3. Assessing the applicability of Global Satellite Mapping of Precipitation (GSMaP) data for agricultural drought application in Indonesia

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Drought is one of the natural hazards caused by a lack of rainfall compared to normal conditions in a certain region. According to the FAO, drought affected agriculture areas the most, absorbing around 80% of direct impacts with multiple effects on agricultural production, food security and rural livelihoods on developing countries. Many methods have been developed for drought assessment, one of them is the Standardized Precipitation Index (SPI) found by McKee et al., in 1993 which only requires long term precipitation data for the input. Based on probability distribution and normalization, SPI is able to assess the wet and dry conditions. On the other hand, the ability of SPI to assess drought based on various precipitation dataset with the same range of drought index can raise another question, is SPI suitable to be used for agricultural drought assessment in tropical-humid regions? To assess the suitability of SPI for agricultural drought assessment in tropical-humid regions during dry crop season, firstly we examined the agreement between the measured precipitation data (MPD) and satellite-based precipitation data (GSMaP). Based on the statistical analysis (Pearson correlation and regression analysis), there is a good agreement between GSMaP and MPD dataset and then the SPI analysis was conducted using GSMaP which has a high spatial resolution. According to the correlation analysis between SPI index and drought affected areas on city-scale, SPI-3 in August is the most suitable to assess the agricultural drought in Indonesia.

Key Words : *Precipitation Data, Satellite-based Data, Agricultural Drought, SPI.*

1 Introduction

Many studies have been carried out in various fields that utilize precipitation data for various purposes. Research on drought will also rely heavily on the precipitation data, especially when drought can be understood as a condition when an area experiences a water deficit from its normal condition. There are 4 types of drought: Meteorological drought started from the deficiency of precipitation (Mokhtari, 2005) that could cause less water going to soil and higher evapotranspiration rate. Over time, the agricultural drought will occur because of the depletion of soil moisture (Ligesse, 2010) that affected crop production. Hydrological drought occurs when there is low water supply on surface and groundwater. If there is still lack of precipitation, the socioeconomic drought when demands exceed supply might occur and affect the social, economic, and environmental aspect. From this understanding, many precipitation-based indexes were developed for drought assessment one of which is Standardized Precipitation Index (SPI).

SPI was found by McKee et al., in 1993 that can be used for drought assessment and only need the long-term precipitation data (minimum 20-30 years). By using the probability density function and normalization, the SPI can assess the wet and dry conditions over any regions (drought occurred where SPI $\leqq$ -1). Another benefit of SPI is the temporal versatility so it can be calculated for various timescale according to user's interest (WMO, 2012).

However, nowadays there are many limitations in the availability of precipitation data, either it does not have enough data spatiotemporally or data not available publicly. The common precipitation data that can be used are measured precipitation data that have an advantage of high accuracy but only available on the point scale area. To assess drought, the spatial precipitation data is also needed. In the area without rainfall-gauge, satellite-based precipitation data can be used because it has a higher spatial resolution but also has many uncertainties that can cause low accuracy when predicting the precipitation value. So, the utilization of satellite-based precipitation data for drought assessment, must be preceded by assessing the agreement of precipitation data between local measurements and the satellite-based dataset.

Previous studies have shown the use of satellite-based weather data for different purposes, including drought analysis by comparing it first with the local data. For example, Mourtzinis et al., (2017) studied about the applicability of satellite-based precipitation data for agricultural application across the US Corn Belt. In this research, the objectives are i) to examine the agreement between local measured precipitation data (MPD) and satellite-based precipitation data (GSMaP) for point data analysis and interpolated-MPD and GSMaP for area data analysis, ii) assessing the spatial distribution of the rainfall distribution, and iii) examine the correlation between SPI index and drought-affected areas on city-scale.

This research was conducted in West Java as one of the provinces in Indonesia with the rainy season from October - March and the dry season from April - September. According to Maryati et al., (2012), 50.02% of the land is an agricultural area, dominated by paddy fields, which is very vulnerable to drought events. Based on the data provided by Lassa (2012), compared to other climate-related hazards, the agriculture area including paddy fields suffer the most from drought events. The results of this study will be helpful to get a better understanding of utilizing the satellite-based precipitation data especially in the area with a limited measured precipitation data for agricultural drought analysis.

2 Materials and methods

2.1 Precipitation Data

The daily measured precipitation data (MPD) are obtained from Meteorology, Climatology, and Geophysical Agency in Indonesia from January 1981 - March 2013 with missing data for some period in some stations. There are a total of 52 stations across 16 regencies in West Java with average coverage reaching 680.38 km^2 per station.

