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FACTOR FOR CORRECTING THE RAINFALL OF CHIRPS SATELLITE DATA AGAINST OBSERVATION DATA ON THE CILIWUNG WATERSHED (CASE STUDY OF KEMAYORAN METEOROLOGI STATION)

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ABSTRACT

Rainfall intensity conditions and seasonal patterns are influenced by the hydrological and environmental cycles in a river area. In analyzing the carrying capacity of water resources, accurate rainfall data is needed at each observation station. However, the availability of rainfall data in an area is often an obstacle in research due to the uneven distribution of rain posts. To support this data, satellite image data is used.
Aims: The objective of this study was to analyze the accuracy of CHIRPS satellite rainfall data from observation stations in the Ciliwung watershed, especially in the DKI Jakarta Province area, over the last 30 years (1993–2022).
Methodology and results: Statistical analysis such as multiple linear regression with the stepwise method is used to analyze CHIRPS rainfall against observed rainfall data according to the location of the rain station. The validation results in this study show that the average results of the two observation stations have a value of R2 = 0.91 and NSE = 0.9068.
Conclusion, significance and impact study: CHIRPS data can be categorized as very good if used as an alternative to limited observational rainfall data, which can then be used in analyzing water availability in the Ciliwung watershed (Jakarta).

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1. INTRODUCTION

Climate is one factor affecting many sectors and lives. Climate is important to study because the conditions of climatic elements on the face of the earth vary greatly depending on the location, latitude, and longitude of the region and the consequences of the uneven surface of the earth [1]. Rainfall is one of the climate components. which is very important. Intensity change rainfall over a long period of time (10–30 year) may influence the determination water availability in an area, and also influence on life activities human [2]. The world's climate is experiencing changes; these changes result in increasing temperatures and sea levels. Future climate change may cause more intensive hydrological cycle processes [3], including increased variations in rainfall [4] and changes in evaporation rates [5]. Increasing global temperatures will increase the rate of evapotranspiration and speed up the water cycle [6]. As a result, an uneven distribution of moisture in the atmosphere will occur, causing heavy rainfall in one region and extreme drought in other regions [7]. Changes in rainfall patterns in Indonesia will lead to a delay in the start of the rainy season and a tendency towards an earlier start at the at the end of the rainy season. This means that the rainy season occurs in a shorter time but has a higher rainfall intensity[8].

Rainfall is an important climate element for human activities. Rainfall has characteristics that vary according to space and time, so the availability of adequate data is important for understanding the characteristics of rainfall in a region [9]. However, the problem is that in some areas, tools for measuring rainfall data are sometimes not available, so to overcome the lack of availability of rain data in recent years, a number of studies have been carried out on the use of rain data based on remote sensing or satellite technology [10]. Many studies have been conducted regarding the use of satellite rainfall data, including [11], [12], using GPM to measure extreme rainfall events in China and North China, [13], using GPM, and PERSIANN to find out estimates. Progo watershed flood discharge, [14] uses GPM and PERSIANN to evaluate the results of satellite rainfall predictions for rainfall that

Rainfall variability is spatially based. on the location or place where the rain falls. In mountainous areas, topography, and elevation is a factor that influences bulk rain and should be considered for prediction and mapping. For the most part, areas have been found that increase rainfall with elevation has a linear relationship. Apart from the elevation factor, other additional factors that Influencing rainfall are also necessary considered. This is due to the nature of rainfall in mountainous orographic areas, where the rainfall pattern is complex and incomprehensible with good results [15]. Mapping the spatial variability of rainfall can be carried out using the method of spatial interpolation. The resolution of topography has the significant effect on the flood simulation results [16].

Rainfall is the amount of water that falls to the ground during a certain period, which is measured in units of height (mm) above the horizontal surface if there is no evaporation, runoff,

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or infiltration, the type of vegetation cover can influence conditions, and rainfall can cause water loss to occur [17] and can affect the flow velocity [18,19].

The research has been carried out regarding CHIRPS data validation. Research conducted shows that the accuracy of CHIRPS rainfall data in West Kalimantan is classified as very good[20], the correlation between CHIRPS data and AWS data in South Lampung is in the weak category[21] and the CHIRPS data correlation is relatively low due to topographic factors, the distance of rain stations to nearby mountains or oceans, and local wind circulation [22].

