



Utilization of GPM Satellite and PERSIANN Satellite Data for Estimated Monthly Rainfall in South Sumatera

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ABSTRACT

Rainfall data are widely used to predict regional rainfall. Limited rainfall data is a problem that has an impact on decreasing accuracy, one of which is in the area of South Sumatera. This can be overcome by using satellites. However, to utilize satellite-based rainfall data, it is necessary to carry out an analysis to determine the accuracy of rainfall data. This research aims to evaluate rainfall data from the GPM satellite and PERSIANN satellite with validation and calibration analysis so that the value of rainfall data from the Satellite is close to the measurement result and can be used to estimate monthly rainfall. In this study, the data used were measured monthly rainfall in the field, GPM, and PERSIANN obtained from 9 South Sumatera districts for 2019 until 2021. The research method was validated using correlation coefficient, Root Mean Square Error (RMSE), and Mean Absolute Error (MAE). Calibration is done using a combination method, a solver algorithm in Microsoft Excel, and manually. The estimated monthly rainfall analysis is carried out using the isohyet method with the IDW interpolation method. The research results were obtained based on the validation and calibration of monthly rainfall data showing that data from the GPM showing it is closer to the results of field rainfall measurements than the data obtained from PERSIANN satellite. Based on the results of research on satellite data that has been calibrated, it can be used to estimate monthly rainfall in the South Sumatera Region.

1. Introduction

Accurate measurement of rainfall data is important because of the various uses of the data. Rainfall data is the main input in various activities such as climate change forecasting, environmental research, hydrological modeling, flood forecasting, drought monitoring, and inspection and management of water sources [1], [2]. There are two methods commonly used to obtain rainfall data. These methods are measurements with measuring instruments and

satellites [3]. Rainfall information is obtained from automatic or manual rainfall stations (Rain Gauge Stations) and through remote sensing systems such as satellites and radar-based satellite imagery [1].

Measuring rainfall data with measuring instruments has the advantage that the measurement results are accurate and guaranteed at a point [4]. Unfortunately, it is difficult to achieve ideal conditions for measuring rainfall with measuring instruments in an area because of the limited number of instruments. Sometimes there are parts of the area with no rainfall-measuring instrument, so you must take data from the nearest rainfall [5]. This will decrease the data accuracy variable because rainfall is strongly influenced by space and time. One of the areas experiencing this problem is South Sumatra, where in some areas, it is difficult to obtain sufficient and sustainable rainfall data [6].

Measurement of rainfall data with satellites can overcome this problem because satellites can retrieve data in a wide range of areas on the earth, with homogeneous spatial resolution and full temporal resolution [7]. However, unlike measurements with measuring instruments, rainfall measurements by Satellite are indirect. Rainfall measurements with satellites are carried out by observing atmospheric parameters and estimating the amount of rain that occurs from these observations. So that rainfall with satellites cannot be separated from random errors and bias [7]. Validation and calibration of satellite-based data need to be done to determine the correlation or similarity of satellite-based data with data from measurements in the field. Rainfall data validation was carried out by calculating the bias parameter, Mean Error, Root Mean Square Error, Pearson correlation coefficient (r), and determinant coefficient (r^2). While checking the accuracy of the model is done by calculating the Nash-Sutcliffe efficiency coefficient [6]

The satellite data sources used are PERSIANN and GPM IMERG V06. GPM is the successor of the first precipitation measurement in collaboration with NASA and JAXA, namely TRMM (Tropical Rainfall Measuring Mission). GPM is superior to TRMM because it inclines 65° (TRMM inclination is 35°), so it can take measurements in mid-latitude, tropical, and subtropical areas [8][9]. The PERSIANN Satellite is designed to extract and combine information from various types of data, including microwave and infrared satellite imagery, radar data on the earth's surface and rain measurement tools, and topographical information on the ground surface [7], [10].

Several studies related to the prediction of rainfall have been carried out on the island of Java [5],[11]–[13]. Research on monthly rainfall data with the GPM satellite and PERSIANN satellite in the South Sumatra district has not been carried out much. Based on a literature study,

research in South Sumatra was conducted in Indralaya, using calibrated daily rainfall data from the short-duration GPM satellite for three months [6]. In this study, the rainfall data is long enough for three years (2019 - 2021) in 9 districts in South Sumatra. In addition to utilizing rainfall data from GPM, this research also utilizes data from the PERSIANN satellite. Previous studies focused more on validating and calibrating satellite data. In this study, apart from validating and calibrating data, research also focused on using calibration satellite data for estimating regional rainfall data.

