Exposure to Drought: Duration, Severity and Intensity (Java, Bali and Nusa Tenggara)

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Abstract. Occurrence of drought is a slow process lasted for a long time until the rainy season come. This natural disaster has broad and severe impact. This research was conducted to examine the level of severity and intensity of drought in Java, Bali and Nusa Tenggara using Standardized Precipitation Evapotranspiration Index (SPEI). SPEI is drought index used for quantifying drought occurrence, and can be used to analyze duration, severity and intensity. Drought is a climatological phenomenon which is difficult how to determine its onset, duration, magnitude, intensity, spatial extent, etc. Therefore, this information of exposure to drought could be describe the characteristics of drought events. To summarise the calculation, for 30 years (1985-2014) from 22 stations BMKG obtained the longest and strongest drought occurred at meteorology Serang – Banten, with long duration is 11 months and severity -16.816 at October 2002 until August 2003. In one period of drought event, not always the longest it’s mean the strongest.

1. Introduction

Occurrence of drought is a slow process lasting for a period longer than a season. This natural hazard has broad and severe impact which often lead to disaster. Drought caused by anomaly weather conditions such as the decreasing of the intensity of rainfall as compared to normal conditions [1,2,3], and the rising of the temperature significantly affect the severity of the drought [4]. It is also affected by conditions of the low soil moisture and surface water availability, which is insufficient [5,6,7]. Drought can be categorized into three types of drought, namely meteorological drought, agricultural drought and hydrological drought [2]. This natural hazard has broad and severe impact which often lead to disaster. Understanding drought characteristic is, an essential element in well-prepared drought management plans.

In representing the dryness of a region, a lot of research using a drought index, which can provide a quantitative assessment of climatic conditions in terms of intensity, duration and severity of drought. There are two main objectives of the drought index, assessing the vulnerability of various systems to drought, monitoring and early warning. Various indices have been developed to detect and monitor droughts, and have been used to analyze meteorological drought. A drought index is a main variable in order to assess the effect of a drought and to determine various drought characteristics, such as duration, intensity and severity [8]. The most common used meteorological drought indicator is the standardized precipitation index (SPI) which has key advantage that it can be calculated with different
timescales. McKee et al. [9] proposed the concept of standardized precipitation index (SPI) based on the long-term precipitation or stream flow record for a chosen period, and adaptable for the analysis of drought at variable time scales; it can be used for monitoring agricultural and hydrological purposes. Vicente et al. [10] proposed a new climatic drought index: the standardized precipitation evapotranspiration index (SPEI). The SPEI is based on a climatic water balance (precipitation – potential evapotranspiration) anomalies. Under global warming conditions, SPEI can identified an increase in drought severity associated with higher water demand as a result of evapotranspiration. It can be calculated at different time scales, allowing exploring the vulnerability of various systems to drought, and based upon the original SPI calculation procedure. With SPEI method can provide information of drought exposure, which can describe the characteristics of drought events by characterizing its severity, duration, interval time, intensity, probability, and return period of drought.

The areas of Java, Bali and Nusa Tenggara is an agricultural center which will be affected by drought. This research is conducted to examine the level of severity, duration and intensity of drought to know the characteristics of drought in Java, Bali and Nusa Tenggara using Standardized Precipitation Evapotranspiration Index (SPEI) with time scale 1 and 3 months.

2. Study Area and Data Used
The location of research focused on the islands of Java, Bali and Nusa Tenggara which are located approximately between 5.7° – 11° S and 105° – 126° E. The stations are selected based on length recording data and completeness of data (empty data minimum). Because of SPEI calculation based on the calculation of the SPI. Calculating SPEI using precipitation and temperature data which data recorded during a period of 30 years.

Data from the Center for Database Meteorology Climatology and Geophysics (BMKG) represent of Java, Bali and Nusa Tenggara BMKG there are 22 stations with a data length of 30 years (1985-2014). There are 17 stations in Java, one station in Bali, and 4 stations in Nusa Tenggara. Data used is climate parameter data, there are monthly precipitation totals, and monthly mean temperature, with a unit of precipitation is millimeter, and temperature is degrees Celsius. To support data processing, required supporting data such as topography data and elevation each station the list of station shown by Table 3, while the position of the station is shown in Figure 1.

