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Assessment of NCEP-CFSR Precipitation Products in Meteorological Drought Monitoring for The Citarum Basin

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Abstract. The availability of various satellite rainfall data potentially be used in monitoring meteorological droughts. In this study, products from the NCEP-CFSR (National Centers for Environmental Prediction Climate Forecast System Reanalysis) were analyzed to estimate meteorological drought in the Citarum Watershed, West Java, Indonesia. Assessment was carried out using NCEP-CFSR data from 1988 to 2013 and was applied to meteorological droughts using the SPI (Standardized Precipitation Index) index. The results showed that rainfall products from the NCEP-CFSR were not recommended to use in meteorological droughts because of the low correlation values of around 33%, MAE (Mean Absolute Error) 17.88 and RMSE (Root Mean Square Error) 22.73. This research can be utilized as a reference to assess rainfall products from better satellite data in the future to monitor meteorological droughts.

1. Introduction

Drought is a natural disaster that occurs in almost all climate zones and causes losses to agriculture, economy and environment. Theoretically, drought is defined as a period marked by a state of rainfall deficit [1]. In tropical regions drought usually occurs in the dry season and will last for several months [2]. To anticipate drought, a comprehensive monitoring system is needed in better disaster mitigation. However, this monitoring faces several challenges such as a lack of long-term field data.

Knowledge of the state of rainfall and spatial distribution in the past is important for monitoring drought [3]. Direct observation data in the field recorded over a long period of time is often not available and even a lot of data is lost. Over the past several decades, with the progress of remote sensing technology many satellite-based rainfall estimation products with high spatial resolution at different time periods have been widely used to overcome the limitations of spatial variation and are considered as an alternative rainfall information [4]. Satellite-based products that are available for global and regional scale include, TRMM (Tropical Rainfall Measurement Mission), TMPA (Multi-satellite Precipitation Analysis) [5] and NCEP-CFSR (National Centers for Environmental Prediction Climate Reanalysis Forecast System) [6].

Recently, there are many studies have compared satellite products with direct measurements. For example, monthly TMPA products for monitoring drought in Africa [7] and TRMM products in China [8]. These studies have shown that the performance of satellite products in monitoring drought varies across regions. To assess the quality of data generated from the NCEP-CFSR will be applied in the Citarum watershed. The aim of this study was to assess the performance of NCEP-CFSR products in monitoring meteorological drought in the Citarum watershed of West Java, Indonesia based on SPI



value (Standardized Precipitation Index) [9]. This research serves as a reference for local authorities and researchers in choosing good satellite products for monitoring drought conditions in the region.

2. Methods

2.1. Study Area

Citarum watershed is located in the province of West Java, Indonesia with a catchment area of around 7400 km² [10]. The highest point in the Citarum watershed is 1700 m above sea level (ASL) and the lowest is 0 m ASL. As the largest water catchment area in West Java, Citarum plays an important role in water supply for many districts in the province. There are three dams that have been built for various purposes, such as agriculture, hydroelectric power plant, fisheries and domestic, namely Saguling in the upstream, Cirata in the middle and Jatiluhur in the downstream, and have nine hydrological observation stations. Currently the Citarum watershed supplies around 7650 million cubic meters of water per year which is used for irrigation 78%, 14% industry and electricity generation and 8% domestic consumption [11].

River flows in the Citarum watershed mainly come from rain during the rainy season in the Australasian monsoon period from November to April [12]. Annual rainfall of around 2580 mm is 1840 mm of rainy season (November-April) and 740 mm in the dry season (May-October) [11].

