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VALIDATION OF RAIN THICKNESS MODEL BASED ON GPM SATELLITE AND SURFACE MEASUREMENTS

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Abstract
The limited acquisition of rainfall data from the Climatological Station of Deli Serdang has resulted in constraints on research in several fields. Global Precipitation Measurement (GPM) has spatial and temporal advantages as a solution to this problem. This study aims to provide information on the rain thickness equation model based on the Global Precipitation Measurement (GPM) Satellite as an alternative to calculating rain thickness at the Climatological Station of Deli Serdang. Data from the Global Precipitation Measurement (GPM) Satellite and Climatological Station of Deli Serdang were used, covering the period from January 1 to December 31, 2021. The Rescaled Adjusted Partial Sums (RAPS) method was used to verify the data quality, and the two data were consistent. The rain thickness equation model was obtained using a simple linear regression method. At the same time, the validation of the rain thickness equation model with surface measurements used the Root Mean Square Error (RMSE), Nash Sutcliffe Efficiency (NSE), and Correlation Coefficient (R) methods. The validation findings demonstrate that the rain thickness data from the Global Precipitation Measurement (GPM) Satellite was close to that of the Climatological Station of Deli Serdang, with an RMSE value of 5.85 mm, NSE of 0.99 mm, and R of 0.99. $Hi = 5.21ti^{0.50}$ mm was the model used to calculate the equation for rain thickness. 6.84 mm, 0.69 mm, and 0.94 mm were the validation results of the equation model for RMSE, NSE, and R.

Keywords: Rain Thickness, Global Precipitation Measurement (GPM), Climatological Station of Deli Serdang, Equation Model, Validation

INTRODUCTION

Prediction and climate change in a region are significant to do. Rainfall is one of the climate parameters needed in several research fields. Rainfall data is necessary for several studies, one of which is research on water availability in an area (Bunganaen et al., 2020; Jiwa Osly et al., 2019; W. Solin, 2012). For analysis of central projections and mapping of flood-prone areas (Aziza et al., 2021; Kasnar et al., 2020). The climatological Station of Deli Serdang was established as an institution tasked with observing, processing, and servicing the acquisition of climate data, including rainfall. Rain thickness and duration are climate parameters that affect the size of precipitation. Rain thickness or rain height collects in a specific time interval. At the same time, the time or duration of rain occurs in minutes, hours, or days the duration of rainfall.

The climatological Station of Deli Serdang used two rainfall gauges: the manual OBS (Observatory) type and the Hellman automatic type. However, observation of rainfall data in an area is challenging to obtain. This is a problem for several research fields, one of which is the analysis of water availability (Saidah et al., 2021). Due to damage to the rainfall gauge, the Climatological Station of Deli Serdang rainfall data may experience data gaps.

The difficulty of obtaining rainfall data is a challenge for the availability of rain data. Complete rainfall data is needed for several types of research in the fields of Physics and hydrology. For analysis to determine the planned flood discharge, complete daily rain data is required for an extended period (Exacty et al., 2014; Nggarang et al., 2020; Pariartha et al., 2021; Patabang et al., 2022). Research on drought in the dry season requires complete rainfall data or where rainfall data is not allowed (Akbar et al., 2021; Hartini, 2017; Novita et al., 2021). In addition, the observed rainfall measurements from the Climatology Station have not been able to reach a broad spatial scale. The existence of these spatial limitations is one of the obstacles to obtaining rain data from surface measurements (Made Duwanda & Sukarasa, 2022).

The Global Precipitation Measurement (GPM) satellite is one of the solutions used to fill the gaps in missing or missing rain data. The Global Precipitation Measurement (GPM) satellite was launched in 2014 by NASA (National Aeronautics and Space Administration) and JAXA (Japan Aerospace and Exploration Agency.

However, there are several gaps in rainfall data for several months in the Climatological Station of Deli Serdang measurements. In addition, when satellites make observations of rain through the atmosphere, the rain that falls to the earth's surface takes a certain amount of time (Nuramalia & Lasminto, 2022). So it is required to validate satellite rainfall data and measurements first to determine the magnitude of the bias between the data (Natadiredja et al., 2018; Welkis et al., 2022). (Arrokhman et al., 2021) conducted an analysis evaluating the suitability of satellite data for rainfall and evaporation for measurement data in the Sutami Reservoir area using validation based on Root Mean Squared Error (RMSE), Nash Sutcliffe Efficiency (NSE), Correlation coefficient (R) and Relative Error (KR).

