Abstract—Java Island, as one of the main Indonesian islands with the largest population and rice production, is considered highly vulnerable towards climate change impacts. Identification of the increasing risk due to climate change enhanced meteorological disasters is very important to support local community resilience. This study aims to analyze the meteorological drought potential in Java Island, as projected by IPCC climate change scenarios. Monthly time series of rainfall data from 1985-2004 are used to determine the current drought potential. Standardized Precipitation Index (SPI) is applied to the observed (1985-2004) and projected (2010-2030) drought index. Geographic Information system (GIS) analysis is utilized to depict the spatial distribution of drought events. The result reveals that although there is a different trend between the western and the eastern part of the island, the drought frequency in general is increasing. The result also indicates that the daily rainfall tendency over the island has decreased significantly since 1960.

Keyword: Climate Change, Drought, Java Island, SPI

1. INTRODUCTION

Climate change impact has potential to have impacts on various aspect of human life. Climate change is causing increased variability of rainfall (Storer [8]). Changes in rainfall characteristic such us flood and drought are closely related to climate change. Drought is lack precipitation over a time period, occurred in local or regional scale (Livada, [5]). There are several drought type, such as meteorological drought, hydrological drought, agricultural drought, and groundwater drought (Wilhite and Glantz 1987; Hamdy 2004; MED WS and D WG 2007; Zakhem, [11]). The other type of drought is socioeconomic drought (Heim, 2001; Zhang, [12]). This study is focused on meteorological drought, which indices by the SPI (Standardized Precipitation Index). Meteorological drought are depict the degree of dryness compared by normal or average amount, that observed in long term period (Zakhem, [11]).

Java Island is the dense island in Indonesia, covering about 129,438,28 km² or 6.77%. As the densest island in Indonesia with 136,610,590 people alive in this island based on statistic bureau of Indonesia (BPS, [1], Java Island is considered highly vulnerable towards climate change impact. Identification of the increasing risk due to climate change enhanced meteorological disaster is very important to community resilience.

Java island, located in the tropical region and Indo-Australian Monsoon (Bemmelem [2]), is characterized by high frequency of temperature, humidity, and rainfall. Based on Oldeman [6] Climate Classification, there are 8 types A1 (4), B1 (16), B2 (7), C2 (25), C3 (14), D2 (5), D3 (20), and E3 (9).

The objective of this study is to (1) analyze changing spatial and temporal extreme drought event by Standardize Precipitation Index (SPI) in Java Island 1985-2004, (2) projected SPI for 2010-2030 and agricultural impact.

2. METHOD AND MATERIALS

2.1 Materials

Monthly precipitation data from 1985-2004 from 31 meteorological station, which are distributed on Java island and around, are used in this study (Fig.1). Those data are collected by ground observation, which obtained from Meteorology Climatology and Geophysics Council (BMKG). Indonesia as tropical region has constant annual temperature, but the precipitation is changed by time towards the season (Tjasyono, [9]).
2.2 Method

Precipitation area are determined by the spline tension method that used Geographic Information System (GIS). This precipitation data is used to determine the drought using Standardized Precipitation Index (SPI). The SPI, is method to quantify the precipitation deficit for multiple time scale that indicate water resource, was designed by Mc Kee et. all in 1993 (Livada, [5]). Time scale is vary from 1, 3, 6, 12, 24, 48 month. This different timescale indicate different meaning. Shorter timescale SPI reflect the soil moisture changes that important for agricultural and longer timescales can depict long-term streamflow variations which is important to identify water reservoir management (Wu et all, 2001; Zhang,[12]).

Below are the following step to get the SPI value:

\[
G(x) = 0 \int g(x)dx = \left\{ \frac{1}{\beta^\alpha} \left( \frac{\alpha}{\beta} \right) \right\} 0 \int x \alpha^{-1} e^{-x/\beta} dx
\]

\[
\alpha \text{ and } \beta \text{ are estimated for each station used the equation below:}
\]

\[
A = \ln(\bar{X}) - \left\{ \sum \ln(x) / n \right\}
\]

Or

\[
\alpha = \frac{X^2}{s^2} \text{ and } \beta = \bar{X} / \alpha \quad \text{for } x > 0
\]

for \( x = 0 \), so value of \( G(x) \):

\[
H(x) = q + (l - q) \cdot G(x)
\]

with \( q \) = number of rainfall event\(= 0 \) (m)/ number of data (n).