![Figure 1. Location map of the 22 stations BMKG in Java, Bali and Nusa Tenggara.](image)
Table 1. List of 22 Stations BMKG in Java, Bali and Nusa Tenggara.

| No | No. Sta | Name of Station                              | Longitude  | Latitude  | Elevation |
|----|--------|---------------------------------------------|------------|-----------|-----------|
| 1  | 88882  | Stageof Lembang                             | 107.6167   | -6.8333   | 1200 M    |
| 2  | 96733  | Sta. Klim. Pondok Betung - Tangerang         | 106.7500   | -6.2558   | 26.2 M    |
| 3  | 96735  | Sta. Geof. Tangerang                        | 106.6667   | -6.2667   | 14 M      |
| 4  | 97637  | Sta. Met. Serang                            | 106.6465   | -6.1167   | 14 M      |
| 5  | 96739  | Sta. Met. Budiarto - Curug                  | 106.6500   | -6.2333   | 46 M      |
| 6  | 96741  | Sta. Met. Maritim Tanjung Priok             | 106.8667   | -6.1000   | 2 M       |
| 7  | 96745  | Sta. Met. Kemayoran - Jakarta               | 106.8533   | -6.1600   | 4 M       |
| 8  | 96751  | Sta. Met. Citeko - Bogor                   | 106.9333   | -6.7000   | 920 M     |
| 9  | 96753  | Sta. Klim. Darmaga - Bogor                 | 106.7498   | -5.5536   | 190 M     |
| 10 | 96783  | Sta. Geof. Bandung                          | 107.6000   | -6.9167   | 791 M     |
| 11 | 96835  | Sta. Klim. Semarang                         | 110.3833   | -6.9833   | 4 M       |
| 12 | 96925  | Sta. Met. Sangkapura - Bawean               | 112.6633   | -5.8675   | 3 M       |
| 13 | 96933  | Sta. Met. Perak I - Surabaya                | 112.4461   | -7.2236   | 3 M       |
| 14 | 96935  | Sta. Met. Juanda - Surabaya                 | 112.7839   | -7.4028   | 2.8 M     |
| 15 | 96937  | Sta. Met. Maritim Perak II - Surabaya       | 112.7356   | -7.2056   | 3 M       |
| 16 | 96945  | Sta. Geof. Tretes                           | 114.3833   | -8.2167   | 50 M      |
| 17 | 96987  | Sta. Met. Banyuwangi                        | 114.3833   | -8.7486   | 50 M      |
| 18 | 97230  | Sta. Met. Ngurah Rai - Denpasar             | 115.16917  | -8.74583  | 3 M       |
| 19 | 97240  | Sta. Met. Selaparang - Mataram              | 116.5333   | -8.56667  | 16 M      |
| 20 | 97270  | Sta. Met. M. Salahuddin - Bima              | 118.69292  | -8.54275  | 2 M       |
| 21 | 97260  | Sta. Met. Sumbawa Besar                     | 117.41367  | -8.48833  | 3.8 M     |
| 22 | 97374  | Sta. Klim. Lasiana - Kupang                 | 123.66722  | -10.13861 | 19 M      |

3. Methodology

The first step is the quality control data by checking the data used. Terms SPEI calculation is data to be filled in complete or without any missing data during the period of use. If there are empty data then do imputation to complete the data. After missing data problem solved, the next step calculated SPEI value on different time scale one-month (SPEI-1) and 3 months (SPEI-3) for each of the BMKG station.

3.1 Method of Completing the Missing Data

Ideally estimating missing data require comparison data from multiple stations are close and correlated with data from the test station [11]. This study used the method of average - arithmetic average [12], a simple method for filling missing rainfall data. Measurements were carried out at several stations at the same time summed and then divided by the number of stations, and if the magnitude of the difference between the average annual rainfall from each stations with the average annual rainfall that will estimated is less than 10%. The formula of missing data (monthly, seasonal or yearly) in station \( p \) is:

\[
 p = \frac{p_1 + p_2 + p_3 + \cdots + p_n}{n}
\]
where \( p \) is missing rainfall data; \( p_1, p_2, p_3, \ldots, p_n \) are rainfall data at the station 1, 2, 3, ..., \( n \); and \( n \) is number of stations.

Another method used is linear regression method which is based on a linear relationship between the data of the test station (station A) and data from station B, and C. The formula is:

\[
pA = a + b * pB + c * pC
\]

where \( a, b, \) and \( c \) are constants regression.