(Bunganaen et al., 2013) Conducted research on the analysis of the relationship between rain thickness and rain duration at the Lasiana Climatological Station, Kupang City. (Nurhaya, 2020) conducted research on the analysis of the Relationship between Rain Duration and Rain Intensity at Pondok Betung Climatological Station. The results of these two studies, the relationship equation model between rain duration and rain thickness, can be used as an alternative to calculating rain thickness values at the Lasiana Climatological Station and the Climatological Stations of Kupang, Pondok Betung City. The two studies only used rain thickness data measured by the Climatological Station to obtain a rain thickness equation model. Where rain gauges sourced from the Climatological Station still have limited spatial coverage.

Further research is needed that uses satellite alternatives as rain thickness data. Based on the narrative of Mr Joko Yulianto Ariantoro, M.Sc, who stated that the Climatological Station of Deli Serdang used an alternative to the Himawari-8 satellite as empty rain data. The Climatological Station of Deli Serdang also analyzed the average rainfall from approximately 250 rain posts spread across the Deli Serdang area with a pattern close to measurement as a solution to the emptiness data. The Global Precipitation Measurement (GPM) satellite was the latest launched satellite from NASA, which has a more accurate spatial resolution than Himawari-8, which was 0.1°× 0.1°. The analysis of the rain thickness equation model used the simple linear regression method, which originates from the Global Precipitation Measurement (GPM) Satellite rain thickness data has not been carried out in the Deli Serdang area, especially the Deli Serdang Class 1 Climatology Station. This research aims to find a rain thickness equation model used to solve data gaps and calculate rainfall data at the Climatological Station of Deli Serdang.

Based on this background, the authors researched validating the rain thickness sales model based on the GPM satellite and surface measurements. The research hypothesis obtained is a sales model that can be used as an alternative in calculating rainfall at the Climatological Station of Deli Serdang.

RESEARCH METHODS

This study uses statistical methods, namely simple linear regression and chi-square test. The data used are Global Precipitation Measurement (GPM) Satellite rainfall data, the spatial resolution of 0.1° × 0.1°, 30 minutes temporal time, and rainfall data from the Climatological Station of Deli Serdang located on Jl. Meteorology No. 17, Tembung, Percut Sei Tuan District, Deli Serdang Regency, is at coordinates 3°37'15.37" North Latitude and 98°42'53.56" East Longitude.

Global Precipitation Measurement (GPM) satellite data were received from the official NASA (National Aeronautics and Space Administration) website at https://giovanni.gsfc.nasa.gov/giovanni/. At the same time, the BMKG's official website at https://dataonline.bmkg.go.id provided information on the rain's thickness data at the Climatological Station of Deli Serdang.

The climatological Station of Deli Serdang and Global Precipitation Measurement (GPM) satellite rain thickness data are checked before the equation model analysis. The reliability of the two rain thickness data was assessed using the Rescaled Adjusted Partial Sums (RAPS) consistency test. Root Mean Square Error (RMSE), Nash Sutcliffe Efficiency (NSE), and Correlation Coefficient were (R) utilized as the validation method.

Data collection was carried out on the duration and thickness of the rain. Rain durations were 30, 60, 90, 120, 180, 240, 360, 720, and 1440 minutes, and rainfall data for 20 years from January 1, 2021, to December 31, 2021. The simple regression method of the linear model was used to determine the model rain thickness equation using Microsoft Office Excel. At the same time, the chi-square test analysis was used to determine the suitability of the measurement data from the Climatological Station of Deli Serdang with the rain thickness equation model in the study.

Root Mean Squared Error (RMSE), Nash-Sutcliffe Efficiency (NSE) techniques, and correlation coefficients (R) were used to re-validate the rain thickness equation model that had been made with a sample from the Climatological Station of Deli Serdang.

RESULTS AND DISCUSSION

Data Quality Test and Validation

The data quality test was carried out to obtain information on the correctness of field measurement data. No errors were found, so the data approached the Climatological Station of Deli Serdang measurement. A consistency test with the Rescaled Adjusted Partial Sums (RAPS) method is used to test the quality of the data.

The results of the consistency test in table 1 show that the Global Precipitation Measurement (GPM) satellite rainfall data and the Climatological Station of Deli Serdang were consistent. This means that the Global Precipitation Measurement (GPM) satellite rain thickness data is close to the rain thickness measurements carried out by the Climatological Station of Deli Serdang so that both data can be validated.

