THE IMPORTANT OF GLOBAL PRECIPITATION MEASUREMENT IN UNGAUGED CATCHMENT

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ABSTRACT

In line with the technological development in the remote sensing field like satellite data, the measurement of rainfall can be carried out by rainfall monitoring in large areas even in places that cannot be reached by conventional tools. This superiority can be utilized to get the rainfall in a region for the importance of water resources management due to the validity and accuracy that can be reliable and represent the rainfall characteristic. Research about the utilization of Global Precipitation Measurement (GPM) data is conducted in the Wonogiri ungauged catchment. However, to utilize the satellite rainfall data is necessary to be carried out a correction, so the rainfall characteristic that is produced by the satellite is close to the condition of observed rainfall data. The correcting is carried out by multiplying every data interval with a certain coefficient, so the produced value by the satellite data approaches the value characteristic that is produced by observed rainfall. Based on the result of trial and error, there is produced as follows: for the interval between 0 and 2 mm, the correction coefficient is 0; for the interval between 2 and 20 mm, the correction coefficient is 0.075; for the interval between 20 until 30 mm, the correction coefficient is 0.8; for the interval between 30 until 50 mm, the correction coefficient is 0.85; and for the interval more than 50 mm, the correction coefficient is 0.95.

Keywords: observed rainfall, satellite rainfall, correction coefficient, GPM.

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1. INTRODUCTION

Nowadays, climate information is very needed by various sectors [1]. One of them is in the water resources field which is a strategic factor. Therefore, the availability of rainfall which is accurate, appropriate, and easily accessible that is as a part of climate information, is a challenge at this moment. The rainfall data is very necessary for policy and strategy taking of a design. The satellite data set is needed for analysing the water availability [2][3], flood analysis [4][5], sedimentation analysis, and erosion [6] which includes the daily rainfall data and also the yearly maximum daily rainfall data.

To overcome the minimal and or not available rainfall data, in several years, there have been carried out several studies about the utilization of satellite-based rainfall data [7] as the complement of rainfall data that is measured in the field. The utilization of Global Precipitation Measurement (GPM) is one of the data alternatives that is necessary to be carried out to overcome the limitation of surface observed data. Therefore, it is hoped can give better and more accurate information on climate classification [8][9] that can be utilized for managing water resources.

Global Precipitation Measurement (GPM) is one of the satellite rainfalls that have been launched by the National Aeronautics and Space Administration (NASA) [10] and Japan Aerospace and Exploration Agency (JAXA) since 2014. The GPM satellite is the successor of the Tropical Rainfall Measuring Mission (TRMM) GPM satellite which can record the rainfall data every 2-4 hours in a day and has the wider scope of the GPM data [11]. If the available rainfall data is minimal, the hydrology parameter that is needed in many cases of water structure design cannot be analysed. As an illustration, the minimal rainfall data is illustrated by many blank rainfall data, so the rainfall period is not long enough [12]. Therefore, further analysis cannot be carried out. The location of rainfall stations in many areas of Indonesia is often outside of the watershed. In addition, there is also spatially uneven. Remember that Indonesia which is so broad with the rainfall stations is uneven in the watershed; so many watersheds in Indonesia have ungauged ground stations.

This research intends to analyse the satellite data until ready to be used for various interests in analysing water resources with the validity and accuracy that can be reliable and represent the rainfall characteristic. The research location is in the Wonogiri watershed, Centre Java Province-Indonesia.

2. MATERIALS AND METHODS

The GPM satellite data is average daily rainfall data that has global characteristics and open source with a grid of 0.1° x 0.1° [13][14]. The GPMCS or Global Precipitation Module Core Satellite was removed on 27th April 2014 by the GMI (GPM Microwave Imager) and DPR (Dual Frequency Precipitation Radar).

Before being carried out the correction level, it is necessary to carry out the identification of the ground-station location in the study location which is the Wonogiri watershed. After it is identified, so it can be made the bar chart for this area. The data is needed for correcting satellite rainfall data through the comparison

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with the ground-station data, distribution, and network density of rainfall observed station in the Wonogiri area that is uneven and it can become a problem in analysing of making rainfall information by using the satellite data. Therefore, it is needed to know how big the RMSE is and how good the correlation between the ground station and the available GPM grid is. The distribution of the ground station is presented in Figure 2.1.