This study aims to evaluate rainfall data from the GPM satellite and PERSIANN satellite with validation and calibration analysis so that the value of rainfall data from the Satellite is close to the measurement result and can be used to estimate monthly rainfall. Rainfall data obtained from satellites and field measurements will be analyzed and compared. The higher the value of satellite-based data validation against the results of measurements in the field, the greater the opportunity to use the data for forecasting rainfall and other fields of science such as hydrological analysis, water resources, and others. The results of this study can be used to estimate monthly rainfall in the South Sumatra Region.

2. Research Method

Monthly rainfall data for three years (2019-2021) was collected from field measurements, the GPM satellite, and the PERSIANN satellite. The accuracy of satellite rainfall data is validated and calibrated so that the value of rainfall data is close to the results of measurements in the field. The satellite rainfall data calibration results estimate monthly rainfall in South Sumatra. Estimation is done by finding the average rain using the isohyet method for the area in South Sumatra.

2.1. Location

South Sumatra is one of Indonesia's provinces with 17 districts. The study was conducted in nine districts in South Sumatra Province. If there is more than one rainfall measurement station in these districts, then only one station will be represented. The coordinates of the location of the rainfall measurement station selected for rainfall data can be seen in **Table 1**.

Table 1. Coordinates of Rainfall Measurement Station

No.	Districts	Rainfall Station	Coordinates
1.	Banyuasin	Srikaton	2°42'21" LS – 105°0'31" BT
2.	Empat Lawang	Pendopo	3°47'24,09" LS – 102°57'36,58" BT
3.	Lahat	Lahat	3°46'54,3" LS – 103°33'43,09" BT
4.	Muara Enim	Tanjung Rambang	3°32'57,31" LS – 104°15'46,77" BT
5.	Musi Rawas	Terawas	3°3'44" LS – 102°49'7" BT
6.	Ogan Ilir	Tanjung Siteko	3°13'55,85" LS – 104°40'45,88" BT
7.	Ogan Komering Ilir	Celikah	3°24'0" LS – 104°49'48" BT
8.	Ogan Komering Ulu Selatan	Rantau Nipis	4°48'1,33" LS – 104°15'46,77" BT
9.	Pagar Alam	Pagaralam	4°0'34" LS – 103°14'55" BT

Source: *BMKG kelas 1 Palembang and BBWS VIII Sumatera Selatan*

2.2. Rainfall Data

As a printed table, rainfall data (field measurement results) were obtained from BBWS VIII and BMKG. The PERSIANN satellite rainfall data was obtained from the CHRS (Center for Hydrometeorology and Remote Sensing) data portal site [14]. The rainfall data is downloaded as a comma-separated value (.csv) file and can be directly opened through a data processing application such as Microsoft Excel. In contrast, the rainfall data for the GPM satellite is obtained from the Giovanni data portal site owned by NASA [15]. The data is downloaded as a rainfall map with the GeoTiff file format (.tiff). GIS applications such as ArcMap can be used to obtain rainfall data from the downloaded map.

2.3. Validation

Monthly rainfall data is validated by calculating the bias parameter [2], [16]. Data validation is carried out to prove whether a process or method can produce consistent results by predetermined specifications [6]. Data validation before and after calibration will be carried out using three statistical parameters, namely correlation coefficient (r), Root Mean Square Error (RMSE), and Mean Absolute Error (MAE). The correlation coefficient is a measure that shows how significant the correlation between two ordinal variables is [17] [11]. The Root Mean Square Error method is an absolute error test method. This method is used to determine the magnitude of the deviation between the predictions of total rainfall compared with the rainfall value from direct measurements [16]. Mean Absolute Error (MAE) is a method used to represent the average magnitude of error [18]. The three statistical parameters are expressed in the following equation [17]:

$$r = \frac{n \sum A_i B_i - (\sum A_i)(\sum B_i)}{\sqrt{\{n(\sum A_i^2) - (\sum A_i)^2\}\{n(\sum B_i^2) - (\sum B_i)^2\}}}$$

$$\text{RMSE} = \sqrt{\frac{\sum_{i=1}^n [B_i - A_i]^2}{n}} \quad \text{MAE} = \frac{\sum_{i=1}^n |B_i - A_i|}{n}$$

With:

A_i = Measurement rainfall data

B_i = Satellite rainfall data

n = Total data

2.4. Calibration

Collecting rainfall data is calculated using a combination method, and the first step is using the add-ins solver in the Microsoft Excel application. Calibration of a model is the process of optimizing parameter values to improve coherence between the observed and simulated hydrological responses [19], [20]. The calibration results are checked again, and if it requires further calibration, it will be done manually. Calibration is carried out to produce a calibration factor. The calibration factor will change the rainfall data from satellite measurements to be closer to the data from field measurements.