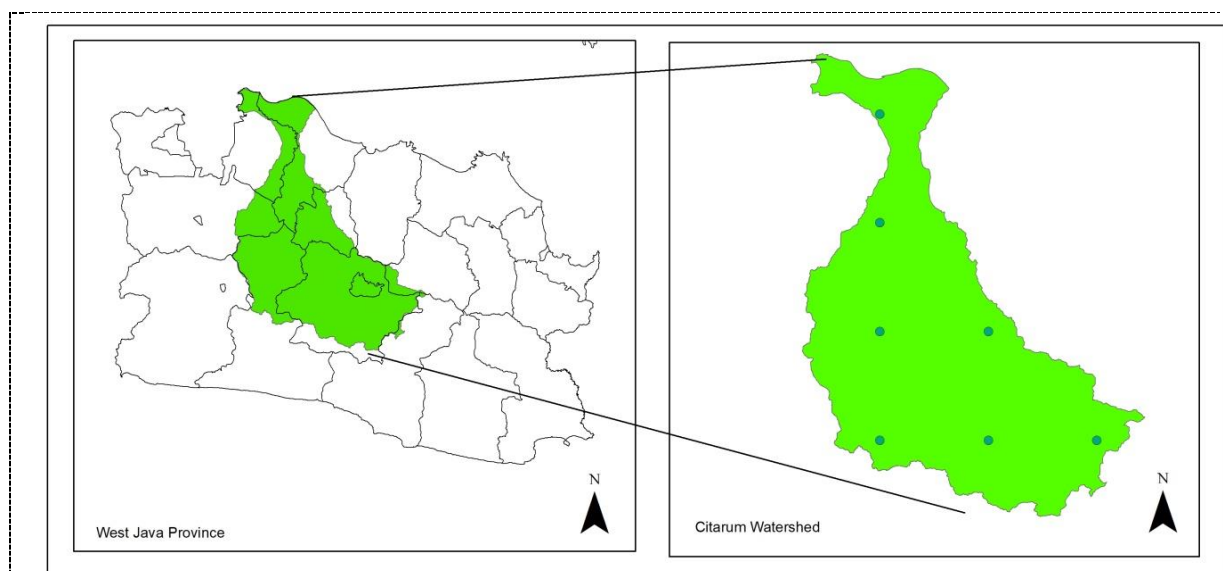


Figure 1. Study Area Citarum Watershed.

Citarum watershed is very vulnerable to climate change and has experienced considerable water deficits, especially in the lowlands, namely Karawang, Bekasi and Purwakarta [11,12]. The region is an agricultural center that will certainly need more water for irrigation. Therefore, research on drought monitoring in the Citarum watershed is very important to conduct as one of the mitigation of drought due to climate change, as well as the use of satellite-based rainfall data.

2.2. Data and Analysis

2.2.1. Data

Rainfall is an important element in meteorological analysis such as drought [13]. Rainfall data is obtained from two sources, namely the PSDA (*Water Resources Management Office*) West Java Province and NCEP-CFSR (*National Centers for Environmental Prediction Climate Forecast System Reanalysis*) which can be accessed on the website <https://globalweather.tamu.edu/data>. NCEP-CFSR data can be utilized for hydrological researching [14] and hydrological modeling [15]. NCEP-CFSR rainfall data used to analysis has a period of 1988-2013, with a total of 7 rain stations.

2.2.2. Data calibration

Each rainfall data was calibrated by MAE (*Mean Absolute Error*) and RMSE (*Root Mean Square Error*). MAE is often used to evaluate predictions of accuracy of time series data and models [16]. RMSE is utilized as a statistical tool to measure model performance in climate and meteorological research [17]. In this case the RMSE da MAE was used in calibrating data on rainfall satellite and rainfall stations. MAE and RMSE equations can be conducted as follows:

$$MAE = \frac{1}{n} \sum_{j=1}^n |\gamma_j - \hat{\gamma}_j| \quad (1)$$

$$RMSE = \sqrt{\frac{1}{n} \sum_{j=1}^n (\gamma_j - \hat{\gamma}_j)^2} \quad (2)$$

2.2.3. SPI (Standardized Precipitation Index) analysis

Drought meteorological research was carried out by the SPI (*Standardized Precipitation Index*) approach. SPI was developed for drought monitoring by utilizing gamma distribution and rainfall data [9,18].

SPI method serves to measure rainfall deficits in various periods based on normal conditions [19]. SPI package makes it easy for researchers to calculate directly, by entering rain data in each rainfall post. Data can be inputted to package. Packages can be accessed through <http://drought.unl.edu/MonitoringTools/DownloadableSPIProgram.aspx>. SPI value calculated is a period of 1 month, 3 months, 6 months, 9 months and 12 months, each period is available in a package [20] and can be measured easily. Calculation of the SPI value is based on the amount of gamma distribution which is defined as the function of frequency or chance of occurrence [9] as follows:

$$F(x) = \int_0^x f(x) dx = \frac{1}{\Gamma(\alpha)\beta^\alpha} \int_0^x x^{\alpha-1} e^{-\frac{x}{\beta}} dx \quad (3)$$

SPI value is a transformation from a gamma distribution to a normal standard with an average of 0 (zero) and a difference of 1, resulting in a classification:

Table 1. Classification of Standardized Precipitation Index

SPI Range	Category
+2 to more	Extremely wet
1.5 to 1.99	Very wet
1.0 to 1.49	Moderately wet
-0.99 to 0.99	Near Normal
-1.0 to -1.49	Moderately dry
-1.5 to -1.99	Severely dry
-2 to less	Extremely dry