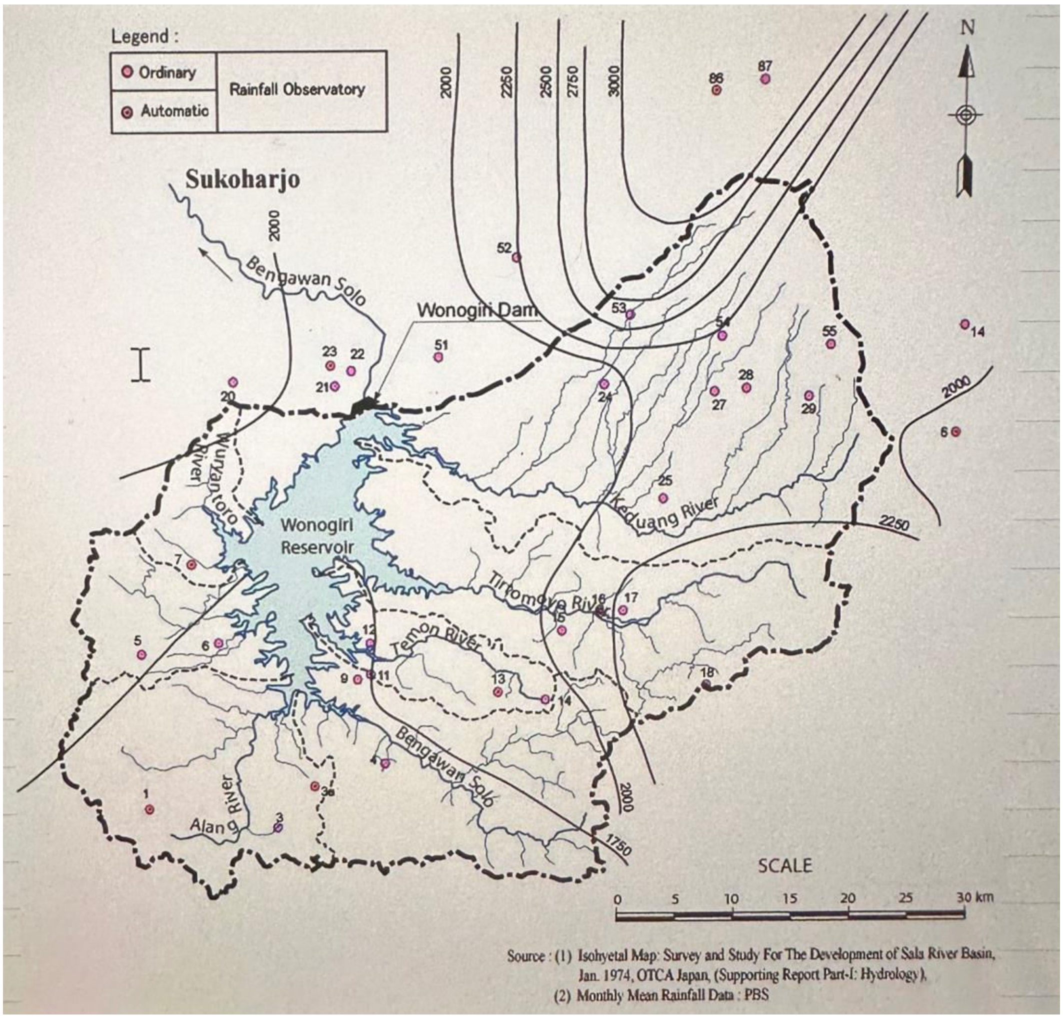

Figure-2.1. Peta DAS Wonogiri.

Before using the satellite data, the data needs to be corrected. The correction is started by selecting the ground station that is used as the correction reference. The ground-station data is selected based on the affinity identification of pattern and daily rainfall between ground-station rainfall data and satellite data.