This research aims to analyze historical changes in rainfall in the Ciliwung watershed, especially in DKI Jakarta Province, by validating CHIRPS satellite data against observational data based on previous research, namely changes in rainfall in the Ciliwung watershed per year from 1993 to 2042, namely 1.29 % [23]. With the hope of gaining an in-depth understanding of changes in rainfall in the Ciliwung watershed (Jakarta) as well as the accuracy between satellite data and observation data.

2. RESEARCH METHODOLOGY

2.1 Case Study: Ciliwung Watershed in Jakarta

The study area is Ciliwung Watershed in Jakarta, Indonesia. The location of the Ciliwung Watershed in Jakarta is presented in Figure 1. Jakarta is a densely populated area and has experienced significant land cover development. The Ciliwung River is a river that flows in the DKI Jakarta area, Bogor Regency, Bogor City, Depok City, Bekasi, and surrounding areas. Ciliwung is recorded as having a main stream length of 120 kilometers, while its catchment area (river flow) is 387 km^2. The Ciliwung River Watershed has very strategic value because it crosses two provinces, namely West Java and DKI Jakarta, but due to the rapid development activities in these two provinces, it has caused significant land use changes and management. The research was conducted in the Ciliwung River Watershed, especially the DKI Jakarta area, with an area of 13,995 ha. This research covers the administrative areas of North Jakarta, East Jakarta, West Jakarta, Central Jakarta, and South Jakarta in the Ciliwung watershed area.

Figure 1. Ciliwung Watershed in Jakarta

2.2 Rainfall datasets

The observed rainfall data used comes from a rainfall observation station, namely the Kemayoran Meteorological Station. The coordinates of Kemayoran Station are 106º 50' 24'' East Longitude and 6º 9' 20'' South Latitude. The data used in the research includes observational rainfall data from BMKG as well as baseline rainfall data from CHIRPS (https://www.chc.ucsb.edu/data/chirps) over the last 30 years, from 1993 to 2022.

Table 1. Datasets

Data	Source
Rainfall baseline (CHIRPS)	https://www.chc.ucsb.edu/data/chirps
Climate Projections (MICROC5)	https://chelsa-climate.org/future/
Rainfall observation	BMKG and BBWS Ciliwung Cisadane

2.3 Climate Hazard Group Infrared Precipitation with Stations (CHIRPS)

CHIRPS (Climate Hazard Group Infrared Precipitation with Stations Data) is rainfall data that comes from combining observational data with satellite data, which has a spatial resolution of around 0.05° (per pixel) or around 5kM x 5kM, to estimate sustainable changes in rainfall in a region. as well as for analysis of rainfall trends. CHIRPS data availability began in 1981 and continues today with daily, monthly, and decade rainfall categories. There are various factors that influence the accuracy of satellite rainfall data, such as environmental conditions, local climate, season, and topography. CHIRPS data requires a further analysis process to validate the data against observed rainfall data.

2.4 Bias Correction

The statistical method used in bias correction as a re-analysis of observational rainfall data is multiple linear regression analysis with a stepwise method. The first step in correcting this method is to calculate the estimated rainfall according to the coordinates of the observation rainfall station, as in the following equation:

$$Y(ik) = a + b1X1(ik) + b2X2(ik) + b3X3(ik) + b4X4(ik) \tag{2-1}$$

where:

$Y(ik)$ = Rainfall observation day -i, grid -k

a = constant day -i, grid -k

bi = regression coefficient day -i

$X1(ik)$ = Rainfall day -i, grid -k

$X2(ik)$ = Grid longitude -k

$X3(ik)$ = Grid latitude -k

The next step is to calculate the error value between the observed rainfall and the estimated rainfall.

$$E(ik) = Y(ik) - Y'(ik) \tag{2-2}$$

Then interpolate the error value according to the size and number of grids. Next, calculate the estimated rainfall and error for all grids using equation (2-2). And as the final step, calculate the corrected rainfall for the entire grid being analyzed by adding up the estimated rainfall with the error value. Note that the corrected rain value, which is negative, is changed to zero.