3.2 Calculating of SPEI Value

The SPEI calculation was done using simple multiscale drought index that combines precipitation and temperature data with the capacity to include the effects of temperature variability on drought assessment. The SPEI is based on the original SPI calculation procedure. The SPI is calculated using monthly or weekly rainfall as input data. While SPEI uses the monthly (or weekly) difference between precipitation and potential evapotranspiration (PET). The first step to estimate of potential evapotranspiration (PET), this represents a simple climatic water balance uses Thornthwaite [13] method, for estimate of PET is not focus only one method.

In this study, SPEI calculation refers to the calculations carried out by Vicente et al. [10], the steps calculation is as follows

3.2.1 Computation of the climatic balance. The simplest approach to calculate PET [13], which has the advantage of only requiring data on monthly-mean temperature and supporting data such as the number of days of the month, the maximum numbers of sun hours, the latitude from each stations. Following this method, the monthly PET (mm) is obtained by

\[
PET = 16K \left( \frac{10^T}{I} \right)^m
\]

where \( T \) is the monthly-mean temperature (°C); \( I \) is a heat index, which is calculated as the sum of 12 monthly index values \( i \), the latter being derived from mean monthly temperature using the formula

\[
i = \left( \frac{T}{5} \right)^{1.514}
\]

\( m \) is a coefficient depending on \( I \): \( m = 6.75 \times 10^{-7} I^3 - 7.71 \times 10^{-5} I^2 + 1.79 \times 10^{-2} I + 0.492 \); and \( K \) is a correction coefficient computed as a function of the latitude and month,

\[
K = \left( \frac{N}{12} \right) \left( \frac{NDM}{30} \right)
\]

Here \( NDM \) is the number of days of the month and \( N \) is the maximum number of sun hours, which is calculated using

\[
N = \left( \frac{24}{\pi} \right) \sigma_s
\]

where \( \sigma_s \) is the hourly angle of sun rising, which is calculated using \( \sigma_s = \arccos(-\tan \phi \tan \delta) \), where \( \phi \) is latitude in radians and \( \delta \) is the solar declination in radians, calculated using

\[
\delta = 0.4093 \left( \frac{2\tau J}{365} - 1.405 \right),
\]

where \( J \) is the average Julian day of the month.

The next step with the values obtained ETP, then to get the difference between precipitation (P) and potential evapotranspiration (PET) month \( i \) is calculated using the equation climatic water balance,
\[ D_i = P_i - \text{PET}_i, \]

it is a simple measure of the water surplus or deficit for one month. The ratio of P to PET as a suitable parameter for obtaining a drought index that accounts for global warming processes [14]. This approach has some disadvantages: the parameter is not defined when PET = 0 (which is common in many regions of the world during winter), and the P/PET quotient reduces dramatically the range of variability and the role of temperature in droughts.

3.2.2 Creation of cumulative series at desired time scale, fitting the data to an adequate distribution function (LogLogistic) and transforming the data into (standardized) z-values. Calculated \( D_i \) at different time scales, following the same as with the SPI procedure. The difference \( D_{ij} \) in the specific month \( j \) and year \( i \) depends on the selected time scale \( k \). For example, accumulated difference for one month in a given year \( i \) with 12-month time scale is calculated using

\[
X^k_{i,j} = \sum_{l=13-k+j}^{12} D_{i-l,i} + \sum_{l=1}^{j} D_{ij}
\]

if \( j < k \) and

\[
X^k_{i,j} = \sum_{l=j-k+1}^{j} D_{i,l}
\]

if \( j \geq k \) and

where \( D_{ij} \) is the \( P - \text{PET} \) difference in the first month of year \( i \), in millimeters.

For calculation of the SPI on different time scales, the probability distribution of the gamma family is used (the two-parameter gamma or three-parameter Pearson III distributions), because the frequencies of precipitation accumulated at different time scales are well modeled using these statistical distributions. Although the SPI can be calculated using two-parameter distribution, such as the gamma distribution, the distribution of the three-parameters needed to calculate the SPEI. In the distribution of two-parameter, the variable \( x \) has a lower limit of zero \( (0 < x < \infty) \), while the distribution of the three-parameters, \( x \) can take values in the range \( (\gamma > x < \infty) \), where \( \gamma \) is the parameter origin of the distribution; consequently, \( x \) can have a negative value, which are common in \( D \) series.