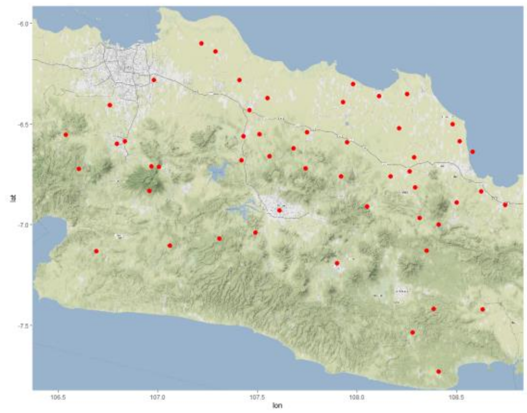

Fig. 1. The Location of 52 Rain Gauge Stations in West Java (represented by red dots)

Meanwhile, the satellite-based precipitation data collected from Japan Aerospace Exploration Agency (JAXA) provides near real-time rainfall data on their product called Global Satellite Mapping of Precipitation (GSMaP). The daily precipitation data are available from March 2000 - present date and were retrieved across West Java with 0.1° x 0.1° resolution.

2.2 Analysis Methods

The total precipitation for different timescale (daily, weekly, biweekly, 30-days, 60-days, 90-days, 120-days, 150-days, 180-days, 210-days, 240-days, 270-days, 300-days, 330-days, and 360-days) were calculated for the period between April 2000 - March 2013 both for MPD and GSMaP dataset.

The coefficient of determination or R-square (R^2) and pearson correlation was calculated to assess the agreement between two precipitation dataset. Those analyses applied both for point data analysis (52 locations of local rainfall gauge stations (MPD) and the grid from GSMaP that coincided with those stations) and area data analysis. For the area data analysis, the interpolation of MPD dataset was conducted using Inverse Distance Weighted (IDW) method with 0.1° x 0.1° resolution (the same with GSMaP resolution).

For the drought assessment, SPI was calculated for the combination of various aggregation timescale (SPI-1, SPI-3, SPI-6, SPI-9, and SPI-12) and also different month reference from January – December. So there were a total of 60 scenarios of SPI calculated. Then, the correlation between SPI index and drought-affected areas was assessed on city-scale.

3 Results and discussion

3.1 Point Data Analysis

Figure 2 summarizes the agreement between MPD and GSMaP where horizontal axis indicates the various timescale and vertical axis indicates the value of R^2. It can be seen that the agreement performed a parabolic pattern for the daily until 360-days scale with the turning point during the 150-days period and an anomaly during the 180-days period where the sudden decrease of R^2 values happened. This pattern and anomaly was predicted to be caused by the characteristic of the rainy and the dry season of the country which happened every 6 months. Also, the result will depend on the characteristics of the season for each region.

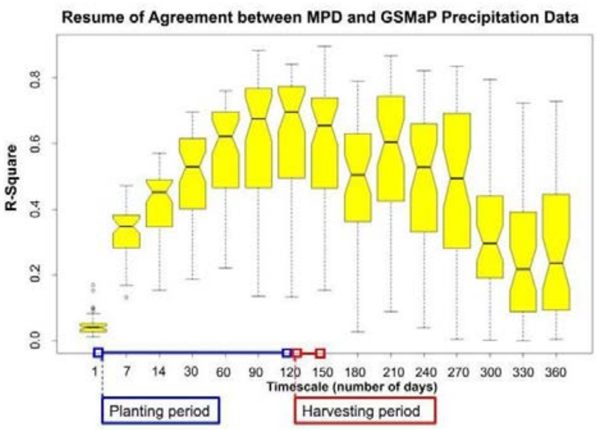

Fig. 2. Resume of agreement between MPD and GSMaP data for various timescale

Based on this result, it can be concluded that the acceptable timescale that can be considered to be used for drought assessment is a 90-days (3-months) period when the value of R^2 reaches the peak.

For additional information, the blue line on the horizontal axis indicates the planting period of paddy occurred within 120 days and the red line indicated the harvesting period which usually occurred in the 30 days after the planting period ended. This result shows a good agreement of the two datasets occurred during the paddy's planting and harvesting period, so the various aggregation timescale can be used for monitoring agricultural drought that might affect the paddy during crop season.

3.2 Area Data Analysis

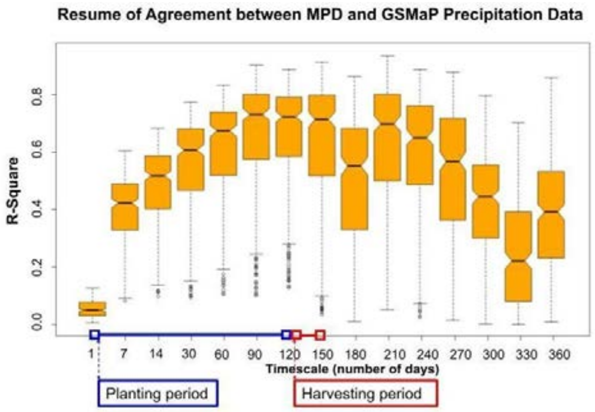

Fig. 3. Resume of agreement between interpolated-MPD and GSMaP data for various timescale

Basically, the analysis to examine the area dataset is the same with point data analysis, the major difference lies in the interpolation method of MPD. The resume of R-square which examines the agreement between interpolated-MPD and GSMaP data can be seen in Figure 3. Generally, the pattern is the same with point dataset analysis (Figure 2), but unlike the point dataset result, during 150-days period or during harvesting period, the agreement shows more stable R-square value and starts decreasing during 180-days period.

