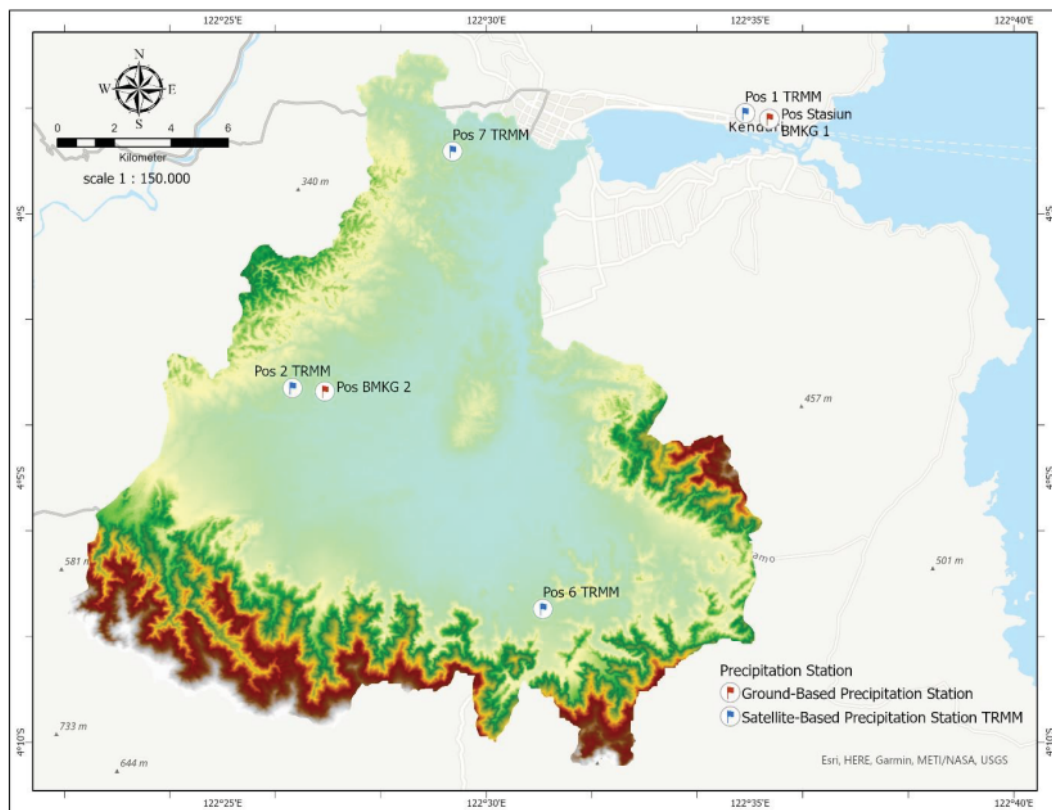


FIGURE 1. Distribution of precipitation stations

Gauge Data

The measured rainfall data used is the BMKG (Meteorological, Climatological, and Geophysics Agency) and TRMM precipitation data issued by the National Aeronautics and Space Agency (LAPAN) of the Republic of Indonesia. The data used is extreme rainfall data, especially during the floods in the Kendari area, especially in July 2013 and June 2019. The data used can be seen in the following table.