The calibration process is carried out in each district for monthly rainfall data for three years. Each calibration process is carried out with the solver repeatedly until the results obtained are close to the results of field measurements [21], [22]. The solver process will produce cumulative and individual errors smaller than the initial conditions. This is caused by the calibration factor in each data generated from the calibration process.

2.5. Analysis of Regional Average Rainfall

The area's average rainfall was analyzed using the isohyet method [3], [23]. The isohyet map is made using the ArcMap application, where the interval between isohyet lines is every 50 mm of rainfall. GIS can generate and calculate rainfall averages, according to the Thiessen polygon, Isohyet method, and Inverse Distance weighting IDW[24]. Research conducted on Monthly Rainfall in East Java for the 2012-2016 period showed that the IDW method was better than the Spline method because the RMSE value of the IDW method was smaller than the Spline method [12], [25]. The isohyet method is expressed in the following equation [3], [23], [24]:

$$\bar{p} = \frac{A_1 \frac{I_1 + I_2}{2} + A_2 \frac{I_2 + I_3}{2} + \dots + A_n \frac{I_n + I_{n+1}}{2}}{A_1 + A_2 + \dots + A_n}$$

With :

\bar{p} = Mean Areal Rainfall

I_1, I_2, I_n, I_{n+1} = isohyet line 1, 2,, n , n + 1

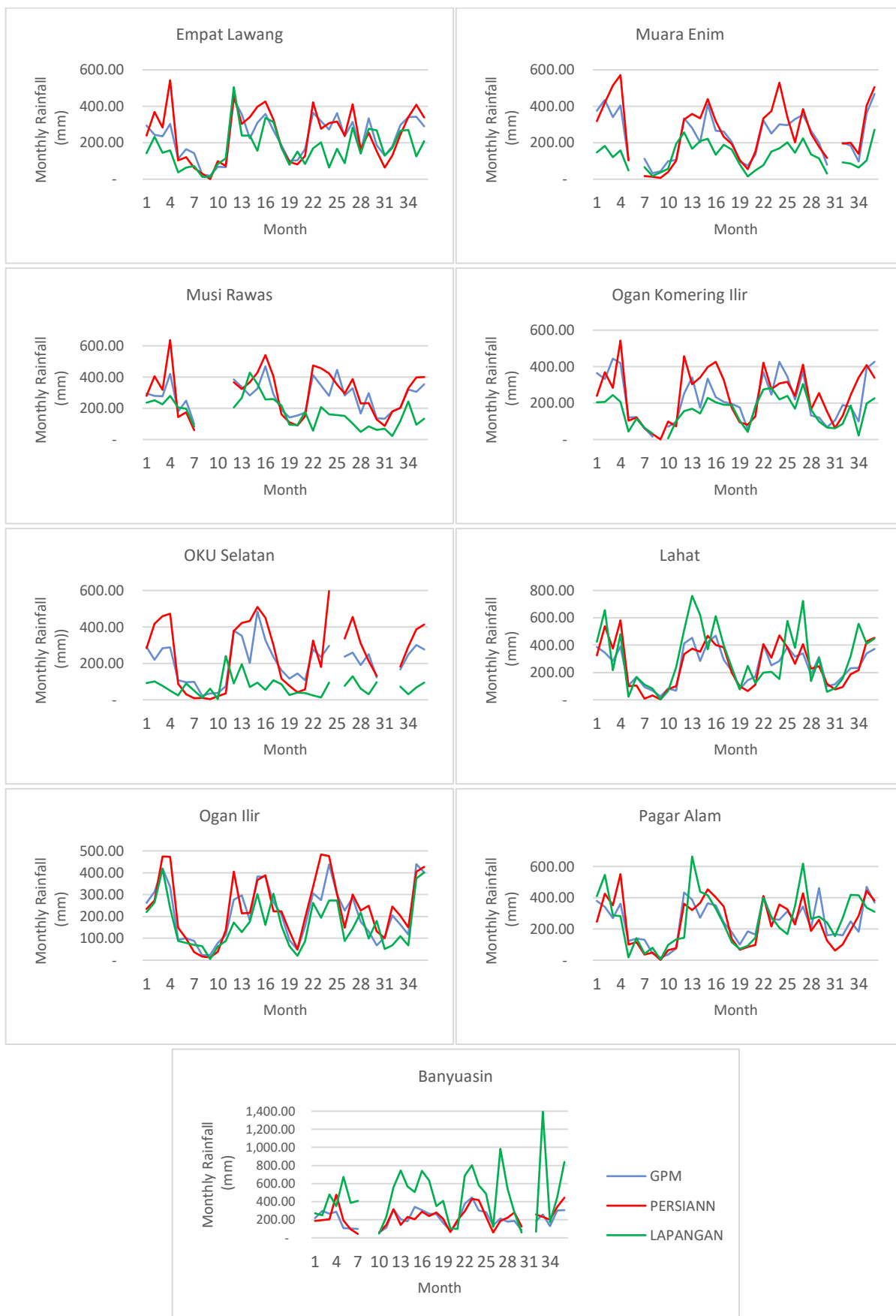
A_1, A_n, A_{n+1} = The area encountered between each series counter lines 1 and 2....., n and n + 1

