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

To cite this article: N L Adhyani *et al* 2017 *IOP Conf. Ser.: Earth Environ. Sci.* **58** 012040

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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 identify 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 the SPEI method, it 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 are agricultural centers 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 of recording data and completeness of data (empty data minimum). Because the SPEI calculation is 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. 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 for each station. The list of stations is shown in Table 3, while the position of the station is shown in Figure 1.

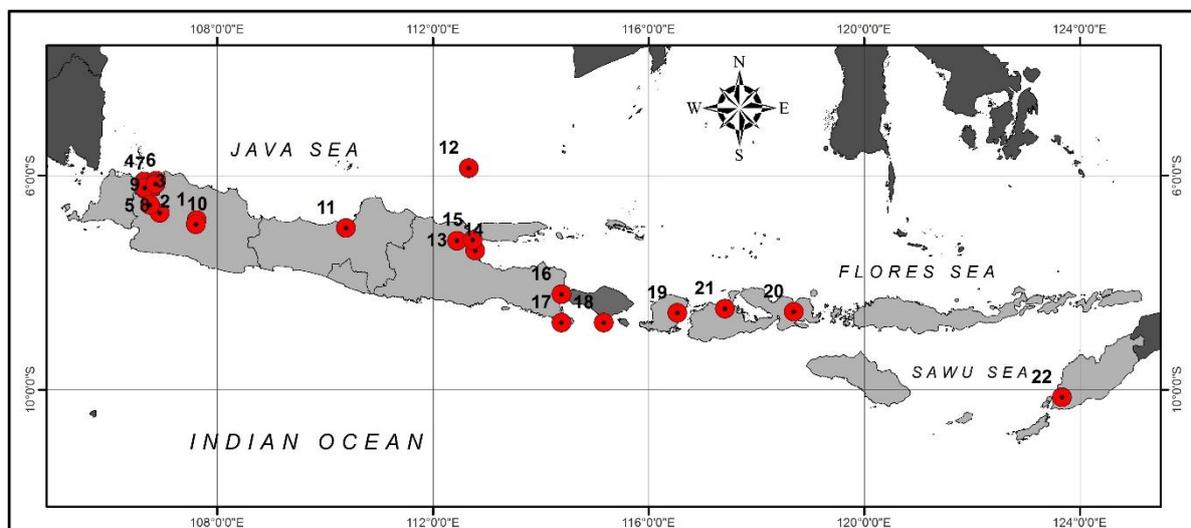


Figure 1. Location map of the 22 stations BMKG in Java, Bali and Nusa Tenggara.

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	-6.5536	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:

$$p = \frac{p_1 + p_2 + p_3 + \dots + p_n}{n}$$

where p is missing rainfall data; $p_1, p_2, p_3, \dots, p_n$ 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

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

where T is the monthly-mean temperature ($^{\circ}\text{C}$); 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

$$N = \left(\frac{24}{\pi} \right) \varpi_s$$

where ϖ_s is the hourly angle of sun rising, which is calculated using $\varpi_s = \arccos(-\tan\varphi \tan\delta)$, where φ is latitude in radians and δ is the solar declination in radians, calculated using

$$\delta = 0.4093 \left(\frac{2\pi J}{365} - 1.405 \right),$$

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,

$$D_i = P_i - PET_i,$$

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 $D_{i,j}^k$ 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

$$X_{i,j}^k = \sum_{l=13-k+j}^{12} D_{i-1,l} + \sum_{l=1}^j D_{i,l}$$

if $j < k$ and

$$X_{i,j}^k = \sum_{l=j-k+1}^j D_{i,l}$$

if $j \geq k$ and

where $D_{i,l}$ is the $P - PET$ 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 γ 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 τ_3 and L kurtosis τ_4) must be calculated. Here τ_3 and τ_4 are calculated as follows:

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

where λ_2 , λ_3 , and λ_4 are L-moments of the D series, obtained from probability-weighted moments (PWMs) using the formulas

$$\begin{aligned} \lambda_1 &= w_0, \\ \lambda_2 &= w_0 - 2w_1, \\ \lambda_3 &= w_0 - 12w_1 + 30w_2 - 20w_3, \end{aligned}$$