The utilization of satellite data is started by carrying out the correcting the satellite data that will be used. The correcting begins by carrying out the selection of ground rainfall data that will be used for correcting the satellite data. The selection of rainfall ground is carried out by identifying the affinity of pattern and monthly rainfall between ground rainfall station and satellite rainfall data. 2 statistical parameters are used due to the validity and reliability of Root Mean Square Error (RMSE) and coefficient of correlation (r). The selected rainfall ground station has to have an RMSE < 200 mm and a correlation coefficient > 0.5. However, the equation for analysing the correlation coefficient is as follows [15]:

$$r = \frac{\sum_{i=1}^{n}(Y_i-\bar{Y})(\hat{Y}_i-\hat{Y})}{\sqrt{\sum_{i=1}^{n}(Y_i-\bar{Y})^2}\sqrt{\sum_{i=1}^{n}(\hat{Y}_i-\hat{Y})^2}} \quad (1)$$

Where:

r = correlation coefficient between GPM satellite data and ground-station rainfall data

Y_i = GPM satellite data at i-period with i = 1, 2, ….n

$\bar{Y}$ = average GPM satellite data

$\hat{Y}_i$ = ground-station rainfall data at i-period with i = 1, 2, .n

$\hat{Y}$ = average ground-station rainfall data

n = length of period

However, the formulation of RMSE is as follows [15]:

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$$RMSE = \sqrt{\frac{1}{n}\sum_{k=1}^{n}(y_i - \hat{y}_i)^2} \qquad (2)$$

Where:

Y = observed result

ŷ = estimation result

i = data sort in database

n = number of data

Then, to find the correction number in every interval of rainfall value by trial and error, so there is obtained the error value and probability curve that is close to the ground rainfall station. Figure-2.2 presents the flow chart of the research.