Vicente et al. [10] tested the most suitable distribution to model the values of \( D_i \) calculated at different time scales. For this purpose, L-moment ratio diagrams used to allow for comparison of the empirical frequency distribution of \( D \) calculated at different time scales with the number of theoretical distributions. The L moments are times analogous to a conventional central moment, able to characterize a wider range of distribution functions and strengthen in relation to the outliers in the data.

To create the L-moment ratio diagrams, L-moment ratios (L skewness \( \tau_3 \) and L kurtosis \( \tau_4 \)) must be calculated. Here \( \tau_3 \) and \( \tau_4 \) are calculated as follows:

\[ \tau_3 = \frac{\lambda_3}{\lambda_2} \quad \text{and} \quad \tau_4 = \frac{\lambda_4}{\lambda_2} \]

where \( \lambda_2, \lambda_3, \) and \( \lambda_4 \) are L-moments of the \( D \) series, obtained from probability-weighted moments (PW Ms) using the formulas

\[
\begin{align*}
\lambda_1 &= w_0, \\
\lambda_2 &= w_0 - 2w_1, \\
\lambda_3 &= w_0 - 12w_1 + 30w_2 - 20w_3,
\end{align*}
\]
The PWMs of order $s$ are calculated as

$$w_s = \frac{1}{N} \sum_{i=1}^{N} (1 - F_i) D_i$$

Where $F_i$ is frequency estimator calculated following the approach of Hosking [15]:

$$F_i = \frac{i - 0.35}{N}$$

where $i$ is the range of observations arranged in increasing order and $N$ is the number of data points. Vicente et al. [10], get the values $\tau_3$ and $\tau_4$ calculated from the $D$ series of 11 observation points between 1910 and 2007 in different regions of the world, tropical (Tampa, Florida; Sao Paulo, Brazil), monsoon (Indore), Mediterranean (Valencia, Spain), semiarid (Albuquerque), continental (Wien, Austria), cold (Punta Arenas, Chile) and marine (Abashiri, Japan). The dataset was obtained from the GHCN-monthly database.

The probability density function of three-parameters log-logistic distributed variable is expressed as

$$f(x) = \frac{\beta}{\alpha} \left( \frac{x - y}{\alpha} \right)^{\beta-1} \left[ 1 + \left( \frac{x - y}{\alpha} \right)^{\beta} \right]$$

where $\alpha$, $\beta$, dan $\gamma$ are scale, shape, and origin parameters, respectively, for $D$ values in the range ($\gamma > D < \infty$).

Parameters of the log-logistic distribution can be obtained following different procedures. Among them, the L-moment procedure is the most robust and easy approach [16]. When L-moment are calculated, the parameters of the Pearson III distribution can be obtained following Singh et al. [17]:

$$\beta = \frac{2w_1 - w_0}{6w_1 - w_0 - 6w_2}$$

$$\alpha = \frac{(w_0 - 2w_1) \beta}{\Gamma \left( 1 + \frac{1}{\beta} \right) \Gamma \left( 1 - \frac{1}{\beta} \right)}$$

$$\gamma = w_0 - \alpha \Gamma \left( 1 + \frac{1}{\beta} \right) \Gamma \left( 1 - \frac{1}{\beta} \right)$$

where $\Gamma(\beta)$ is the gamma function of $\beta$.

The log-logistic distribution adapted very well to the $D$ series for all time scales. The probability distribution function of the $D$ series, according to the log-logistic distribution, is given by

$$F(x) = \left[ 1 + \left( \frac{x - y}{\alpha} \right)^{\beta} \right]^{-1}$$

The $F(x)$ values for the $D$ series at different time scales adapt very well to the empirical $F(x)$ values at the different observations, independently of the climate characteristics and the time scale of the analysis. This demonstrates the suitability of the log-logistic distribution to model $F(x)$ values from the $D$ series in each region of the world. With $F(x)$ the SPEI can easily be obtained as the standardized values of $F(x)$. For example, following the classical approximation of Abramowitz and Stegun [18],

$$SPEI = W - \frac{C_0 + C_1 W + C_2 W^2}{1 + d_1 W + d_2 W^2 + d_3 W^3}$$
where

\[ W = \sqrt{-2 \ln(P)} \quad \text{for} \quad P \leq 0.5 \]

and \( P \) is the probability of exceeding a determined \( D \) value, \( P = 1 - F(x) \). If \( P > 0.5 \), then \( P \) is replaced by \( 1 - P \) and the sign of the resultant SPEI is reversed. The constants are \( C_0 = 2.515517, C_1 = 0.802853, C_2 = 0.010328, d_1 = 1.432788, d_2 = 0.189269, \) and \( d_3 = 0.001308 \).