The PWMs of order s are calculated as

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

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 τ_3 and τ_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

$$f(x) = \frac{\beta}{\alpha} \left(\frac{x - \gamma}{\alpha} \right)^{\beta-1} \left[1 + \left(\frac{x - \gamma}{\alpha} \right)^{\beta} \right]^{-2}$$

where α , β , dan γ 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]:

$$\begin{aligned} \beta &= \frac{2w_1 - w_0}{6w_1 - w_0 - 6w_2} \\ \alpha &= \frac{(w_0 - 2w_1)\beta}{\Gamma\left(1 + \frac{1}{\beta}\right)\Gamma\left(1 - \frac{1}{\beta}\right)} \\ \gamma &= w_0 - \alpha\Gamma\left(\frac{1+1}{\beta}\right)\Gamma\left(\frac{1-1}{\beta}\right) \end{aligned}$$

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

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

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

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],

$$SPEI = W - \frac{C_0 + C_1W + C_2W^2}{1 + d_1W + d_2W^2 + d_3W^3}$$

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

$$S = - \sum_{i=1}^D SPEI_i$$

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

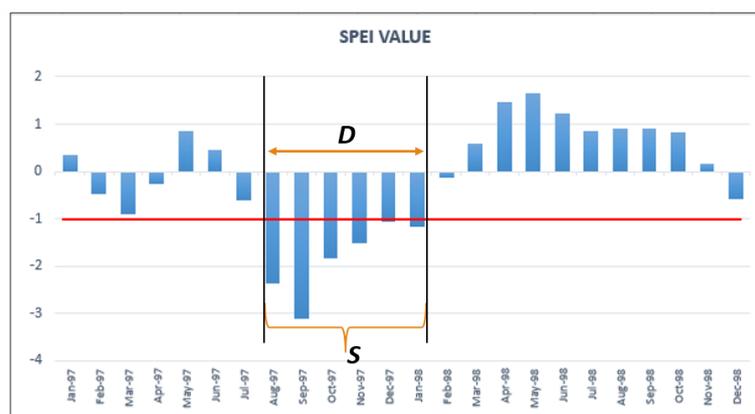


Figure 2. Definition of drought characteristics.

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:

Table 2. Classification Value of SPI/SPEI.

SPI/SPEI Value	
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.