The analysis results of the average rainfall in the area are classified based on the value of monthly rainfall. There are four groups of rainfall classifications, namely low rainfall (0-100 mm), medium (100-300 mm), high rainfall (300-500 mm), and very high rainfall (more than 500 mm).

3. Results and Discussions

3.1. Rainfall Data

The data to be used is in the form of monthly rainfall data for three years, namely 2019, 2020, and 2021. The data comes from two types of rainfall measurements, namely by measuring instruments and satellites. This data is secondary because it is obtained not through direct measurements but from related institutions that carry out rainfall measurements. For rainfall measurement results with measuring instruments, rainfall data are used from the Center for the River Basin (BBWS) and the Meteorology, Climatology, and Geophysics Agency (BMKG). In comparison, the rainfall data from satellite measurements comes from PERSIANN and GPM IMERG V06. Monthly rainfall data from field measurements and satellite data in districts in South Sumatra for the period 2019, 2020, and 2021 can be seen in **Figure 1**.



Source: Author's Analysis (2022)

Figure 1. Monthly Rainfall Data

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Figure 1 shows that not all satellite-based rainfall data are close to the results of rainfall data measurements in the field. In this study, from 9 districts, Empat Lawang, Ogan Komering Ilir, Lahat, Ogan Ilir, and Pagar Alam have satellite-based rainfall values that are close to the results of measurements in the field compared to other districts. Based on the data collected, data from the GPM satellite has a value closer to the field conditions in several districts than the PERSIANN satellite. Rainfall data that has been collected will be validated and calibrated so that satellite-based rainfall data in the future can be used for rainfall estimation.

3.2. Validation data

The results of the validation of monthly rainfall data found that based on the value of the correlation coefficient, in general, the data had a moderate to very strong correlation. There are only a few pieces of data with low correlation, including rainfall data for the OKU Selatan district from the two satellites. The recapitulation of the results of the validation calculations before calibration can be seen in **Table 2**.

The initial validation results are used to determine the correlation between the rainfall data measured in the field and the rainfall data from the Satellite. **Table 2** shows that the correlation between the data is included in the low to strong correlation criteria, which are shown from the calculation of the correlation coefficient, MAE and RMSE. The higher the value of the correlation coefficient, the closer the results of measurements in the field. Conversely, the smaller the value of MAE and RMSE, the closer the value of satellite data to the conditions of field measurements. Districts with a strong correlation are Empat Lawang, Lahat, Muara Enim, Ogan Ilir, Ogan Komering Ilir, and Pagar Alam.

Table 2. The results of the validation monthly rainfall data from the GPM satellite and PERSIANN Satellite

Districts	Rainfall Station	r		MAE		RMSE	
		GPM	PERSIANN	GPM	PERSIANN	GPM	PERSIANN
Banyuasin	Srikaton	0,523	0,627	260,829	267,768	355,460	360,631
Empat Lawang	Pendopo	0,708	0,709	76,817	95,332	99,224	129,911
Lahat	Lahat	0,794	0,692	104,838	121,174	147,916	158,270
Muara Enim	Tanjung Rambang	0,746	0,500	113,253	140,464	136,661	177,540
Musi Rawas	Terawas	0,452	0,784	112,258	138,763	140,844	176,053
Ogan Ilir	Tanjung Siteko	0,848	0,793	63,145	84,291	82,148	111,791
Ogan Komering Ilir	Celikah	0,836	0,262	75,913	95,277	101,766	127,757
OKU Selatan	Rantau Nipis	0,228	0,685	149,180	205,072	173,866	250,692
Pagar Alam	Pagaralam	0,658	0,627	93,055	96,896	123,786	125,367

Source: Author's Analysis (20222)