The static performance test on CHIRPS Re-Analysis rainfall uses two static parameters, namely:

- **Coefficient of Determination (R^2)**
  R^2 shows the level of linear relationship between observation data and model data. The R^2 value ranges from 0 to 1. If R^2 is 1, the result shows perfect agreement between the model data and the observed data.

$$R^2 = \left[\frac{\sum_{i=1}^{N}\left[(Yi^{obs}-\overline{Yi}^{obs})(Yi^{sim}-\overline{Yi}^{sim})\right.}{\sqrt{\sum_{i=1}^{N}\left[(Yi^{obs}-\overline{Yi}^{obs}\right)^2\sum_{i=1}^{N}\left[(Yi^{sim}-\overline{Yi}^{sim}\right)^2}}\right]^2 \tag{2-3}$$

Where $\bar{Y}iobs$ is the average of observation data and $\bar{Y}isim$ is the average of simulation data.

- **NSE (Nash-Sutcliffe Efficiency)**
  NSE (Nash-Sutcliffe Efficiency) represents how well the simulated value compares to the observed value. The NSE value ranges from ∞ to 1, and the closer to 1, the better the model performance is said to be. NSE can be calculated using the equation (Gupta et al. 2009):

$$NSE = \left[1 - \left(\frac{\sum_{i=1}^{n}(Yi^{obs} - Yi^{sim})^2}{\sum_{i=1}^{n}(Yi^{obs} - \bar{Y}i^{obs})^2}\right)\right] \quad (2\text{-}4)$$

Data Penelitian

Data yang digunakan dalam penelitian meliputi data curah hujan observasi dari BMKG serta data curah hujan baseline dari CHIRPS (https://www.chc.ucsb.edu/data/chirps) dalam kurun waktu 30 tahun terakhir dari tahun 1993 hingga 2022.

Table 2. Parameter Assessment [,,,]

Parameter	NSE	R^2
Very Good	0.75≤NSE≤1	$0.75 \le R^2 \le 1$
Good	0.65≤NSE≤0.75	$0.65 \le R^2 \le 0.75$
Satisfactory	0.5≤NSE≤0.65	$0.5 \le R^2 \le 0.65$
Unsatisfactory	NSE≤0.5	$R^2 \le 0.5$

3. RESULTS AND DISCUSSION

Constraints in the availability of rainfall data in a region often become obstacles in research, mainly due to the uneven distribution of rain posts and a lack of complete observation data. In an effort to overcome this problem, this research utilizes global data sources, such as CHIRPS (Climate Hazard Group InfraRed Precipitation with Station Data). The CHIRPS rainfall data used in this research first carried out a performance test by comparing data obtained at rain posts in the Ciliwung watershed area of DKI Jakarta, namely the BMKG Meteorological Station. Figure 2 shows the CHIRPS monthly maximum rainfall pattern and maximum observed rainfall, as well as the fitting curves at rain station. Visually, the CHIRPS data rainfall pattern has rainfall values that are unable to follow observed rainfall.

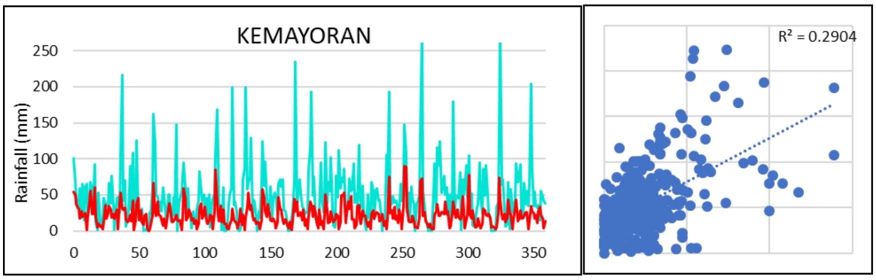

Figure 2. Maximum Rainfall Pattern and Fitting Curve between Observed Rainfall and CHIRPS.

Visually, CHIRPS rainfall values are unable to follow observed rainfall. This is supported by the static test results in Table 3, showing that the performance of CHIRPS data is very low, where R2 and NSE are in the not good enough category, or it can be said that CHIRPS data underestimates observational data. So further analysis of CHIRPS rainfall values is needed by conducting trial and error.

Table 3. CHIRPS Rainfall Static Test Results

	R^2	NSE
Kemayoran	0.2904	-0.1794

Based on the R^2 and NSE statistical tests, it shows that the performance of CHIRPS data compared to observation data is very low, where the R^2 value is below 0.5 and the NSE value is below 0.5. This shows that CHIRPS data underestimates observation data at selected rain stations. So further analysis of CHIRPS rainfall values is needed by conducting trial and error.