Sources: [9,18]

2.2.4. IDW (inverse distance weighted)

The results of each SPI drought index value will be mapped using IDW (*inverse distance weighted*) in GIS (*Geographic Information System*) software. IDW interpolation formula is analyzed mathematically

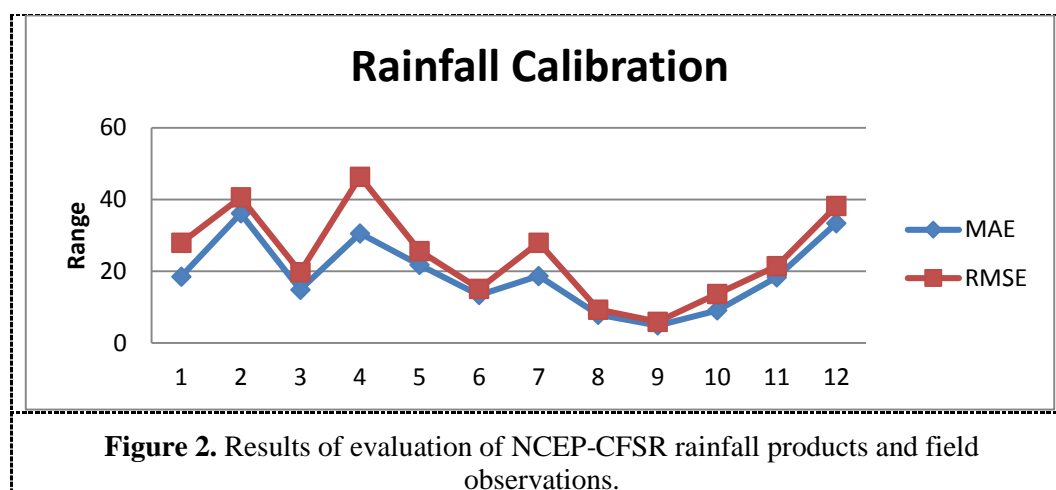
and is utilized in a schema-langrang context to describe a broad class of physical phenomena [21]. Interpolation model needs to be calibrated with the RMSPE (*root mean square prediction error*), RMSPE is widely used as a criterion for the performance of multivariate calibration models [22] the smaller value is better results. Mapping is conducted to most extreme SPI value in each monthly period.

3. Results and Discussions

3.1. Data Calibration

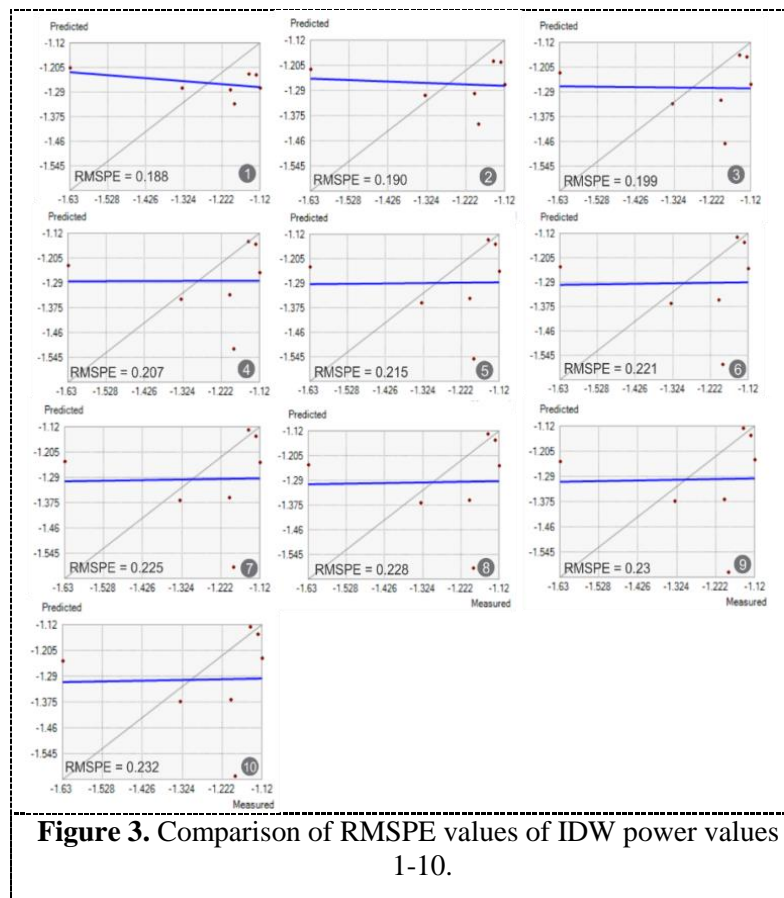
Meteorological drought calculations require accurate data so that the results are representative, it is necessary to calibrate the NCEP-CFSR satellite product data with rainfall products from field measurements. The results of the evaluation of satellite rainfall products and measurements directly can be seen (Figure 2).