Table 1. Data Quality Test

Data	RAPS Method		Description
	Q_{count}	R_{count}	
Climatological Station of Deli Serdang	0.47	0.42	Consistent
	0.47	0.41	Consistent

Validation of The Data

Both the Climatological Station of Deli Serdang and Global Precipitation Measurement (GPM) satellite rain thickness data were validated before analyzing the rain thickness equation model. Data validation was done to evaluate a model and offer information about the degree of uncertainty and variations in the rain projection process (Partarini et al., 2021).

Monthly rainfall data from the Global Precipitation Measurement (GPM) satellite and Climatological Station of Deli Serdang for the 20 years between January 1, 2002, and December 31, 2021, are the data that were validated for the study.

The validation results in table 2 show that the Global Precipitation Measurement (GPM) satellite rain thickness data was satisfactory and very good, so it was suitable for use at the Climatological Station of Deli Serdang. Thus, the Global Precipitation Measurement (GPM) satellite rain thickness data can be used to analyze the rain thickness purchase model, which is used as an alternative to calculating rain thickness at the Climatological Station of Deli Serdang.

Table 2. Rain Thickness Data Validation

Station	GPM Satellite		
	RMSE	NSE	R
Climatological Station of Deli Serdang	5.85 mm	0.99	0.99

Average Maximum Rain Thickness Data

After collecting rain duration data for 30 minutes, 60 minutes, 90 minutes, 120 minutes, 180 minutes, 240 minutes, 360 minutes, 720 minutes, and 1440 minutes, and data on maximum rainfall thickness of 20 years from January 1 2021 – December 31 2021. Then the average calculation was carried out as in table 3.

Table 3. Average Maximum Rain Thickness

Num	**Rain Duration (minutes)**	**Annual Average Maximum Rain Thickness (mm)**
1	30	23.18
2	60	36.69
3	90	52.61
4	120	67.68
5	180	79.13
6	240	96.49
7	360	111.25
8	720	130.11
9	1440	165.88

Rain Thickness Model Results

The rain thickness equation model was obtained using the simple linear regression method, and the chi-square test was used to determine the suitability of the rain thickness data from the Global Precipitation Measurement (GPM) satellite and the Climatological Station of Deli Serdang. The rain thickness equation model obtained is the relationship between rain duration (ti) and rain thickness (Hi) with units of mm.

Table 4 shows that the coefficient value (a) = 0.72 and the regression coefficient value for the thickness of the rain (b) = 0.50. That was if the rain duration (ti) was 0 minutes, then the rain thickness (Hi) was 0.72 mm, and if it goes up by 1 minute, it will produce heavy rain (Hi) of 0.50 mm. From the known value of the constant (a), the coefficient value of k = 5.21 is obtained. The correlation value (r) between the duration of rain (ti) and the thickness of rain (Hi) was r = 0.97, and the value of r^2 = 0.94. Thus, the relationship between rain duration (ti) and rain thickness (Hi) was very strong, where the correlation coefficient was 0.8-1. Thus, this study's rain thickness model (Hi) was Hi = $5.21ti^{0,50}$ mm.

Table 4. Simple Linear Regression Table

Num	ti (minutes)	Hi (mm)	X	Y	XY	X^2	Y^2
1	30	23.18	1.48	1.37	2.02	2.18	1.86
2	60	36.69	1.78	1.56	2.78	3.16	2.45
3	90	52.61	1.95	1.72	3.36	3.82	2.96
4	120	67.68	2.08	1.83	3.81	4.32	3.35
5	180	79.13	2.26	1.90	4.28	5.09	3.60
6	240	96.49	2.38	1.98	4.72	5.67	3.94
7	360	111.25	2.56	2.05	5.23	6.53	4.19
8	720	130.11	2.86	2.11	6.04	8.16	4.47
9	1440	165.88	3.16	2.22	7.01	9.98	4.93
∑		763.04	20.50	16.74	39.26	48.91	31.75

Notes: ti = rain duration (minutes); Hi = Thickness of rain (mm); X = Log ti; Y = Log Hi

The Chi-Square test results in table 5 show that the rain thickness equation model (Hi) was suitable for use at the Climatological Station of Deli Serdang. The results obtained by X2table are 15.51, while X^2count was 15.17. So, the X^2 count was smaller than the X^2table. Figure 1 illustrates the relationship between rain duration (ti) and rain thickness (Hi) in graphical form.