TABLE 1. Precipitation data

Date	Precipitation Data July 2013 (Station 1)		Precipitation Data June 2019 (Station 2)	
	Satellite-Based (TRMM)	Ground-Based (BMKG)	Satellite-Based (TRMM)	Ground-Based (BMKG)
1	77.17	90.30	30.24	11.10
2	28.39	27.60	71.90	91.50
3	2.12	14.20	48.79	56.70
4	2.76	11.20	9.79	16.70
5	2.88	12.00	0.00	11.30
6	33.85	34.20	0.00	2.50
7	6.20	2.40	28.47	0.40
8	7.79	2.00	64.12	86.40
9	6.82	3.30	22.42	33.20
10	47.02	84.00	27.10	31.40
11	7.76	32.50	33.83	21.20
12	10.11	5.50	1.26	1.40
13	5.79	1.40	14.60	16.70
14	46.31	25.20	4.00	7.00
15	185.57	213.30	0.00	0.80
16	86.54	90.90	0.00	0.00
17	17.13	7.90	0.00	0.00
18	0.00	0.00	0.00	0.00
19	0.00	0.00	2.75	0.00
20	28.33	23.90	0.00	0.00
21	0.53	0.40	0.00	1.80
22	0.00	0.00	0.00	0.00
23	19.45	15.80	0.00	1.00
24	30.94	29.10	0.00	0.00
25	43.52	41.30	0.00	0.00
26	0.00	0.00	0.00	0.00
27	0.00	0.00	0.00	2.10
28	0.00	0.00	0.00	0.00
29	11.34	0.40	1.63	0.00
30	7.11	1.50	2.42	0.00
31	0.00	0.00		

Source: BMKG and TRMM Data from LAPAN

Statistical Analysis

The validation of satellite precipitation data against measured rainfall data is carried out using several statistical methods, namely the Root Mean Square Error (RMSE) and the coefficient of determination (R²) which are widely used in statistical analysis [4]. The equation in calculating the root mean square error is as follows.

$$RMSE = \sqrt{\frac{\sum_{i=1}^n (P_i - O_i)^2}{n}} \quad (1)$$

Where P_i is the predicted value, O_i is the actual value and n is the amount of data. While the coefficient of determination is calculated based on the equation below:

$$R^2 = \frac{SSR}{SST} \quad (2)$$

$$SSR = \sum_i (\hat{y}_i - \bar{y})^2 \quad (3)$$

$$SST = \sum_i (y_i - \bar{y})^2 \quad (4)$$

Where SSR is the sum of squared regression also known as variation explained by the model and SST is total variation in the data also known as the sum of the squared total, y_i is the predicted value of y for observation i , and \bar{y} is the mean of y value.

RESULTS AND ANALYSIS

The first step in data validation is to compare the data between the TRMM satellite-based precipitation and the measured data from the Meteorological, Climatological, and Geophysics Agency (BMKG). Based on the data used in general, the data from field measurements have a greater value than the data from the TRMM satellite imagery. This is because the satellite-based precipitation data is basically an estimate of rainfall based on the appearance of clouds in the atmosphere and also covers several areas [5]. Meanwhile, measured precipitation data is data and information on rainfall that falls and is measured only at the measurement point or station. The comparison between satellite-based data and measured precipitation can be seen in Figs. 2 and 3.