Evaluation results show that RMSE and MAE values of NCEP-CFSR rainfall products from daily rainfall data cannot be utilized to describe the meteorological drought process in the Citarum watershed. Average RMSE and MAE values are 17.88131 and 22.73198, respectively. The smallest value of MAE from the calibration results is 2.038908 and the largest is 46.65346. While the RMSE value has the smallest value of 4.8769 and the largest is 49.1786. If using correlation, only has a 33% confidence level.



3.2. Data Interpolation

Interpolation techniques are conducted to predict unknown values of existing values. IDW (Inverse Distance Weighted) is utilized to predict the distribution of drought index in the Citarum watershed. IDW explicitly makes the assumption that things that are close to one another are more alike than those that are farther apart (Faber, 1999). The optimal use of IDW interpolation method is carried out by looking at the power value. Optimal power values can be determined by reducing the value of RMSPE (Root Mean Square Prediction Error) [22]. The results of the analysis of the power IDW value is known that value of RMSPE power 1 is smallest value when compared with range of values 1-10 (Figure 3).



3.3. NCEP-CFSR based SPI Results in Citarum Basin

NCEP-CFSR rainfall data was first applied to monitor drought in the Citarum watershed by SPI index. SPI is strongly influenced by the recorded rainfall notes, such as the 30-year application example [23]. However, utilization of the data used in this study considers availability of data from NCEP-CFSR for 25 years. Then range of years between 1988-2013 was chosen for meteorological drought analysis with the SPI time period for 1, 3, 6, 9, and 12 months.

Based on analysis of the SPI, it shows that droughts generally occur in the downstream Citarum watershed. The downstream Citarum watershed is a coastal area which usually experiences a rain deficit. The highest drought occurred in November 1994 and January 1995. SPI results have shown that the worst drought was in May 1994 (SPI 1), February 2011 (SPI 3), January 1998 (SPI 6), November 1994 (SPI 9), and July 2012 (SPI 12) (Table 2) (Figure 4).

Table 2. Extreme Drought Events 1988-2013

Periode	range	Year	Months
1	-2.1 – -2.97	1994	May
	-1.06 – -2.16	1997	June
	-0.71 – -2.71	1999	January
	-1.64 – -2.29	2002	October
	-0.57 – -2.15	2008	February
3	-1.44 – -2.8	1994	July
	-0.3 – -2.2	1998	January
	-0.3 – -3.7	2002	December

	-1.32 – -1.93	2006	November
	1.2 – -2.9	2011	February
6	-1.4 – -2.5	1994	October
	-0.3 – -2.0	1997	December
	-0.4 – -2.9	1998	January
	-1.4 – -1.8	2006	November
	-0.8 – -1.9	2008	Juny
9	-1.69 – -2.98	1994	November
	-1.45 – -2.98	1995	January
	-0.46 – -2.66	1998	January
	1.64 – -2.11	2011	August
	2.16 – -2.26	2012	April
12	-0.75 – -1.77	1994	November
	-0.97 – -1.75	1995	February
	-0.31 – -1.99	1998	January
	-1.03 – -1.75	2007	March
	-0.45 – -2.13	2012	July

The worst drought of the Citarum watershed occurred in 1994 during the SPI periods 1, 3, 6, 9, and 12. In accordance with other studies which stated that 1994 and 1997 climate anomalies that occurred in West Java had caused drought in technical irrigated rice fields which resulted in a decrease in agricultural production [24]. Climate anomalies (El Nino) have occurred quite often in Indonesia for the last 25 years, namely in 1982, 1987, 1991, 1994, 1997, 2002, 2003, 2004 and 2006[25]. However, the results of the assessment of the NCEP-CFSR product cannot detect the worst drought that occurred in 1991, 2003 and 2004 over various time periods.