Table 5. Chi-Square Test

No	ti (minutes)	O (mm)	E (mm)	$(O-E)^2$	$(O-E)^2/E$
1	30	23.18	28.54	28.64	1.00
2	60	36.69	40.36	13.41	0.33
3	90	52.61	49.43	10.16	0.21
4	120	67.68	57.07	112.44	1.97
5	180	79.13	69.90	85.26	1.22
6	240	96.49	80.71	249.06	3.09
7	360	111.25	98.85	153.79	1.56
8	720	130.11	139.80	93.93	0.67
9	1440	165.88	197.71	1012.86	5.12
∑		763.04	762.36	1759.55	15.17

Notes: ti = duration of rain (minutes); O = Thickness of rain measured by satellite (mm); E = Thickness of rain model equation (mm)

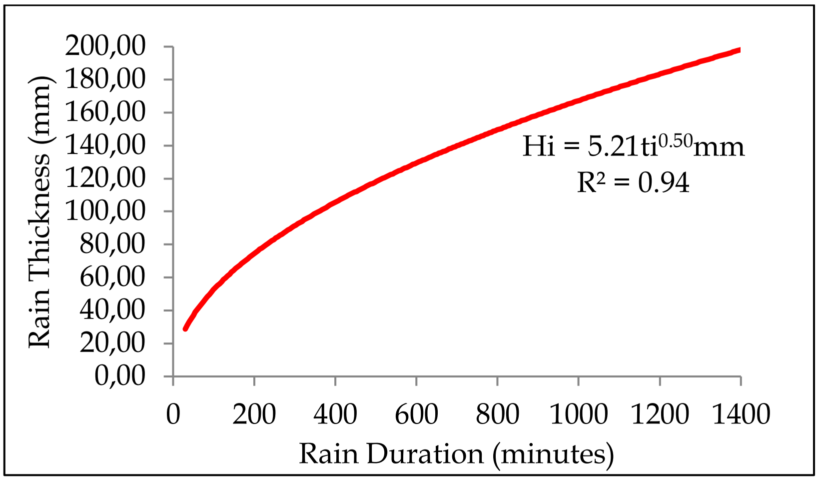

Figure 1. Graph of Rain Duration Performance Model Against Rain Thickness

Validation of Rain Thickness Equation Model

The rain thickness equation model resulting from the study was re-validated with the rainfall thickness measured at the Climatological Station of Deli Serdang based on the Hellman-type rainfall gauge. The data used as the sample was rained on September 3, 2022.

Table 6 compares the thickness of rain measured by the Climatological Station of Deli Serdang on September 3, 2022, with the rain thickness equation model.

Table 6. Comparison of rain thickness measurement data and equation models

No	Ti	Pi (mm)	Qi (mm)
1	5	10.00	11.65
2	10	20.00	16.48
3	15	24.00	20.18
4	30	30.00	28.54
5	45	43.00	34.95
6	60	51.50	40.36
7	120	54.50	57.07
8	180	57.80	69.90
	$\overline{P}$	36.35	
	$\sum$	290.80	279.12

Notes: ti = duration (minutes); Pi = Rain measurement (mm); Q = Rain model equation (mm)

Validation calculations were carried out using the Root Mean Squared Error (RMSE) method, Nash-Sutcliffe Efficiency (NSE) and Correlation Coefficient (R), as shown in Table 7.

Table 7. Validation of the rain thickness equation model

Station	GPM Satellite		
	RMSE	NSE	R
Climatological Station of Deli Serdang	6.84 mm	0.69	0.94

The climatological Station of Deli Serdang used manual and automatic rain gauges. This resulted in the absence of rainfall data. Satellites have better accuracy than rain measurements from the Climatology Station. One of the satellites that functioned to measure rain was the Global Precipitation Measurement (GPM) (Satria WD et al., 2022).

From the analysis of data quality tests in table 1, the results obtained were that the Global Precipitation Measurement (GPM) satellite rain thickness data and Climatological Station of Deli Serdang were consistent and stable. From the results of the two consistent rain thickness data, the data on the Climatological Station of Deli Serdang and the Global Precipitation Measurement (GPM) satellite, the measurements and placement of the tools were correct.