The average value of SPEI is 0, and the standard deviation is 1. The SPEI is a standardized variable, and it can therefore be compared with other SPEI values over time and space. An SPEI of 0 indicates a value corresponding to 50\% of the cumulative probability of \( D \), according to a log-logistic distribution.

At the 3-month time scale of the output SPEI-3 value series, if the data were used 30 years (360 months) there will be a 358 of SPEI-3 values. Furthermore, based on the value of SPEI-1 and SPEI-3, drought analysis can be done in Java, Bali and Nusa Tenggara.

3.3 Duration, severity and intensity of drought

A drought index is main variable in order to assess the effect of a drought and to determine various drought characteristics, such as duration, intensity and severity [8]. In this research, used meteorological drought indicator is SPEI [10] and calculated for the different time scale, 1 month and 3 months.

Figure 2, is used to determine drought characteristics. The negative and positive values of SPI are considered as the drought and non-drought event. As drought is defined when the values of SPI fall below zero, a drought event is considered a period with negative SPEI values. In order to measure length of drought duration and magnitude of drought severity, a threshold value must be defined. The drought duration \( (D) \) is the period length in which the SPEI is continuous negative, started from the SPEI values is equal to -1 and ends when the SPEI values turn out to be positive. The drought severity \( (S) \) is the cumulated SPEI values within the drought duration, which is defined by

\[ S = - \sum_{i=1}^{D} \text{SPEI}_i \]

and intensity of drought is the ratio of severity of drought to its duration.

![Figure 2. Definition of drought characteristics.](image)

Many drought planners appreciate the flexibility SPI as part of the monitoring and early warning efforts, because the SPEI calculation based on the calculation of the SPI then the classification level of dryness follow SPI classification proposed by McKee et al. [9], as follows:

| Classification Value of SPI/SPEI |  |
|---------------------------------|--|
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3.4 SPI-based drought analysis

In this research, we used monthly and three-monthly SPEI values for the period from January 1986 to December 2016 to study drought characteristics in the region of Java, Bali and Nusa Tenggara. The distribution of SPEI values is shown in Figure 2, where the green line represents the SPEI and the orange line represents the drought duration. The drought severity is calculated as the cumulative SPEI values within the drought duration, which is defined by

\[ S = - \sum_{i=1}^{D} \text{SPEI}_i \]

and intensity of drought is the ratio of severity of drought to its duration.
| SPI/SPEI Value | Condition       |
|---------------|-----------------|
| 2.0+          | 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 and less   | extremely dry   |

4. Results and Discussion

4.1 Climatology condition

The pattern of rainfall on Java, Bali and Nusa Tenggara is a monsoonal as described by Aldrian et al. [19]. High rainfall occurred at the beginning and end of the year, in the middle of the year tends to be low, see at figure 3. Based on Oldeman climate classification, which differentiates wet months, humid months and dry months. Criteria used limits of monthly rainfall, which the wet months is the monthly rainfall > 200 mm, the humid months is about 100 - 200 mm, and dry months with monthly rainfall < 100 mm [12]. That periods of dry months is apparent in Java, Bali and Nusa Tenggara start from May until October. More details see Table 3, show recaps dry months in Java, Bali and Nusa Tenggara, represented by BMKG station.

![Figure 3](image)

(a). Climatology Station Semarang  
(b). Meteorology Station Ngurah Rai, Denpasar  
(c). Meteorology Station Selaparang, Mataram  
(d). Climatology Station Lasiana, Kupang

**Figure 3.** Average Monthly Rainfall of 30 years (1985 – 2014) in Java, Bali and Nusa Tenggara
4.2 Analysis of drought
During the period 1985 - 2014, the results of SPEI-1 at 22 stations BMKG there are 37-54 drought events. Most drought events recorded in Meteorology Station Budiarto, Curug is as much as 54 times of drought events. Which have a length of more than 2 months that occurred in 1991, 1994, 1997 dan 2006. The longest drought occurred about 4 months in 1997, while the lowest incidence of droughts recorded in Meteorology Station M. Salahudin – Bima as much as 37 times of droughts.