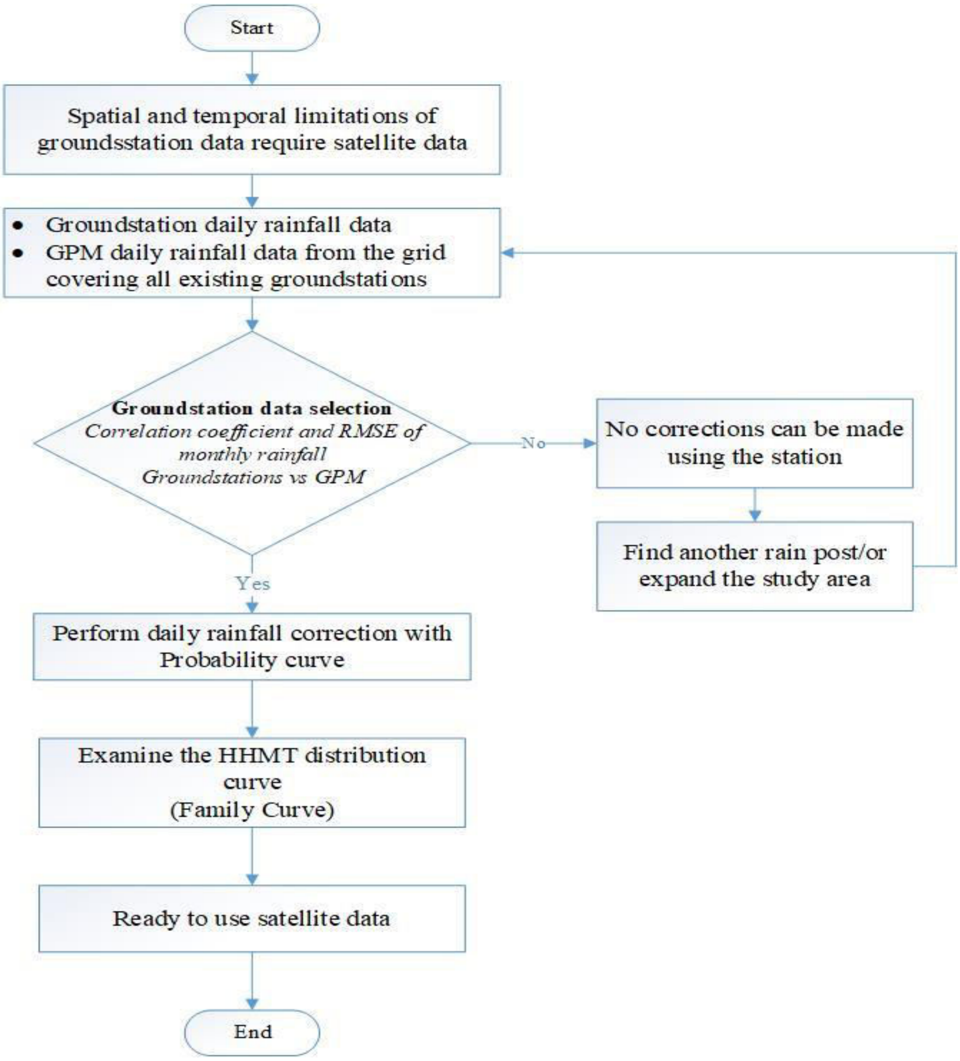

Figure-2.2. Flowchart of Research. Source: own study

3. RESULTS AND DISCUSSIONS

3.1 Identification of Ground Rainfall Station Location

Before being carried out the correction level, it is needed to identify the location of the ground-rainfall station. The study location is in the Wonogiri watershed, and then it is made the bar chart for this area. The identification result shows that there are 12 ground-rainfall stations in the Wonogiri watershed. This data is needed to make easy the correction of satellite rainfall data that is to compare the satellite data with the ground-station data. Table 3.1 presents the ground-rainfall station that has been identified in the Wonogiri watershed.

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Table-3.1. Ground-Rainfall-Station that has been identified in Wonogiri Watershed.

No	Station	Regency	District	Village	Lat	Long
1	Giriwoyo	Wonogiri	Giriwoyo	Giriwoyo	-8.03	110.95
2	Jatipuro	Karanganyar	Jatipuro	Jatipuro	-7.75	111.02
3	Jatisrono	Wonogiri	Jatisrono	Jatisrono	-7.83	111.13
4	Parangjoho	Wonogiri	Eromoko	Eromoko	-7.95	110.82
5	Songputri	Wonogiri	Eromoko	Sindukarto	-7.99	110.83
6	Waduk Nawangan	Wonogiri	Giriwoyo	Platarejo	-8.04	110.90
7	Wonogiri	Wonogiri	Wuryorejo	Donoharjo	-7.84	110.92
8	Eromoko	Wonogiri	Eromoko	Eromoko	-7.96	110.85
9	Kedung uling	Wonogiri	Eromoko	Ngunggahan	-7.94	110.84
10	Sidoharjo	Wonogiri	Sidoharjo	Sidoharjo	-7.82	111.08
11	Slogohimo	Wonogiri	Slogohimo	Gunan	-7.82	111.17
12	Wuryantoro	Wonogiri	Wuryantoro	Mlopoharjo	-7.90	110.86

The density and distribution of the ground-rainfall-station network in the Wonogiri watershed have been uneven will cause problems in making information on rainfall based on the satellite data. Therefore, it is necessary to be analyzed by using RMSE and the correlation between ground-rainfall-station data and available grid GPM. Table-3.2 presents the bar chart data for ground rainfall. However, Tables 3.3 and 3.4 present each for correction number and RMSE value.

Table 3.2 Bar chart of ground-rainfall-data.