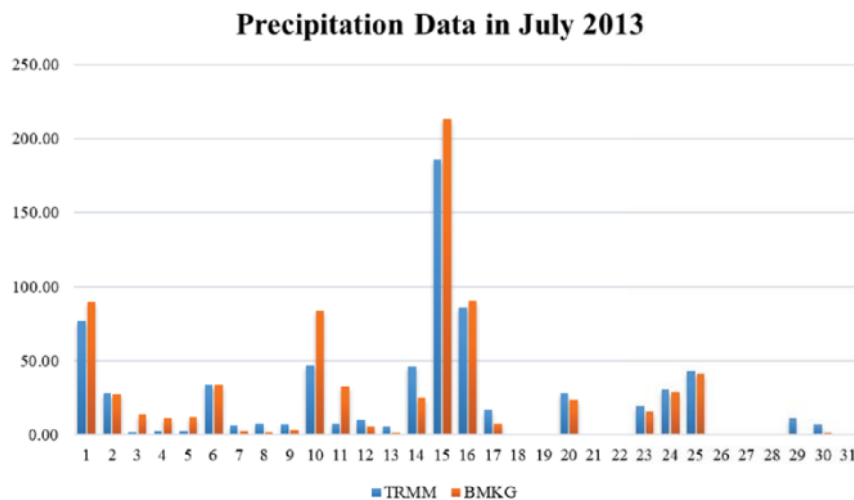


FIGURE 2. Comparison of TRMM and BMKG precipitation data in July 2013

Using the precipitation data, the RMSE calculation is carried out. The analysis result indicates that the RMSE value for station one is 11.45 and station two is 9.33. This shows that the bias or the average difference between measured data and satellite data is 11.45 mm 9.33 mm. If we look at the physical aspect of the area, the number of errors generated is also influenced by the topographic conditions of the area and also the land cover so that the estimated precipitation in satellite imagery is not measured optimally [6]. Based on the results of the coefficient of determination analysis, it was found that the coefficient of determination of the data at station one was 0.943 or 94.3 percent. This data depicts that the data measured using TRMM satellite imagery have a strong pattern and correlation with BMKG's measured data so that it can be used to estimate rainfall in areas without a measurement station in the field. The pattern, correlation, and linear regression equation for predicting TRMM precipitation data based on the measurement results at station one can be seen in Fig. 4.

Precipitation Data in June 2019

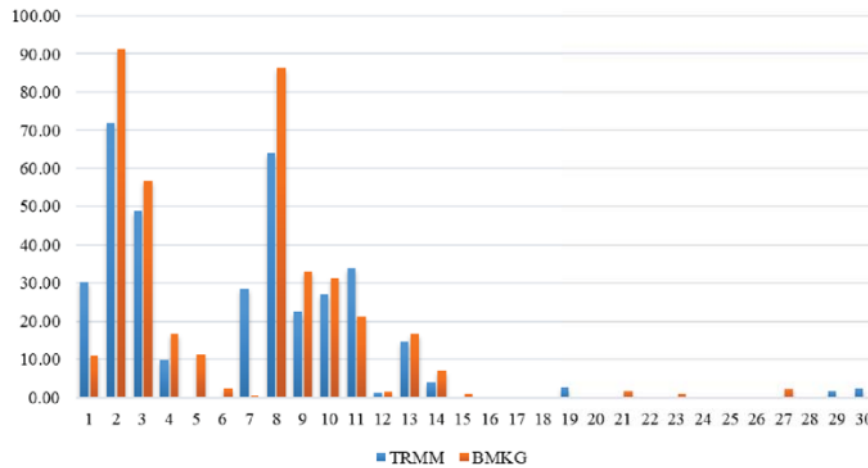


FIGURE 3. Comparison of TRMM and BMKG precipitation data in June 2019

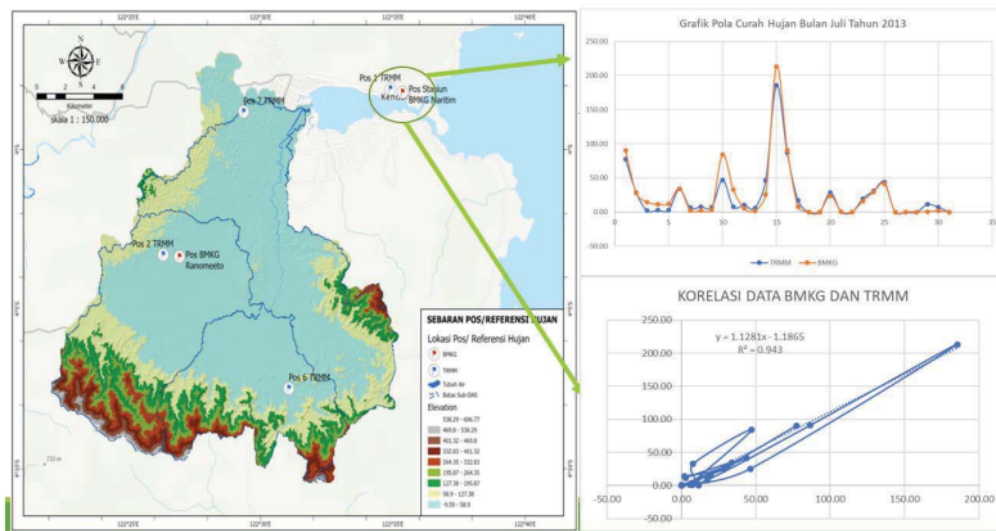


FIGURE 4. The results of the analysis of the coefficient of determination at station one