The overall results of this study clearly show that the NCEP-CFSR is not suitable for monitoring drought in Citarum watershed, West Java Province, Indonesia. NCEP-CFSR products are considered to overestimate the total rainfall in the Citarum watershed. This is similar with the evaluation of NCEP-CFSR products in Singapore [26]. Peninsular Malaysia in Kelatan watershed and Johor River Valley [27]. Error in measuring the NCEP-CFSR is not limited to the tropics, but in United States reliability of this product cannot measure severity of meteorological drought [28]. Most likely, the measurement error of the NCEP-CFSR product lies in the spatial resolution that is too broad to effectively capture local micro-climate [15]. This is also supported by results of the validation of rainfall values from the NCEP-CFSR with observation value showing a positive correlation with a 33% confidence level, so that this data cannot be used for purpose of meteorological drought analysis.

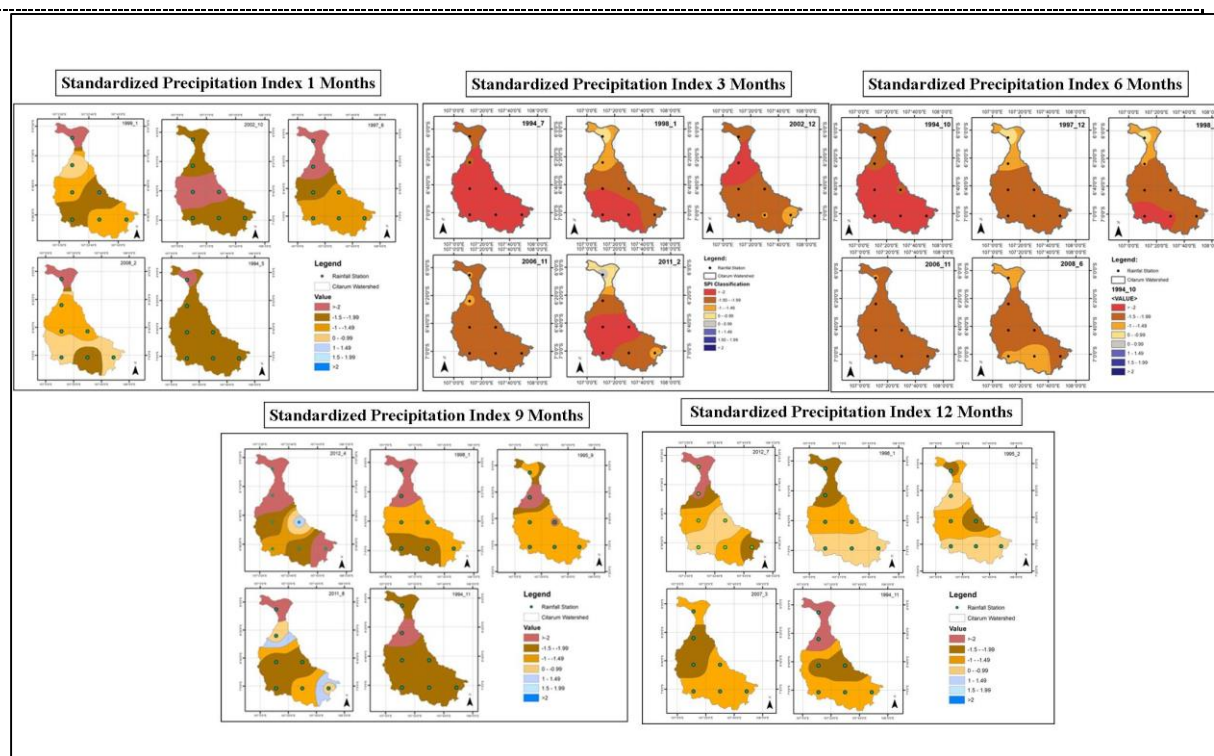


Figure 4. Extreme Period Drought Map 1, 3, 9, 12 months 1988-2013.

4. Conclusions

This study assessed rainfall products from the NCEP-CFSR in analyzing meteorological drought in the Citurum watershed, West Java from 1988-2013. Assessment between NCEP-CFSR products and rainfall data from measurement results is carried out on a daily basis data and then used to monitor meteorological drought in the Citurum watershed, West Java using the SPI index. Assessment results have shown that the NCEP-CFSR data for meteorological drought assessment is less recommended, because it is based on a low correlation value of around 33%. Although the results considered have shown extreme droughts that occurred in the downstream region of the Citurum watershed with the most extreme occurrences in November 1994 and January 1995. However, this product incorrectly predicts the great drought that occurred during history in the Citurum watershed. Regardless of the results assessed, this research can be utilized as a reference in selecting satellite products for monitoring meteorological drought in the future.

5. Acknowledgment

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