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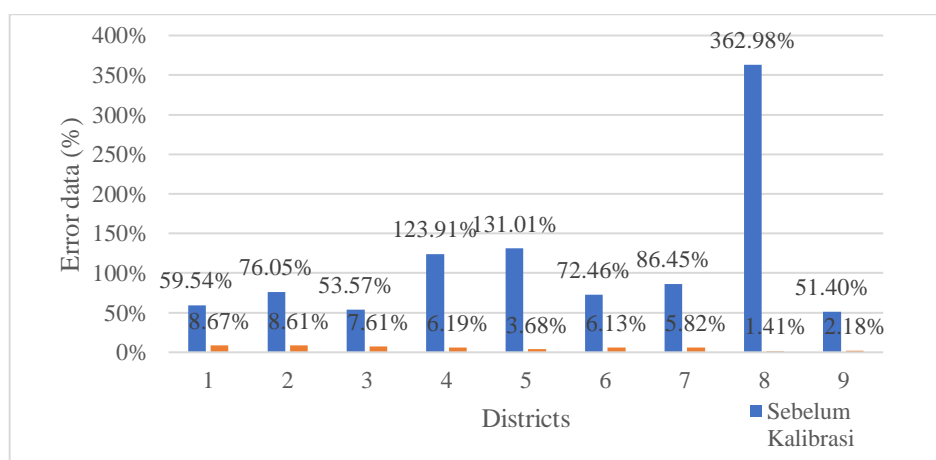
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While the validation results of rainfall data from the GPM satellite show very good validation results in several districts. In the Ogan Ilir district, the Ogan Komering Ilir validation results show a very strong correlation value, where the validation value is above 0,8, and the districts with a strong correlation are in four maces, Lahat, Muara Enim, and natural fences. The greater correlation value indicates the rainfall value from satellite data is closer to the value in the field. Validation results from satellite-based rainfall data show that not all districts have a validation value with a strong correlation, which identifies that the rainfall data is not close to the results of measurements in the field. Therefore, in the next stage, a calibration process will be carried out so that the satellite-based rainfall data can be close to the measurement data in the field.

3.3. Calibration

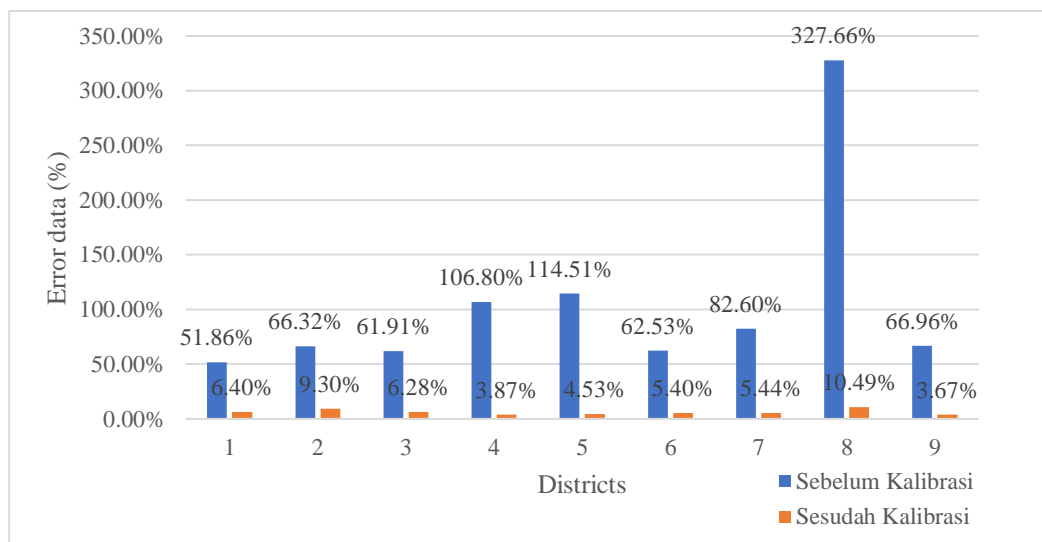
Calibration aims to adjust the accuracy of GPM and PERSIANN satellite data by comparing it with field measurement data as a reference. The calibration results will obtain a correction factor based on rainfall classification (low, medium, high, and very high rainfall). The result of multiplying the rainfall data from the Satellite with the correction factor from the calibration results shows that the value of the satellite rainfall data is closer to the rainfall value from the field. In **Figure 3** and **Figure 4**, it can be seen that all data experienced a significant decrease in the average data error value after calibration. Error data calculation aims to see the difference between field and satellite measurement data. Data errors are expressed in proportions, where each data will be calculated by the difference or difference between the two data, then averaged for each district for three years. In addition to rainfall data for the OKU Selatan district from the GPM satellite, the average data error after calibration is below 10%.