No.	Station	197...					198...									
		5	6	7	8	9	0	1	2	3	4	5	6	7	8	9
1	Giriwoyo		12	12	12	12	12	12	12	12	12	12	12	12	12	12
2	Jatipuro															
3	Jatisrono	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12
4	Parangjoho			3	12	12	12	12	12	12	12	12	12	12	12	12
5	Songputri			12	12	12	12	12	12	12	12	12	12	11	12	12
6	Waduk Nawangan	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12
7	Wonogiri															
8	Eromoko															
9	Kedung uling															
10	Sidoharjo															
11	Slogohimo															
12	Wuryantoro															

No.	Station	199...										200...									
		0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9
1	Giriwoyo	12	12	12	12	12	12	12	12	12	12	12	12	12							
2	Jatipuro																				
3	Jatisrono	12	11	12	12	12	12	12	12	12	12	12	12	11	6	11	12	12	12	9	12
4	Parangjoho	10	12	12	12	12	12	12	7	12	12	12	12	12	12	12	12	12	9	12	12
5	Songputri	12	12	12	12	12	10	12	5	12	12	6	3	12	12	12	12	12	3	12	12
6	Waduk Nawangan	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12
7	Wonogiri																				
8	Eromoko	12	12	12	12	12	12	11					1	12	5	7	9	12	12	11	12
9	Kedung uling	12	12	12	12	12	12	12	12	12	11			11	6	6	12	1	12	12	12
10	Sidoharjo	12	12	12	12	12	12	12	12	12	12	12	12	10	2					1	
11	Slogohimo	12	12	12	12	12	12	12	12	11	2	12	11	9	2	1	10	12	12		11
12	Wuryantoro	12	12	12	12	12	12	12	12	12	12	12	11	10	4	7	4	12	12	12	12

No.	Station	201...										202...	
		0	1	2	3	4	5	6	7	8	9	0	1
1	Giriwoyo			12	12	12	12	12	12	12	12	12	12
2	Jatipuro					12	12	12	12	12	12	12	12
3	Jatisrono	12	12	12	12	12	12	12	12	12	12	12	12
4	Parangjoho	12	12	12	12	12	12	12	12	12	12	12	12
5	Songputri	12	12	12	12	12	12	12	12	12	12	12	12
6	Waduk Nawangan	12	12	12	12	12	12	12	12	12	12	12	12
7	Wonogiri					12	12	12	12	12	12	12	12
8	Eromoko	12	12	12	12	12	12	12	12	12	12		
9	Kedung uling	12	12	12	12	12	12	12	11	12	11		
10	Sidoharjo		10	12	12	12	12	12	12	12	12		
11	Slogohimo	10	12	12	12	12	12	12	12	12	12		
12	Wuryantoro	12	12	12	12	12	12	12	12	12	12		

Source: Source: own study

Table-3.3 shows that the length of data in every station is different and there are many blank data. Therefore, it is needed the GPM satellite rainfall data for completing the blank data. The hydrology analysis in water resources management needs complete and relatively long data.

Table-3.3. Correlation coefficient between satellite rainfall data and ground-rainfall data.

Grid	Giriwoyo	Jatipuro	Jatisrono	Parangjoho	Songputri	Waduk Nawangan	Wonogiri	Eromoko	Kedung uling	Sidoharjo	Slogohimo	Wuryantoro
Grid 1	0.451	0.810	0.827	0.827	0.807	0.806	0.825	0.867	0.774	0.820	0.764	0.848
Grid 2	0.433	0.819	0.832	0.830	0.800	0.802	0.828	0.868	0.766	0.825	0.767	0.848
Grid 3	0.424	0.812	0.828	0.818	0.787	0.786	0.821	0.860	0.756	0.817	0.767	0.835
Grid 4	0.445	0.828	0.821	0.830	0.805	0.820	0.832	0.870	0.768	0.827	0.750	0.851
Grid 5	0.429	0.812	0.823	0.816	0.780	0.785	0.820	0.857	0.764	0.817	0.767	0.837
Grid 6	0.422	0.814	0.822	0.810	0.777	0.781	0.820	0.851	0.753	0.815	0.764	0.830

Source: own study

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Table-3.4. RMSE value of satellite rainfall data to the ground-rainfall-data.