The SPI calculation from gamma distribution was transferred to normal distribution with mean) and difference 1, or use the equation below:

\[
Z = SPI = -\left\{ t - \frac{c_1 + c_3 + c_2}{1 + d_1 + d_2 + d_3} \right\} \text{for: } 0 < H(x) < 0.5
\]

\[
Z = SPI = -\left\{ t - \frac{c_1 + c_3 + c_2}{1 + d_1 + d_2 + d_3} \right\} \text{for: } 0.5 < H(x) < 1.0
\]

where,

\[
t = \sqrt{\ln \{1/(H(x))2\}} \text{ for: } 0 < H(x) < 0.5
\]

\[
t = \sqrt{\ln \{1/(1.0 - H(x))2\}} \text{ for: } 0.5 < H(x) < 1.0
\]

### Table 1. Drought level by SPI value (WMO, [10]).

<table>
<thead>
<tr>
<th>SPI Value</th>
<th>Drought severity</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt;2</td>
<td>Extreme Wet</td>
</tr>
<tr>
<td>1.5&lt; SPI &lt; 2</td>
<td>Severe wet</td>
</tr>
<tr>
<td>1&lt; SPI &lt;1.5</td>
<td>Mild wet</td>
</tr>
<tr>
<td>-1&lt; SPI &lt; 1</td>
<td>Normal</td>
</tr>
<tr>
<td>-1.5 &lt; SPI &lt; -1</td>
<td>Mild drought</td>
</tr>
<tr>
<td>-2 &lt; SPI &lt; -1.5</td>
<td>Severe drought</td>
</tr>
<tr>
<td>&lt; -2</td>
<td>Extreme drought</td>
</tr>
</tbody>
</table>

The spatial analysis used Geographic Information System. The SPI value are showed with SPI map in Java Island. Rainfall data from station is the point data. So, interpolation method is needed to make rainfall region.

The SPI value from each station is interpolated with spline method. Spline is a polynomial-based interpolation method (Hofierka, [3]). Spline described as a ruler that is elastic and can be bent to form a pattern following the dots that have been plotted. For example, if known point with a interval \( (x_k, x_{k+1}) \), spline interpolation calculations can be performed using the formula:

\[
f = Af_k + Bf_{k+1}
\]

In this case:

\[
A = \frac{x_{k+1} - x_k}{x_{k+1} - x_k} \quad B = 1 - A = \frac{x - x_k}{x_{k+1} - x_k}
\]

### 3. RESULT AND DISCUSSION

1-Monthly SPI

Drought severity is needed to examine the impact of climate change (Jiang, [4]). SPI was commonly used to determine meteorological droughts all over the world (Zhang, [12]). Meteorological drought investigate in Java Island using SPI with 20 years monthly rainfall data (1985-2004). The result of 1-monthly SPI show that considering extreme drought (SPI< -2) occurred with great variability. The largest number of extreme drought event was occurred in 1997, while the second largest is in 1991 (Fig.2).

The peak number of extreme value was the same time with severe El Nino in Indonesia in 1997. This condition occurrence was estimated because of climate change impact. The anomaly between Hindia ocean heat and Pacific Heat occurred cause the climate change. The other extreme value analysis from each month is showed in Fig. 3 below.
Extreme drought event number are dominant occurred in October to June. The largest number are in March and November. March is normally dry because of in java is dry season. In contrast, extreme drought in November, the beginning of wet season, is the anomaly event. The 1995-1999 is the driest event. This phenomena also connected to the El Nino event.

Projected SPI 2010-2030

Projected SPI for 2010-2030 depict the increasing number of drought event through Java Island. According to WMO [10] the 3-month SPI can be good indicator to analyze drought condition in the monsoon region. Additionally, the 3-month SPI projection is used to see period of agricultural activity, especially rice. WMO [10] state that the 3-month SPI can describe available moisture condition to indicate growing season begins.

Fig. 5 depict that western part of Java Island is more have drought than eastern part of Java Island. Those area are projected to less productive in the 2010-2030 period. Field observation showed that some area in the middle-north of java in 2014 are failed harvesting. This condition will need the government action to help the food security. The longer projection about drought will very important to anticipate the lack of rice in the future.

4. CONCLUSION

Extreme drought event largest occurrence in 1997 with 34 station record. The largest number extreme drought event are occurred in March and November period 1995-1999. Middle-
north and middle-western part of Java Island show lowest SPI value. Projected SPI for 2010-2030 show that western part of Java Island is drier than eastern part of Java Island. The projection of drought event has agricultural impact. The anticipation are needed to face the lack of food.

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