RMSE method validation results of 5.85 mm. RMSE is a validation parameter used to analyze the amount of bias between Global Precipitation Measurement (GPM) rainfall data and the Climatological Station of Deli Serdang. The magnitude of the average monthly rainfall of the Global Precipitation Measurement (GPM) satellite compared to the Climatological Station of Deli Serdang is the cause of the large bias between the two data (Sun et al., 2018). Another reason was that the monthly rainfall data at the Climatological Station of Deli Serdang was empty.

To find out the accuracy of the Global Precipitation Measurement (GPM) satellite rain thickness data and Climatological Station of Deli Serdang, a Nash-Sutcliffe Efficiency (NSE) validation was carried out. For a Nash-Sutcliffe Efficiency (NSE) value of 0.99, the interpretation results show 0.99 > 0.75 is good. This means that the accuracy of the Class 1 Climatology Station of Deli Serdang and the Global Precipitation Measurement (GPM) Satellite is good.

The parameter Correlation Coefficient (R) results are 0.99, and the interpretation shows 0.99 – 1, which is very strong. From the validation results of the Nash-Sutcliffe Efficiency (NSE) and Correlation Coefficient (R), it shows that the Global Precipitation Measurement (GPM) rain thickness data match with the measurements at Class 1 Climatology Station Deli Serdang (Kurniawan & Jendra, 2022; Sungmin et al., 2017).

From the linear regression analysis in table 4, the coefficient value (a) = 0.72 is obtained and the regression coefficient value for the thickness of the rain (b) = 0.50. That is, if the rain duration (ti) is 0 minutes, then the rain thickness (Hi) is 0.72 mm, and if it increases by 1 minute, it will produce a rain thickness (Hi) of 0.50 mm. From the known value of the constant (a), the coefficient value of k = 5.21 is obtained. The value of the correlation coefficient (r) between the duration of rain (ti) and the thickness of rain (Hi) is r = 0.97, and the value of r^2 = 0.94. Thus, the relationship between rain duration (ti) and rain thickness (Hi) shows a very strong relationship, where the correlation coefficient is 0.8-1. So, this study's rain thickness equation model (Hi) is Hi = $5.21ti^{0,50}$ mm.

The thickness of the rain comes from measurements of the Hellman-type measuring device at the Climatological Station of Deli Serdang, September 3, 2022, as shown in table 6, with the symbol Pi. And the value of the rain thickness from the rain thickness equation model, which Qi denotes. Based on the acquisition of rain thickness data between the two, the equation model resulting from the research follows the theory put forward by (Bunganaen et al., 2013) and (Nurhaya, 2020) that the thickness of the rain will be higher if the duration of the rain increases.

The rain thickness equation model validation results based on the Root Mean Squared Error (RMSE) was 6.84 mm, the Nash-Sutcliffe Efficiency (NSE) was 0.69, and fulfil. The correlation coefficient (R) was 0.94, with a strong interpretation of 0.80-1. Based on the validation analysis of the rain thickness equation model, the results are that the research equation model can be used as an alternative to calculating rain thickness at the Climatological Station of Deli Serdang.

The value of the rain thickness between the observations of the Climatological Station of Deli Serdang Station and the equation model sourced from the Global Precipitation Measurement (GPM) satellite, it is concluded that the rain thickness of the equation model is higher than the observations of the Climatological Station of Deli Serdang. The thing that causes this is the thickness of the rain resulting from the equation model is greater than the measurement of the Climatological Station of Deli Serdang. The difference in measurement medium made between the Global Precipitation Measurement (GPM) Satellite and the Climatological Station of Deli Serdang is also the cause, where observations made by the Global Precipitation Measurement (GPM) Satellite are carried out in the atmosphere. At the same time, the Climatological Station of Deli Serdang takes measurements on surfaces with limited area coverage resolution. Temperature and wind factors also cause errors (Wahdianty et al., 2016). Heavy rains can occur due to high air humidity. This is because there is a lot of water vapour in the atmosphere (Siregar et al., 2020).

CONCLUSION

The model equation for the relationship between rain duration and rain thickness is $Hi = 5.21ti^{0,50}$ mm. The rain thickness equation model validation results are based on the Root Mean Squared Error (RMSE) of 6.84 mm, Nash-Sutcliffe Efficiency (NSE) of 0.69, and fulfil. The correlation coefficient (R) of 0.94, with an interpretation of 0, 80 - 1, is very strong. Based on the validation analysis of the rain thickness equation model, the result is that the equation model resulting from the research can be used as an alternative to calculating rain thickness at Climatology Station Class 1 Deli Serdang.

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