Grid	Giriwoyo	Jatipuro	Jatisrono	Parangjoho	Songputri	Waduk Nawangan	Wonogiri	Eromoko	Kedung uling	Sidoharjo	Slogohimo	Wuryantoro
Grid 1	198	97	100	109	113	112	104	101	120	104	123	97
Grid 2	201	93	99	110	115	114	103	102	123	103	122	99
Grid 3	201	95	99	112	116	117	105	102	123	105	122	101
Grid 4	196	89	100	106	110	107	103	99	120	102	126	95
Grid 5	204	97	102	115	121	120	105	106	124	105	122	102
Grid 6	205	97	103	117	121	121	105	108	126	106	123	104

Source: owns study

Based on the identification result of the ground-rainfall station, the number of grids that can be corrected is 6 grids in the ground-rainfall station and the Wonogiri watershed area. For validation of satellite rainfall data to the ground-rainfall data, is carried out by analyzing the correlation coefficient (r) (Table 3.3) and RMSE value (Table 3.4) for every ground-rainfall station to the satellite rainfall data. The result shows that the Giriwoyo rainfall station cannot be used for correcting the GPM satellite data. Then, there is carried out the analysis for obtaining the correction factor that will be used for correcting the GPM data.

3.2 Correction Factor of Satellite Rainfall Data to the Ground-Rainfall Station Data

To obtain the correction factor, there is used trial and error. The error value is hoped to decrease and the probability curve is close to the ground rainfall. Table 3.5 presents the correcting coefficient of satellite rainfall data to the ground-rainfall data.

Table-3.5. Correcting coefficient of satellite rainfall data to the ground-rainfall data.

Rainfall interval (mm)	Correction coefficient
0	
2	0.00
20	0.75
30	0.80
50	0.85
70	0.95
100	0.95
≥ 100	0.95

Source: own study

After being carried out the correction, it is seen that the error value of satellite data to the ground data before and after correction is getting smaller (Figure-3.1). Furthermore, it is also seen that the probability curve of GPM after being corrected is moving toward the probability curve of ground rainfall (Figure-3.2). It indicates that the GPM satellite data is valid enough.

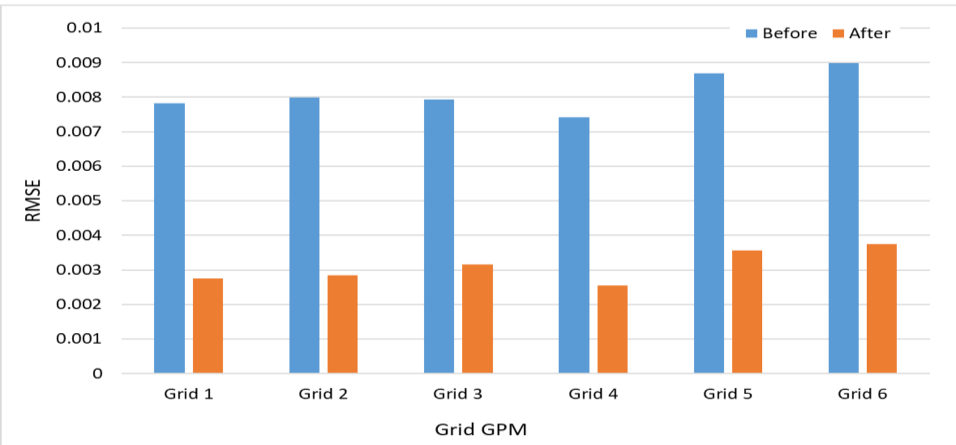

Figure-3.1. Error Comparison between daily rainfall that is produced before and after correction source: Own study