SPEI-3 values showed there are 22 to 36 of drought events, with the highest incidence records in Meteorology station Sumbawa Besar, and lowest in Meteorology station Kemayoran – Jakarta. In Sumbawa Besar, the drought events Which have a length of more than 2 months that occurred in 1987-1988, 1996, 2001, 2003, 2004, 2012 and 2014. The longest drought occurred about 6 months in 2003. Figure 4 shows the number of occurrences of droughts for each station BMKG for SPEI-1 and SPEI-3. The results showed that the longer time scale of SPEI calculation then the number of occurrences of drought will be decrease however length of drought will be increase.

4.3 Duration, severity and intensity of drought
Results of SPEI-1 calculation, obtained maximum duration of each station, the maximum value is shown in Figure 5.a ranges between 2 – 6 months or very short until short duration. The longest recorded at three stations, there are meteorology maritime Tanjung Priuk-Jakarta, meteorology station Citeko – Bogor, and meteorology station M. Salahudin – Bima, into the category short.

While the results of SPEI-3 shows the duration of the drought that occurred longer than SPEI-1. The maximum duration of SPEI-3 is shown in Figure 5.b ranges between 5-11 months in category short until medium duration. There are 2 stations with medium duration which 11 months duration, and the longest recorded at the geophysics station Tangerang and meteorology station Serang.

SPEI-1 calculation, obtained maximum severity of each station, the maximum value is shown in Figure 6.a ranges between very low and low category. The highest severity recorded at the meteorological station Citeko – Bogor occurred at 1985 which a peak of drought in February 1985 with index value -2.338 (extremely dry).

The maximum severity of SPEI-3 calculation is shown in Figure 6.a ranges between low and high category. The highest severity recorded at the meteorology station Serang occurred at 2002 – 2003 which a peak of drought in March 2003 with index value -1.802 (severely dry).

| NO | NOSTA     | STATION                              | DRY MONTHS | Description       |
|----|-----------|--------------------------------------|------------|-------------------|
| 1  | 88882     | Stageof Lembang                      | 4          | June - September  |
| 2  | 96733     | Sta. Klim. Kelas II Pondok Betung - Tangerang | 1          | August            |
| 3  | 96735     | Sta. Geof. Kelas I Tangerang         | 5          | June - October    |
| 4  | 97637     | Sta. Met. Kelas I Serang             | 5          | June - October    |
| 5  | 96739     | Sta. Met. Kelas III Budiarto - Curug | 3          | July - September  |
| 6  | 96741     | Sta. Met. Kelas I Maritim Tanjung Priok - Jakarta | 6          | May - October    |
| 7  | 96745     | Sta. Met. Kelas III Kemayoran - Jakarta | 4          | June - September  |
| 8  | 96751     | Sta. Met. Kelas III Citeko - Bogor   | 2          | July - August     |
| 9  | 96753     | Sta. Klim. Kelas I Darmaga - Bogor   | 0          | -                 |
| 10 | 96783     | Sta. Geof. Kelas I Bandung           | 4          | June - September  |
| 11 | 96835     | Sta. Klim. Kelas I Semarang          | 3          | June - August     |
| 12 | 96925     | Sta. Met. Kelas III Sangkapura - Bawean | 4          | July - October    |
| 13 | 96933     | Sta. Met. Kelas III Perak I - Surabaya | 6          | May - October    |
| 14 | 96935     | Sta. Met. Kelas I Juanda - Surabaya  | 4          | July - October    |
| 15 | 96937     | Sta. Met. Kelas II Maritim Perak II - Surabaya | 6          | May - October    |
| 16 | 96945     | Sta. Geof. Kelas II Tretes           | 4          | July - October    |
| 17 | 96987     | Sta. Met. Kelas III Banyuwangi       | 6          | May - October    |
| No | Code   | Station Name                          | Duration |
|----|--------|---------------------------------------|----------|
| 18 | 97230  | Sta. Met. Kelas I Ngurah Rai - Denpasar | May - October |
| 19 | 97240  | Sta. Met. Kelas II Selaparang - Mataram | June - October |
| 20 | 97270  | Sta. Met. Kelas III M. Salahuddin - Bima | April - October |
| 21 | 97260  | Sta. Met. Kelas III Sumbawa Besar      | May - October |
| 22 | 97374  | Sta. Klim. Kelas II Lasiana - Kupang   | April - October |

**Figure 4.** The numbers of drought events for 1985 – 2014 in Java, Bali and Nusa Tenggara.

(a). SPEI-1 values

(b). SPEI-3 values

**Figure 5.** Maximum duration of drought in Java, Bali and Nusa Tenggara.
Figure 6. Maximum severity of drought in Java, Bali and Nusa Tenggara.