The results of the analysis of the coefficient of determination at station two show different values, namely 0.86 or 86 percent. The data shows that the measurement result using TRMM satellite imagery has a strong choreography but is lower than that of station one. Many factors can affect these differences, including the physical condition of the area which also includes aspects of topography, land cover, or can also be caused by technical problems related to the accuracy of the data at the measuring station. The results of this analysis also indicate the need for a follow-up study to determine how much influence land cover and topography have on the accuracy of rainfall estimation data using TRMM satellite imagery. Patterns, correlations, and linear regression equations resulting from the results of data analysis at station two can be seen in Fig. 5.

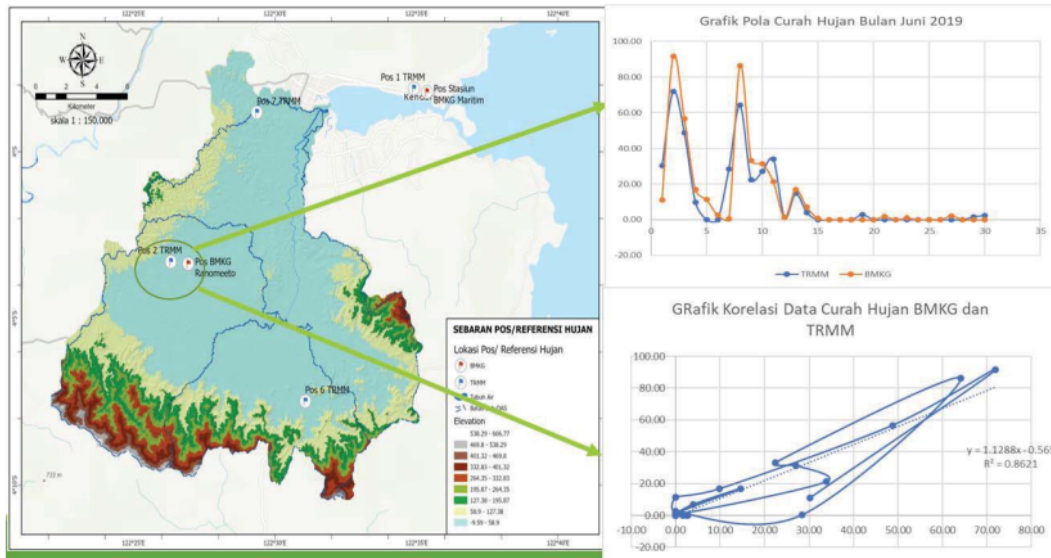


FIGURE 5. The results of the analysis of the coefficient of determination for station two

CONCLUSION

The estimation of rainfall data using the TRMM satellite was validated using two field measuring stations in the administrative area of Kendari City and the Wanggu River Basin. Two statistical methods were used, namely RMSE and the coefficient of determination (R^2). The RMSE value is used to determine the average bias value of the satellite estimation data against the measured precipitation data. While the value of determination is used to see how much correlation between satellite data and measured data in the field and at the same time produces an equation to estimate the measured data in the field based on satellite estimation of precipitation data. The results depict that the RMSE value at station one was 11.45 and at station two was 9.33. These results indicate that the resulting error or difference between satellite estimation data and measured data at station one is 11.45 mm and at station two is 9.33 mm. The result of the calculation of the coefficient of determination at station one is 0.943 or 94.3 percent with the linear regression equation $y = 1.1281x - 1.1865$ where y is the estimated rainfall and x is measured data (BMKG). The result of the calculation of the coefficient of determination at station two is 0.862 or 86.2 percent with the linear regression equation $y = 1.1288x - 0.565$.

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