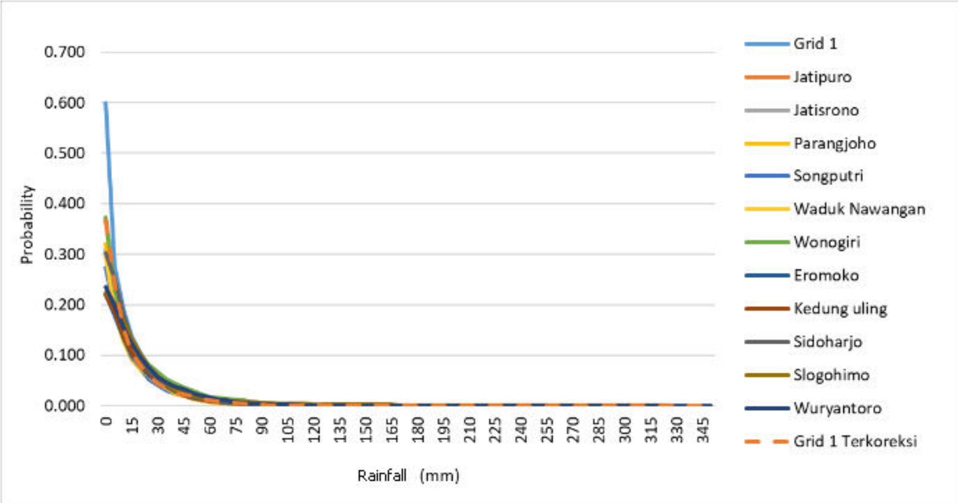

Figure-3.2. Probability curve for correcting the gpm grid 1 daily rainfall data source: Own study.

Besides the daily rainfall above, there is also carried out the correction to the maximum daily rainfall data. Figure-3.3 presents the error comparison between yearly maximum rainfall data before and after correction. However, Figure-3.4 shows the probability for correction of the GPM grid yearly maximum daily rainfall data. It is seen that the error value of satellite data to the ground data before and after correction on the yearly maximum daily rainfall before and after correction is getting small (Figure-3.3). Then, it is also seen that the GPM probability curve after correction is moving towards the probability curve of ground rainfall (Figure-3.4). It indicates that the GPM satellite is valid enough.

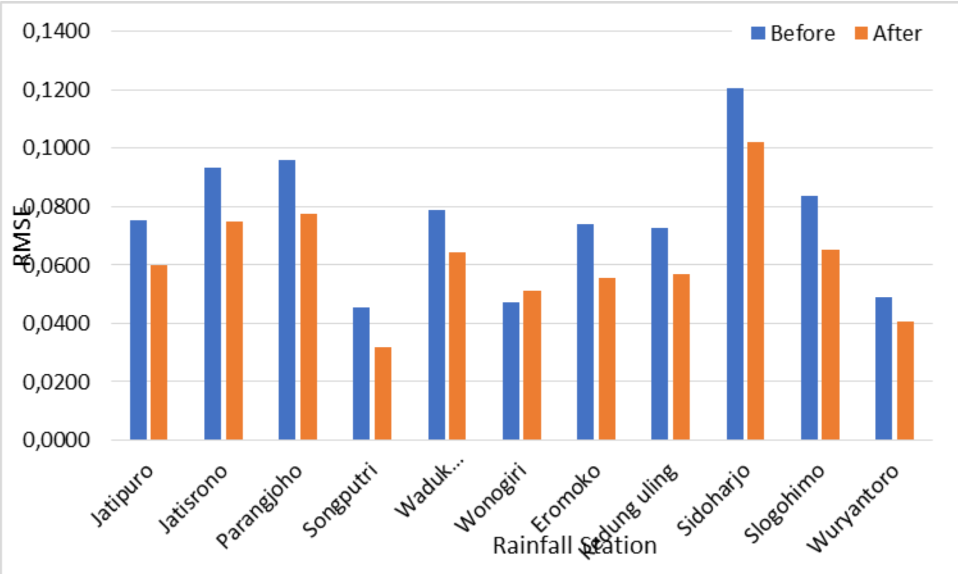

Figure-3.3. Error Comparison between yearly maximum daily rainfall before and after correction source: Own study