The maximum intensity for SPEI with time scales 1 (SPEI-1) and 3 (SPEI-3) months shown in Figure 7. The magnitude of the intensity its mean in one period of drought has a high severity and short duration. For SPEI-1, the highest intensity that occurred in geophysics station Lembang – Bandung about -2.931 in October 2012 with a value of severity -2.931 with a month duration. And the highest intensity for SPEI-3 was recorded in meteorology station Selaparang – Mataram about -2.485 with severity -7.455 and duration of 3 months occurred in June – August 2009.
Based on the statement above, that the longer of the time scale of SPEI then the number occurrences of drought event will decrease but the duration of the drought will increase. From the calculations, obtained the longest and strongest drought occurred at meteorology station Serang – Banten, with long duration is 11 months and severity -16.816 at October 2002 until August 2003. In one period of drought event, the longest it doesn't mean the strongest, and vice versa.

Table 4 shows the summary results of duration, severity and intensity calculation for each station with the time scales 1 and 3 months. Recapitulation shown apparent difference in duration, severity and intensity of each region, it describe the characteristics of drought in one regions had a difference with other regions.

Table 4. Recapitulation of drought events the longest and strongest for SPEI-1 and SPEI-3.

| NO | STATIONS | TIME SCALE | LONGEST | STRONGEST | HIGHEST |
|----|----------|------------|---------|-----------|---------|
|    |          |            | YEAR    | D         | YEAR    | S       | YEAR    | I       |
| 1  | 88882    | SPEI-1     | 1991    | 4         | 1991    | -6.062  | 2012    | -2.931  |
|    |          | SPEI-3     | 2012    | 4         | 2012    | -9.575  | 2012    | -2.394  |
| 2  | 96733    | SPEI-1     | 2011    | 3         | 2011    | -5.131  | 2007    | -1.969  |
|    |          | SPEI-3     | 1994 - 1995 | 8   | 2011    | -10.353 | 2003    | -1.753  |
|    |          | SPEI-1     | 2012    | 3         | 2012    | -4.374  | 2002    | -1.852  |
|    |          | SPEI-3     | 1997 - 1998 | 11  | 1997 - 1998 | -14.994 | 2011    | -1.787  |
| 3  | 96735    | SPEI-1     | 2009    | 5         | 2009    | -6.520  | 2003    | -2.170  |
|    |          | SPEI-3     | 2002 - 2003 | 11  | 2002 - 2003 | -16.816 | 1985    | -1.888  |
| 4  | 96737    | SPEI-1     | 1991    | 4         | 1991    | -5.303  | 1985    | -2.156  |
|    |          | SPEI-3     | 1997 - 1998 | 8   | 1997 - 1998 | -12.451 | 1999    | -1.642  |
| 5  | 96739    | SPEI-1     | 2003    | 6         | 2003    | -8.843  | 2010    | -2.608  |
|    |          | SPEI-3     | 1997 - 1998 | 7   | 1997 - 1998 | -9.481  | 2003    | -2.322  |
| 6  | 96741    | SPEI-1     | 2002    | 5         | 2002    | -6.891  | 2014    | -2.494  |
|    |          | SPEI-3     | 1997 - 1998 | 10  | 1997 - 1998 | -13.056 | 2003    | -1.760  |
| 7  | 96751    | SPEI-1     | 1985    | 6         | 1985    | -11.121 | 2003    | -2.035  |
References helps the incidence of droughts relationship with the global phenomena such as El-nino. Duration, severity and intensity with long time scales such as 6 and 12 months, and next analysis it drought events, and the difference for one region to another. In the future needs to calculate the And SPEI-3 give the results that meteorology station had the longest and strongest drought event with drought of SPEI-1 occurred in meteorology station Citeko which range duration 6 months at 1985. Occurrences of drought will decrease but the dryness will be increase. Duration, severity and intensity drought in each stations been identified. The longer of the time scale of SPEI then the number of Analysis of duration, severity, and intensity of drought in Java, Bali and Nusa Tenggara had been conducted using SPEI with time scales 1 and 3 months. Twenty two meteorology station were used for 5. Summary and Conclusion Analysis of duration, severity, and intensity of drought in Java, Bali and Nusa Tenggara had been conducted using SPEI with time scales 1 and 3 months. Twenty two meteorology station were used for a period of 30 years (1985 – 2014). The results shows that duration, severity and intensity of drought increase from western to eastern part of Indonesia. The Longest of drought, the strongest severity of drought in each stations been identified. The longer of the time scale of SPEI then the number of occurrences of drought will decrease but the dryness will be increase. Duration, severity and intensity were calculated for Java, Bali and Nusa Tenggara with the following the longest and the strongest drought of SPEI-1 occurred in meteorology station Citeko which range duration 6 months at 1985. And SPEI-3 give the results that meteorology station had the longest and strongest drought event with 11 months duration from October 2002 until August 2003. By calculating the duration, severity and intensity of each region can describe the characteristics of drought events, and the difference for one region to another. In the future needs to calculate the duration, severity and intensity with long time scales such as 6 and 12 months, and next analysis it helps the incidence of droughts relationship with the global phenomena such as El-nino.