Source: Author's Analysis (20222)

Figure 2. PERSIANN Satellite Data Error Analysis Results Before Calibration and After Calibration.

The calibration of rainfall data from the PERSIANN satellite shows a significant decrease in data error. In the southern OKU district, the data error value was 362.98% before the data was calibrated, and after calibration, the data error value was 1.42%. Likewise with other districts, in **Figure 2**, the value of rainfall data from the PERSIANN satellite after being calibrated is closer to the results of measurements in the field. These results indicate a great opportunity to utilize PERSIANN satellite data as a substitute for the measured rainfall data.



Source: Author's Analysis (20222)

Figure 3. GPM Satellite Data Error Analysis Results Before Calibration and After Calibration

The results of the calibration of GPM satellite rainfall data In **Figure 3**, it can be observed that all data experienced a very significant decrease in the average data error value. In addition to rainfall data from the OKU Selatan district from the GPM satellite, the average data error after calibration is below 10%. From the results of this calibration, it can be concluded that the data from the GPM and PERSIANN satellites that have been calibrated using the add-ins solver in the Microsoft Excel application are close to the results of rainfall measurements in the field. This calibration data will then be used to estimate monthly rainfall in each district in South Sumatra

3.4. Validation Data After Calibration

The results of the validation on the data that have been calibrated, in the table it can be seen that all statistical parameters have improved compared to the data before calibration. This indicates that the calibration has been performed correctly. An example is in Banyuasin Regency, where the correlation coefficient of data from the GPM satellite before calibration is 0.523 (medium correlation). After calibration, the correlation of the data rose to 0.885 (very

strong correlation). All data have a strong to very strong correlation after the calibration process.

The recapitulation of the validation results after calibration can be seen in Table 3.

Table 3. Validation Results After Calibrating Data From The GPM Satellite and PERSIANN Satellite

Districts	Rainfall Station	r		MAE		RMSE	
		GPM	PERSIANN	GPM	PERSIANN	GPM	PERSIANN
Banyuasin	Srikaton	0,885	0,798	47,438	52,249	141,173	184,477
Empat Lawang	Pendopo	0,948	0,955	15,957	10,914	33,031	29,917
Lahat	Lahat	0,947	0,991	28,636	6,401	73,183	28,569
Muara Enim	Tanjung Rambang	0,976	0,865	4,539	12,227	15,189	36,029
Musi Rawas	Terawas	0,978	0,964	5,625	6,921	19,557	24,988
Ogan Ilir	Tanjung Siteko	0,976	0,959	10,050	12,568	23,540	32,175
Ogan Komering Ilir	Celikah	0,980	0,981	5,123	6,489	15,881	16,116
OKU Selatan	Rantau Nipis	0,893	0,982	9,095	1,794	24,768	9,414
Pagar Alam	Pagaralam	0,974	0,994	11,561	5,725	39,048	18,507

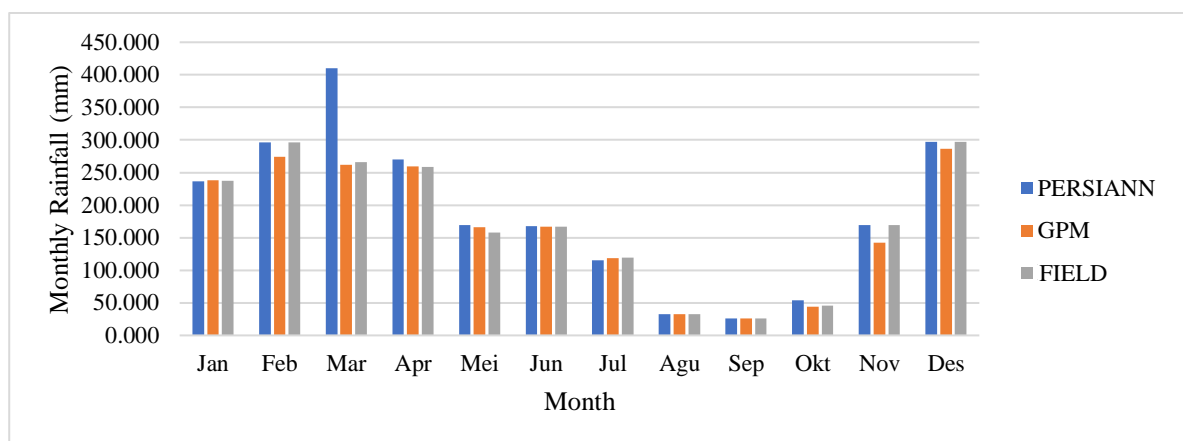
Source : Author's Analysis (20222)