After trial and error correction of bias 5 (five) times, the CHIRPS data was tested for performance at the observation station. The results show that the 5th trial has a good value. The recap results in Table 4 show that the performance test has improved data quality compared to before analysis, namely that the R^2 value shows a value above 0.5, and likewise, with the NSE test, the corrected CHIRPS data for stations is close to 1, which indicates a more accurate model.

Table 4. CHIRPS Rainfall Static Test Results (Trial)

	R^2	NSE
Kemayoran	0.9279	0.9111

Figure 3 shows visually that the CHIRPS data after analysis shows good ability to follow patterns and approach the observed data values at both rain stations. So it has great potential to be used to predict changes in rainfall in the future.

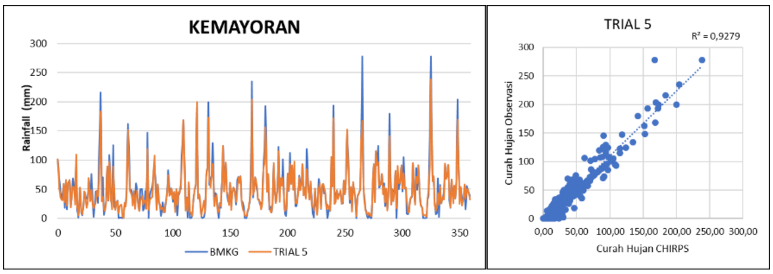

Figure 3. Maximum Rainfall Pattern and Fitting Curve between Observed Rainfall and CHIRPS.

Then the CHIRPS data was compared by making a daily maximum rainfall curve from 1993 to

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2022, both before and after correction. This aims to assess how well MIROC5 accurately estimates actual rainfall and provides an important basis for further use of this data in future climate change-related research. Analysis of baseline rainfall characteristics in the Ciliwung watershed, especially the Jakarta area, provides a significant picture of rainfall variability at monitoring stations.

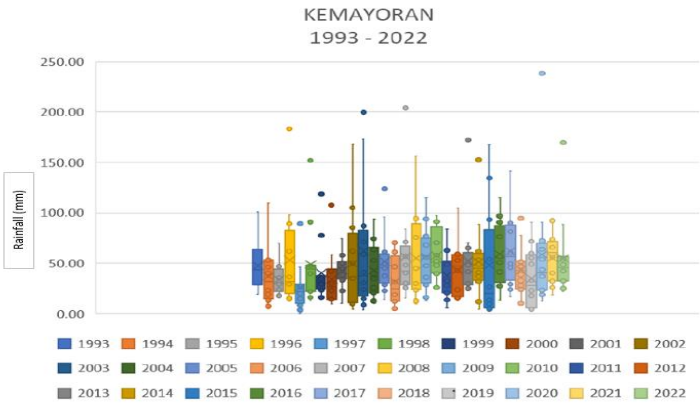

Figure 4 Box plot of maximum rainfall for the period 1993–2022.

Figure 4 displays a box plot of baseline rainfall at Kemayoran Station in the Ciliwung watershed, providing additional insight into understanding the climate characteristics of the Ciliwung watershed. The maximum average annual rainfall for 30 years (1993–2022) is 1021.87 mm/year; the minimum average is 227.47 mm/year. while the average annual rainfall at Kemayoran Station is 487.32 mm/year.

4. CONCLUSION

CHIRPS data estimates for daily rainfall for the period 1993–2022 at the BMKG meteorological station tend to have very good CHIRPS data accuracy values (average percent bias = 9.27%, NSE = 0.9111). This shows that CHIRPS data is able to estimate events of rain in the Ciliwung watershed area, especially in the Jakarta area. CHIRPS estimates are higher in light rainfall (< 30 mm) and lower in heavy to very heavy rainfall. Utilization of CHIRPS data can be done by first increasing the accuracy of CHIRPS data by applying a correction factor to two groups of daily rainfall categories, namely the light category and the medium to very heavy category in the research area. This is supported by the land cover conditions in the research area. CHIRPS data can be categorized as very good if used as an alternative to limited observational rainfall data, which can then be used in analyzing water availability in the Ciliwung watershed (Jakarta).