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Information

|   |   |   |   |   |   |
|---|---|---|---|---|---|
| SPEI-3 | 2002 - 2003 | 6 | 1985 | -11.168 | 1985 | -2.234 |
| SPEI-3 | 2010 - 2011 | 4 | 2010 - 2011 | -6.460 | 2010 | -2.135 |
| SPEI-3 | 2006 | 9 | 2006 | -13.297 | 2001 | -2.128 |
| SPEI-1 | 1991 | 4 | 1991 | -6.249 | 2010 | -1.906 |
| SPEI-3 | 2006 | 8 | 2006 | -11.645 | 1991 | -2.026 |
| SPEI-3 | 1997 - 1998 | 7 | 1997 - 1998 | -9.034 | 2007 | -1.822 |
| SPEI-3 | 2014 | 3 | 2014 | -3.688 | 1998 | -2.003 |
| SPEI-3 | 1997 - 1998 | 7 | 1997 - 1998 | -9.034 | 2007 | -1.822 |
| SPEI-3 | 2014 | 3 | 2014 | -4.589 | 2004 | -2.129 |
| SPEI-3 | 2005 | 7 | 2005 | -10.808 | 1997 - 1998 | -1.997 |
| SPEI-3 | 2009 | 4 | 2009 | -7.134 | 2014 | -2.289 |
| SPEI-3 | 2009 | 8 | 2009 | -11.083 | 2004 | -1.899 |
| SPEI-3 | 2009 | 4 | 2009 | -6.532 | 2010 | -2.628 |
| SPEI-3 | 2008 | 9 | 2008 | -12.434 | 2009 | -1.675 |
| SPEI-3 | 2009 | 4 | 2009 | -7.413 | 1991 | -2.118 |
| SPEI-3 | 2006 - 2007 | 6 | 2006 - 2007 | -8.779 | 2009 | -1.898 |
| SPEI-3 | 2008 | 4 | 2008 | -5.124 | 2007 | -2.001 |
| SPEI-3 | 2006 - 2007 | 8 | 2006 - 2007 | -11.647 | 1997 | -1.699 |
| SPEI-1 | 1992 | 5 | 1992 | -6.739 | 2005 | -2.067 |
| SPEI-3 | 1991 - 1992 | 9 | 1991 - 1992 | -14.909 | 1998 | -1.708 |
| SPEI-3 | 1997 - 1998 | 5 | 1997 - 1998 | -7.164 | 2001 | -2.334 |
| SPEI-3 | 1997 - 1998 | 9 | 1997 - 1998 | -14.934 | 1995 | -1.969 |
| SPEI-3 | 2010 | 3 | 2010 | -3.934 | 2000 | -2.177 |
| SPEI-3 | 1997 - 1998 | 6 | 1997 - 1998 | -10.283 | 2009 | -2.485 |
| SPEI-3 | 2014 | 2 | 2014 | -3.927 | 2005 | -2.771 |
| SPEI-3 | 2004 | 6 | 2004 | -8.090 | 2009 | -1.916 |
| SPEI-3 | 2009 | 6 | 2009 | -8.606 | 2010 | -2.639 |
| SPEI-3 | 2009 - 2010 | 9 | 2009 - 2010 | -16.509 | 1997 | -1.856 |
| SPEI-3 | 2013 | 3 | 2013 | -4.015 | 2002 | -2.456 |
| SPEI-3 | 2006 - 2007 | 5 | 2006 - 2007 | -9.212 | 2012 | -1.930 |

Information:

D : Length of drought (Duration) in the month; S : Severity; I : Intensity
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