In **Table 3.** it can be seen that the validation results of rainfall data from the PERSIANN satellite and the GPM satellite on rainfall data measured in the field after calibration show that the value of the correlation coefficient of the data has increased to be very strong for all districts in South Sumatra. The results of the MAE and RMSE calculations from Table 2 and Table 3 show that the calculated values are getting smaller, which indicates that the Satellite data is getting closer to field conditions. The results of the validation analysis, the average validation value after calibration closest to the measurement results is the rainfall data from the GPM satellite.

The results of the validation and calibration analysis of satellite-based rainfall data with measurements of rainfall data from measurements in several districts in South Sumatra show very good results. The results of the calibration of rainfall data from the PERSIANN satellite and the GPM satellite show that the average error value is much reduced so that the calibration data can be used to analyze rainfall estimation. The calibration data is then used to estimate monthly rainfall data, considering that the data used is rainfall data from 2019 to 2021. The next step is calculating the average monthly rainfall for districts in South Sumatra using the isohyet method. The isohyet method is the most accurate method for calculating regional average rainfall compared to other methods. The results of the analysis of the average regional rainfall each month can be used to estimate and classify the rainfall each month. The rainfall classification is classified into low, medium, high and very high.

3.5. Analysis of the Regional Average Monthly Rainfall in 2019

The analysis of monthly rainfall data from the field, GPM satellite, and PERSIANN Satellite for 2019 found that the analysis results with GPM satellite data were closer to the analysis results with field rainfall data when compared to the analysis using PERSIANN data. This can be seen in Figure 4, where apart from February, November, and December, the analysis with GPM data has results that are close to the analysis results with field data.



Source: Author's Analysis (20222)

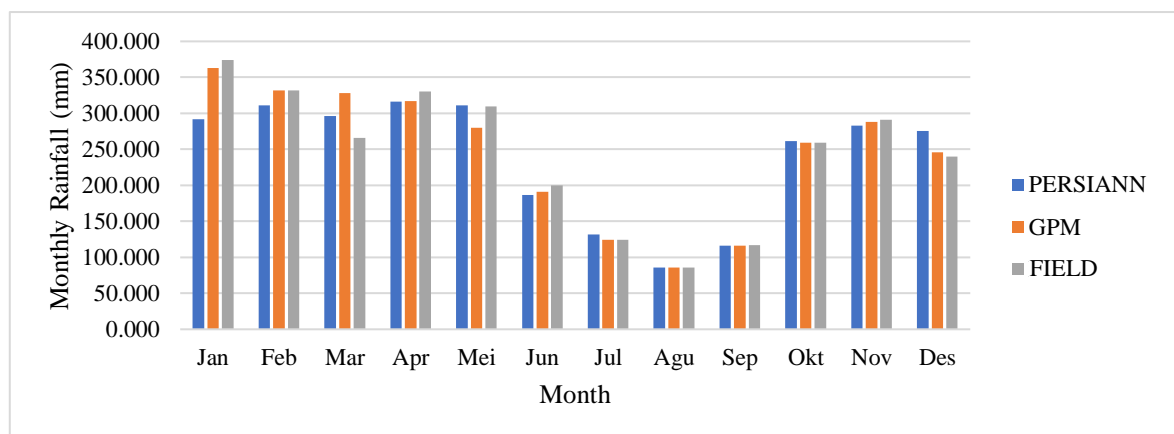
Figure 4. Comparison of Average Monthly Rainfall in 2019

Figure 4 shows that in 2019, from August to October, the rainfall was in a low category (0-100 mm). In addition to the average rainfall in March, the analysis results using PERSIANN data (409.91 mm, high category) from November to July have rainfall that is included in the medium category (100-300 mm).

3.6. Analysis of the Regional Average Monthly Rainfall in 2020

Based on the analysis results on monthly rainfall data from the field, GPM, and PERSIANN for 2020, it was found that the results of the analysis with GPM satellite data were closer to the results of the analysis with field data when compared to the analysis using PERSIANN satellite data. This can be seen in **Figure 5**. Apart from March and May, the analysis with GPM data has results closer to the results of the analysis with field data.