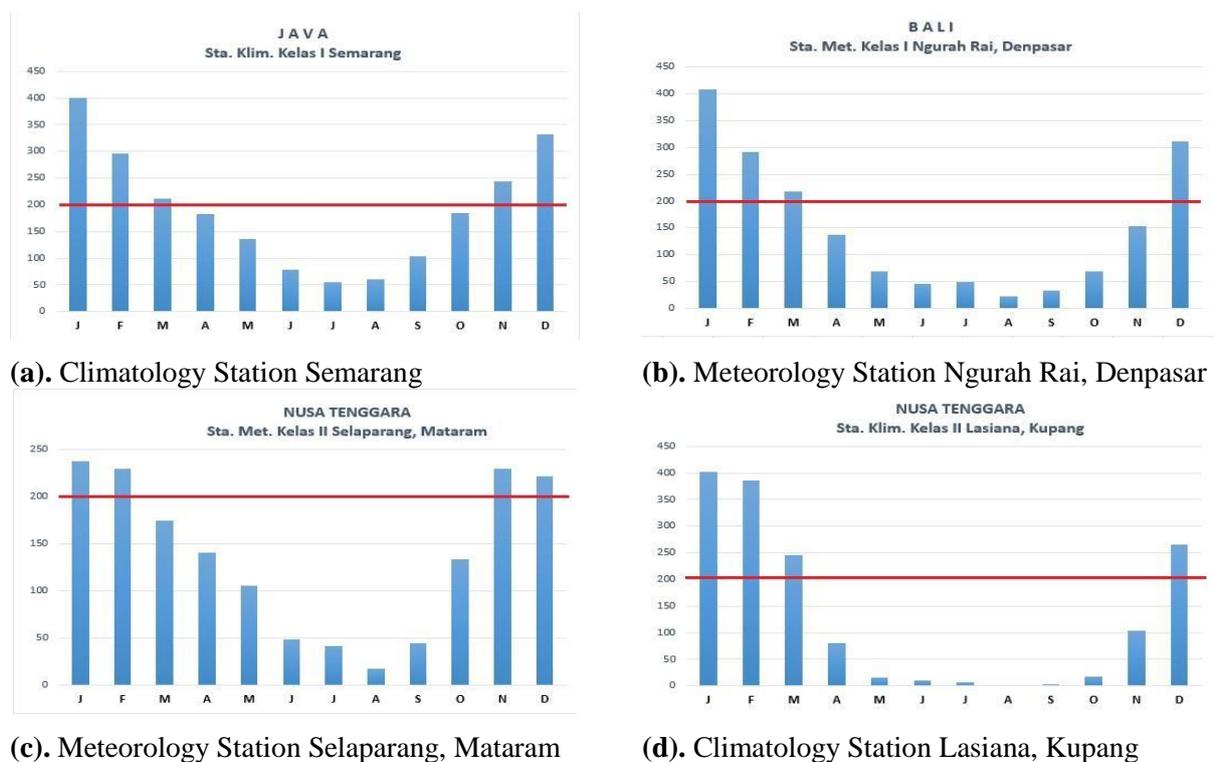


Figure 3. Average Monthly Rainfall of 30 years (1985 – 2014) in Java, Bali and Nusa Tenggara

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).

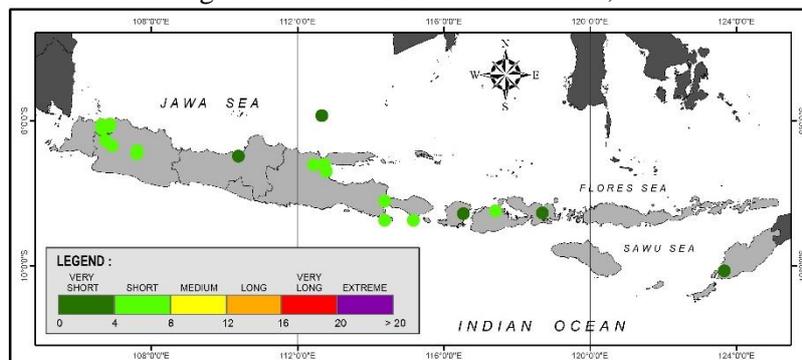
Table 3. Recapitulation of Dry Months in Java, Bali and Nusa Tenggara.

NO	NOSTA	STATION	DRY MONTHS	
			Total	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

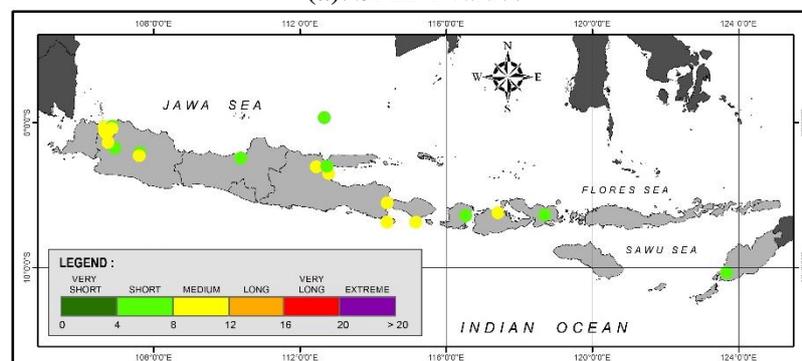
18	97230	Sta. Met. Kelas I Ngurah Rai - Denpasar	6	May - October
19	97240	Sta. Met. Kelas II Selaparang - Mataram	4	June - October
20	97270	Sta. Met. Kelas III M. Salahuddin - Bima	7	April - October
21	97260	Sta. Met. Kelas III Sumbawa Besar	6	May - October
22	97374	Sta. Klim. Kelas II Lasiana - Kupang	7	April - October