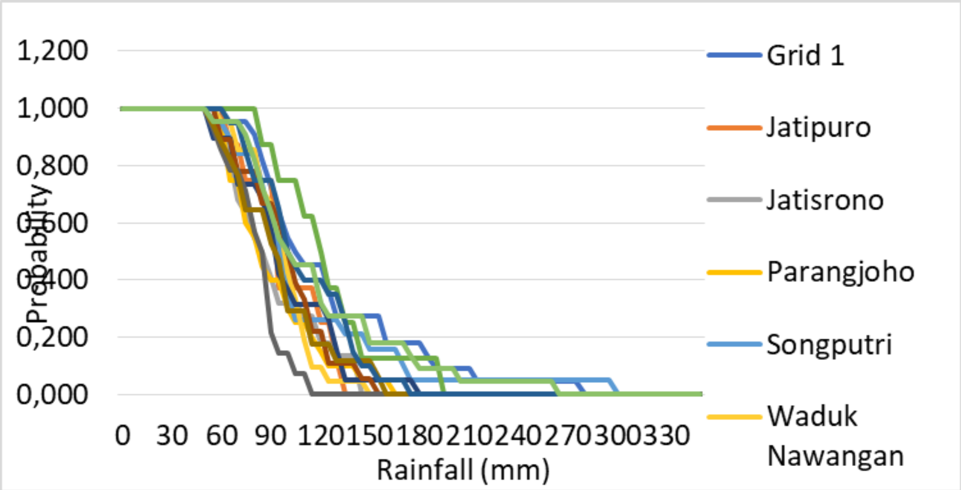

Figure-3.4. Probability curve for correction of GPM grid 1 yearly maximum daily rainfall data source: Own study.

In the final stage, it is needed to make certain the truth that GPM daily rainfall has been close to the characteristic of ground rainfall. So, there is made a monthly average curve on every GPM grid has been corrected as presented in Figure-3.5.

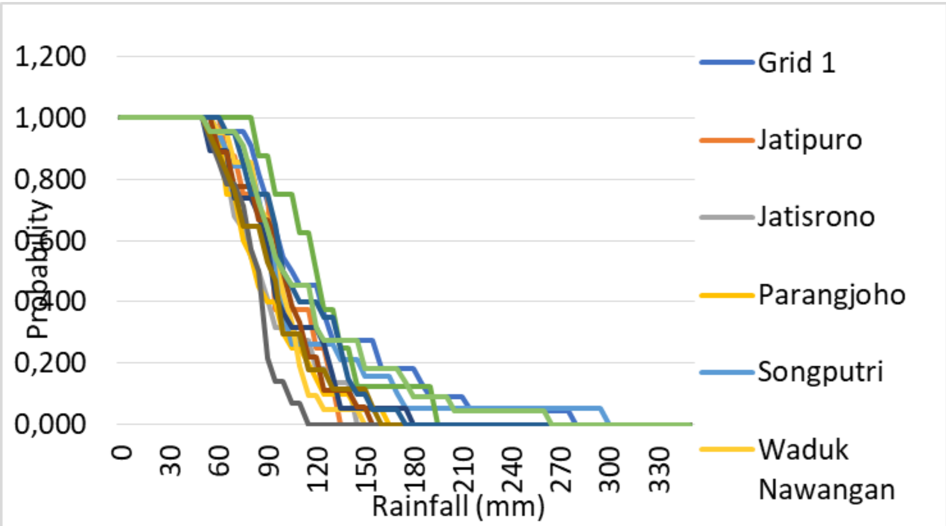

Figure-3.5. Average value of monthly GPM before and after correction source: Own study

Figure-3.5 shows that the monthly rainfall average curve of the GPM satellite that has been corrected is close to the ground rainfall station. It indicates that the GPM daily rainfall has been close to the characteristic of ground rainfall.

4. CONCLUSIONS

The satellite rainfall data can be used as the changer of ground-rainfall, but it has to be carried out the correcting first so the satellite rainfall data is closer to the characteristic of ground-rainfall-data. In the Wonogiri watershed, the correction result shows that the correction value of GPM satellite rainfall data to the ground-rainfall data experiences error decreasing and the moving of the satellite rainfall probability curve is towards the ground rainfall probability. It indicates that the characteristic of GPM satellite data has been close to the ground rainfall probability.

Based on the trial and error result, there is produced as follows: for the interval between 0 and 2 mm, the correction coefficient is 0; for the interval between 2 and 20 mm, the correction coefficient is 0.075; for the interval between 20 until 30 mm, the correction coefficient is 0.8; for the interval between 30 until 50 mm, the correction coefficient is 0.85; and for the interval more than 50 mm, the correction coefficient is 0.95

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