In **Figure 5** it can also be noted that in 2020, only August had low rainfall (0-100 mm). In June, July, September, October, and December, an average rainfall of 100-300 mm was recorded, which was included in the medium category. Meanwhile, from January to May, analysis of the average rainfall tends to produce numbers in the range of 300-400 mm (high rainfall category). The exceptions to this category are the average rainfall data for January with PERSIANN satellite, March with GPM satellite and field data, and May with GPM satellite.

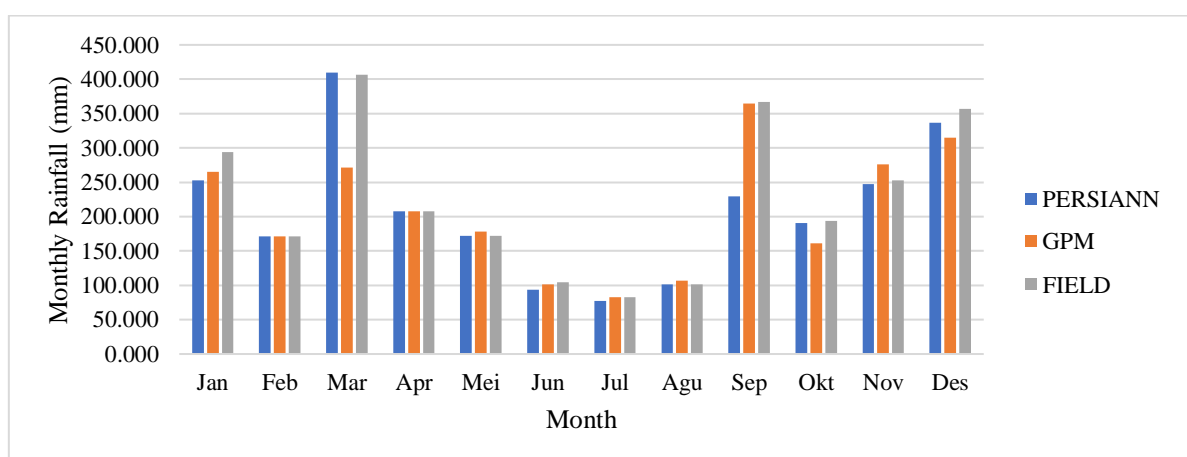


Source : Author's Analysis (20222)

Figure 5. Comparison of Average Monthly Rainfall in 2020

3.7. Analysis of the Regional Average Monthly Rainfall in 2021

Based on the results of the analysis of monthly rainfall data from the field, GPM satellite, and PERSIANN Satellite for 2021, it was found that the results of the analysis with PERSIANN satellite data were closer to the results of the analysis with field data when compared to the analysis using GPM satellite data. This can be seen in Figure 6, where in addition to January, June, July, and October, analysis with PERSIANN satellite data has results closer to the analysis results with field data.



Source : Author's Analysis (20222)

Figure 6. Comparison of Average Monthly Rainfall in 2021

Figure 6 shows that in 2021, June to August tends to have an average rainfall in the low category (0-100 mm). In October, November, January, February, April, and May, the average rainfall is 100-300 mm (middle category). Meanwhile, the average rainfall in

September, December, and March was in the high category (300-400 mm) except for two data. The two data are the average rainfall in March with GPM satellite data (271.40, medium category) and the average rainfall in September with PERSIANN satellite data (229.36, medium category).

Based on the results of the validation and analysis, it was found that monthly rainfall data from the GPM satellite is better for modeling rainfall data in the province of South Sumatra compared to data from the PERSIANN satellite. The analysis results will be better with calibrated data because the data is close to the data from field measurements. Calibrating rainfall data from satellites for research or other purposes in the South Sumatra region can be carried out using the calibration factor for rainfall data for each district obtained from this study.

4. Conclusion

Based on the research conducted, the results of rainfall data on the GPM satellite and PERSIANN satellite are not close to the results of measurements in the field. After calibrating using the correlation coefficient, MAE and RMSE show results that are close to the conditions of rainfall measurements in the field so that the GPM and PERSIANN satellite data can be utilized in the analysis of monthly rainfall estimates for the South Sumatra Region. Based on the results of the validation and analysis carried out during observations from 2019 to 2021, it was found that monthly rainfall data from the GPM satellite is better for modeling rainfall data in South Sumatra Province compared to data from the PERSIANN satellite. The analysis results will be better with calibrated data because the data is close to the data from field measurements. The results of the analysis are expected to be a recommendation for researchers or related agencies who have problems with limited rainfall data so that they can utilize calibrated satellite-based rainfall data for the estimation of monthly rainfall in the South Sumatra district in the coming year as well as for analysis that uses monthly rainfall data.

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