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or infiltration, the type of vegetation cover can influence conditions, and rainfall can cause water loss to occur [17] and can affect the flow velocity [18,19].

The research has been carried out regarding CHIRPS data validation. Research conducted shows that the accuracy of CHIRPS rainfall data in West Kalimantan is classified as very good[20], the correlation between CHIRPS data and AWS data in South Lampung is in the weak category[21] and the CHIRPS data correlation is relatively low due to topographic factors, the distance of rain stations to nearby mountains or oceans, and local wind circulation [22].

This research aims to analyze historical changes in rainfall in the Ciliwung watershed, especially in DKI Jakarta Province, by validating CHIRPS satellite data against observational data based on previous research, namely changes in rainfall in the Ciliwung watershed per year from 1993 to 2042, namely 1.29 % [23]. With the hope of gaining an in-depth understanding of changes in rainfall in the Ciliwung watershed (Jakarta) as well as the accuracy between satellite data and observation data.

2. RESEARCH METHODOLOGY

2.1 Case Study: Ciliwung Watershed in Jakarta

The study area is Ciliwung Watershed in Jakarta, Indonesia. The location of the Ciliwung Watershed in Jakarta is presented in Figure 1. Jakarta is a densely populated area and has experienced significant land cover development. The Ciliwung River is a river that flows in the DKI Jakarta area, Bogor Regency, Bogor City, Depok City, Bekasi, and surrounding areas. Ciliwung is recorded as having a main stream length of 120 kilometers, while its catchment area (river flow) is 387 km^2. The Ciliwung River Watershed has very strategic value because it crosses two provinces, namely West Java and DKI Jakarta, but due to the rapid development activities in these two provinces, it has caused significant land use changes and management. The research was conducted in the Ciliwung River Watershed, especially the DKI Jakarta area, with an area of 13,995 ha. This research covers the administrative areas of North Jakarta, East Jakarta, West Jakarta, Central Jakarta, and South Jakarta in the Ciliwung watershed area.

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Figure 1. Ciliwung Watershed in Jakarta

2.2 Rainfall datasets

The observed rainfall data used comes from a rainfall observation station, namely the Kemayoran Meteorological Station. The coordinates of Kemayoran Station are 106º 50' 24'' East Longitude and 6º 9' 20'' South Latitude. The data used in the research includes observational rainfall data from BMKG as well as baseline rainfall data from CHIRPS (https://www.chc.ucsb.edu/data/chirps) over the last 30 years, from 1993 to 2022.

Table 1. Datasets

Data	Source
Rainfall baseline (CHIRPS)	https://www.chc.ucsb.edu/data/chirps
Climate Projections (MICROC5)	https://chelsa-climate.org/future/
Rainfall observation	BMKG and BBWS Ciliwung Cisadane

2.3 Climate Hazard Group Infrared Precipitation with Stations (CHIRPS)

CHIRPS (Climate Hazard Group Infrared Precipitation with Stations Data) is rainfall data that comes from combining observational data with satellite data, which has a spatial resolution of around 0.05° (per pixel) or around 5kM x 5kM, to estimate sustainable changes in rainfall in a region. as well as for analysis of rainfall trends. CHIRPS data availability began in 1981 and continues today with daily, monthly, and decade rainfall categories. There are various factors that influence the accuracy of satellite rainfall data, such as environmental conditions, local climate, season, and topography. CHIRPS data requires a further analysis process to validate the

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data against observed rainfall data.

2.4 Bias Correction

The statistical method used in bias correction as a re-analysis of observational rainfall data is multiple linear regression analysis with a stepwise method. The first step in correcting this method is to calculate the estimated rainfall according to the coordinates of the observation rainfall station, as in the following equation:

$$Y(ik) = a + b1X1(ik) + b2X2(ik) + b3X3(ik) + b4X4(ik) \quad (2\text{-}1)$$

where:

$Y(ik)$ = Rainfall observation day -i, grid -k

a = constant day -i, grid -k

bi = regression coefficient day -i

$X1(ik)$ = Rainfall day -i, grid -k

$X2(ik)$ = Grid longitude -k

$X3(ik)$ = Grid latitude -k

The next step is to calculate the error value between the observed rainfall and the estimated rainfall.

$$E(ik) = Y(ik) - Y'(ik) \quad (2\text{-}2)$$

Then interpolate the error value according to the size and number of grids. Next, calculate the estimated rainfall and error for all grids using equation (2-2). And as the final step, calculate the corrected rainfall for the entire grid being analyzed by adding up the estimated rainfall with the error value. Note that the corrected rain value, which is negative, is changed to zero.