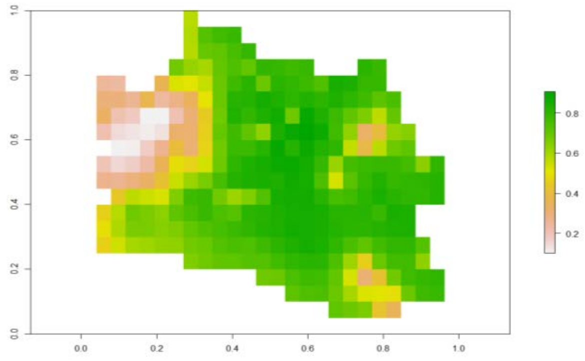

Fig. 4. Map of distribution R-square value for 90-days timescale

To see the difference in spatial distribution of precipitation between interpolated-MPD and GSMaP dataset, Figure 4 shows the map of West Java with information about 90-days R-square values on each grid from various timescale. The greenish color indicated higher R-square values which meen better agreement between two dataset, meanwhile the reddish color indicated lower R-square values or lower agreement between the dataset. The good agreement is an important aspect to be considered, because in this context, it can be interpreted that there is a strong relationship between the GSMaP dataset and the interpolated-MPD dataset or the difference between two precipitation dataset was much lower.

3.3 Correlation between SPI Index and Drought-Affected areas

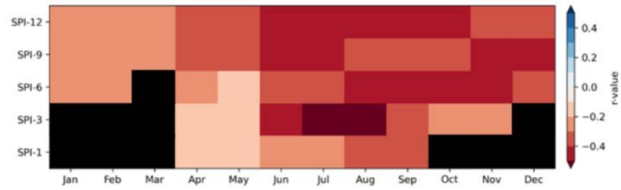

Fig. 5. Heatmap of Mean of Correlation Value between SPI Index and Drought-Affected Areas

Figure 5 showed the heatmap of average correlation value where vertical axis indicated the SPI aggregation timescale and horizontal axis indicated the month reference. The black color on the heatmap involved only a wet season which is not a target period of this study, so the result is not included. Based on the heatmap, the correlation resulted in negative values, indicated by the red color, to all the scenarios of SPI index. This result can be interpreted that the decrease of SPI index, or a dry condition, is associated with the increase of drought-affected areas in the agriculture area. In addition, the highest correlation was produced during the SPI-3 in August. Moreover, this is also coincided with the peak of dry season which is very significant to the crop production during the dry cropping period.

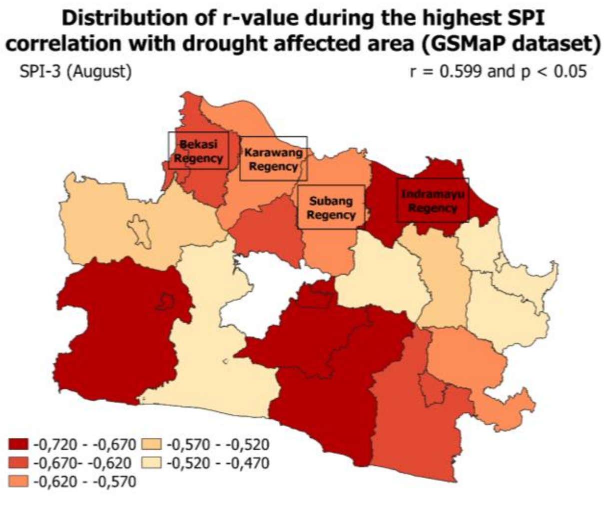

Fig. 6. Spatial Distribution of R-Value in West Java

After the most suitable SPI index was determined, the next step was examined the spatial distribution of r-value. Through this process, the different response can be observed in each regency towards the SPI-3 in August. Based on the map of distribution r-value showed in Figure 5.9, the significance correlation was found in all the regencies, but the value was varied from -0.47 until -0.72. The difference of r-value in each regency can indicate the strength of correlation between SPI as drought index and the impact of drought itself and this will be determined by the characteristic of the region. For agriculture area, especially wet crop, one of the fundamental things is the system that allow the water supply into paddy fields, or irrigation system. So, to assessing the agricultural drought, examine the water accessibility is also important.

4 Conclusion

For the location with limited measured precipitation data, the satellite-based data can be utilized by assessing the agreement between the two datasets first. In West Java, it is concluded that GSMaP precipitation data can be used for drought assessment in Indonesia. Moreover, from the correlation analysis between SPI index and drought-affected areas, showed a significance result of the dry condition which associated with the increase of drought-affected areas. But for the agricultural application, water accessibility assessment is needed to understand the drought impact.

5 References

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