The static performance test on CHIRPS Re-Analysis rainfall uses two static parameters, namely:

- **Coefficient of Determination (R^2)**
  R^2 shows the level of linear relationship between observation data and model data. The R^2 value ranges from 0 to 1. If R^2 is 1, the result shows perfect agreement between the model data and the observed data.

$$R^2 = \left[\frac{\sum_{i=1}^{N}\left[(Yi^{obs} - \overline{Yi}^{obs})(Yi^{sim} - \overline{Yi}^{sim})\right.}{\sqrt{\sum_{i=1}^{N}\left[(Yi^{obs} - \overline{Yi}^{obs}\right)^2 \sum_{i=1}^{N}\left[(Yi^{sim} - \overline{Yi}^{sim}\right)^2}}\right]^2 \quad (2\text{-}3)$$

Where $\bar{Y}iobs$ is the average of observation data and $\bar{Y}isim$ is the average of simulation data.

- **NSE (Nash-Sutcliffe Efficiency)**

  NSE (Nash-Sutcliffe Efficiency) represents how well the simulated value compares to the observed value. The NSE value ranges from ∞ to 1, and the closer to 1, the better the model performance is said to be. NSE can be calculated using the equation (Gupta et al. 2009):

$$NSE = \left[1 - \left(\frac{\sum_{i=1}^{n}\left(Yi^{obs} - Yi^{sim}\right)^2}{\sum_{i=1}^{n}\left(Yi^{obs} - \bar{Y}i^{obs}\right)^2}\right)\right] \quad (2\text{-}4)$$

Data Penelitian

Data yang digunakan dalam penelitian meliputi data curah hujan observasi dari BMKG serta data curah hujan baseline dari CHIRPS (https://www.chc.ucsb.edu/data/chirps) dalam kurun waktu 30 tahun terakhir dari tahun 1993 hingga 2022.

Table 2. Parameter Assessment [,,,]

Parameter	NSE	R^2
Very Good	0.75≤NSE≤1	$0.75 \le R^2 \le 1$
Good	0.65≤NSE≤0.75	$0.65 \le R^2 \le 0.75$
Satisfactory	0.5≤NSE≤0.65	$0.5 \le R^2 \le 0.65$
Unsatisfactory	NSE≤0.5	$R^2 \le 0.5$

3. RESULTS AND DISCUSSION

Constraints in the availability of rainfall data in a region often become obstacles in research, mainly due to the uneven distribution of rain posts and a lack of complete observation data. In an effort to overcome this problem, this research utilizes global data sources, such as CHIRPS (Climate Hazard Group InfraRed Precipitation with Station Data). The CHIRPS rainfall data used in this research first carried out a performance test by comparing data obtained at rain posts in the Ciliwung watershed area of DKI Jakarta, namely the BMKG Meteorological Station. Figure 2 shows the CHIRPS monthly maximum rainfall pattern and maximum observed rainfall, as well as the fitting curves at rain station. Visually, the CHIRPS data rainfall pattern has rainfall values that are unable to follow observed rainfall.

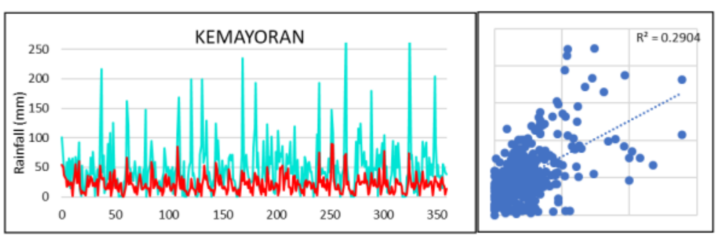

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Figure 2. Maximum Rainfall Pattern and Fitting Curve between Observed Rainfall and CHIRPS.

Visually, CHIRPS rainfall values are unable to follow observed rainfall. This is supported by the static test results in Table 3, showing that the performance of CHIRPS data is very low, where R2 and NSE are in the not good enough category, or it can be said that CHIRPS data underestimates observational data. So further analysis of CHIRPS rainfall values is needed by conducting trial and error.

Table 3. CHIRPS Rainfall Static Test Results

	R^2	NSE
Kemayoran	0.2904	-0.1794

Based on the R^2 and NSE statistical tests, it shows that the performance of CHIRPS data compared to observation data is very low, where the R^2 value is below 0.5 and the NSE value is below 0.5. This shows that CHIRPS data underestimates observation data at selected rain stations. So further analysis of CHIRPS rainfall values is needed by conducting trial and error.

After trial and error correction of bias 5 (five) times, the CHIRPS data was tested for performance at the observation station. The results show that the 5th trial has a good value. The recap results in Table 4 show that the performance test has improved data quality compared to before analysis, namely that the R^2 value shows a value above 0.5, and likewise, with the NSE test, the corrected CHIRPS data for stations is close to 1, which indicates a more accurate model.

Table 4. CHIRPS Rainfall Static Test Results (Trial)

	R^2	NSE
Kemayoran	0.9279	0.9111

Figure 3 shows visually that the CHIRPS data after analysis shows good ability to follow patterns and approach the observed data values at both rain stations. So it has great potential to be used to predict changes in rainfall in the future.

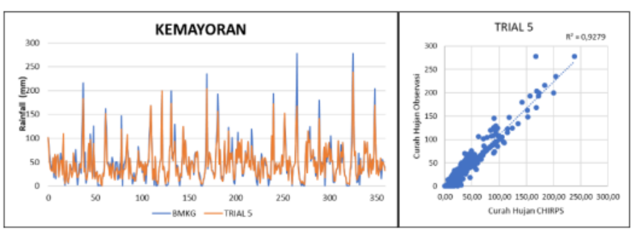

Figure 3. Maximum Rainfall Pattern and Fitting Curve between Observed Rainfall and CHIRPS.

Then the CHIRPS data was compared by making a daily maximum rainfall curve from 1993 to

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2022, both before and after correction. This aims to assess how well MIROC5 accurately estimates actual rainfall and provides an important basis for further use of this data in future climate change-related research. Analysis of baseline rainfall characteristics in the Ciliwung watershed, especially the Jakarta area, provides a significant picture of rainfall variability at monitoring stations.

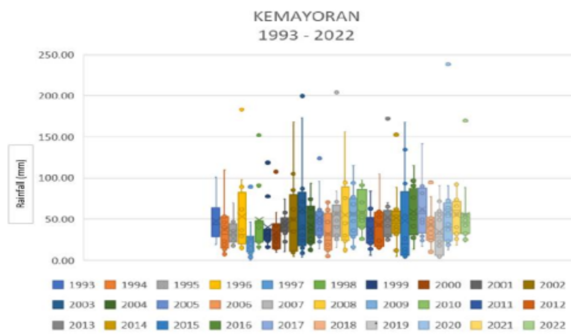

Figure 4 Box plot of maximum rainfall for the period 1993–2022.

Figure 4 displays a box plot of baseline rainfall at Kemayoran Station in the Ciliwung watershed, providing additional insight into understanding the climate characteristics of the Ciliwung watershed. The maximum average annual rainfall for 30 years (1993–2022) is 1021.87 mm/year; the minimum average is 227.47 mm/year. while the average annual rainfall at Kemayoran Station is 487.32 mm/year.

4. CONCLUSION

CHIRPS data estimates for daily rainfall for the period 1993–2022 at the BMKG meteorological station tend to have very good CHIRPS data accuracy values (average percent bias = 9.27%, NSE = 0.9111). This shows that CHIRPS data is able to estimate events of rain in the Ciliwung watershed area, especially in the Jakarta area. CHIRPS estimates are higher in light rainfall (< 30 mm) and lower in heavy to very heavy rainfall. Utilization of CHIRPS data can be done by first increasing the accuracy of CHIRPS data by applying a correction factor to two groups of daily rainfall categories, namely the light category and the medium to very heavy category in the research area. This is supported by the land cover conditions in the research area. CHIRPS data can be categorized as very good if used as an alternative to limited observational rainfall data, which can then be used in analyzing water availability in the Ciliwung watershed (Jakarta).

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