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

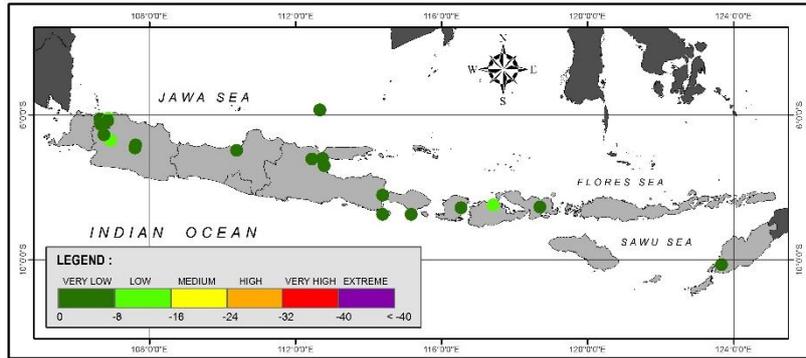


(a). SPEI-1 values

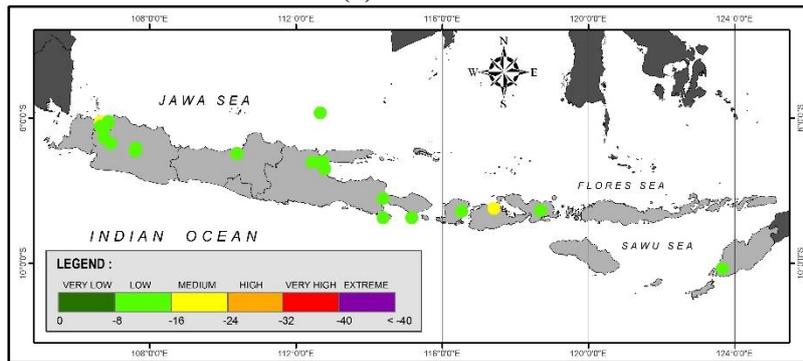


(b). SPEI-3 values

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



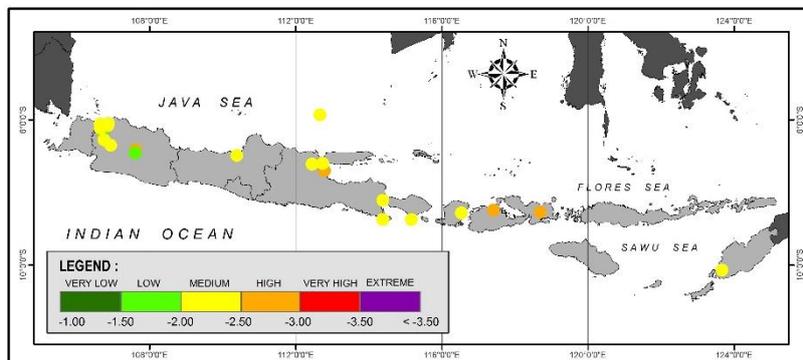
(a). SPEI-1.



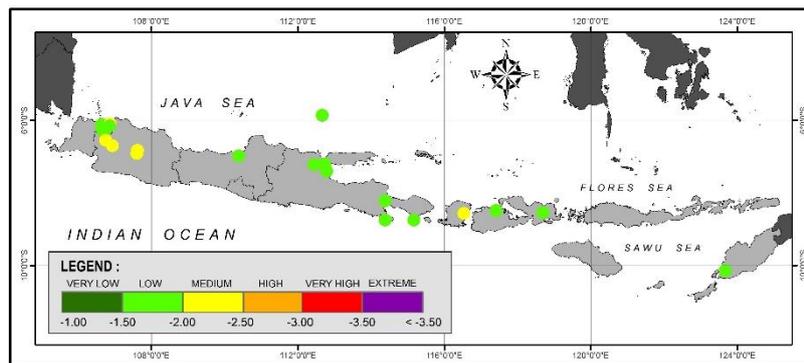
(b). SPEI-3.

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.



(a). SPEI-1



(b). SPEI-3.

Figure 7. Maximum intensity of drought in Java, Bali and Nusa Tenggara.

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
3	96735	SPEI-1	2012	3	2012	-4.374	2002	-1.852
		SPEI-3	1997 - 1998	11	1997 - 1998	-14.994	2011	-1.787
4	96737	SPEI-1	2009	5	2009	-6.520	2003	-2.170
		SPEI-3	2002 - 2003	11	2002 - 2003	-16.816	1985	-1.888
5	96739	SPEI-1	1991	4	1991	-5.303	1985	-2.156
		SPEI-3	1997 - 1998	8	1997 - 1998	-12.451	1999	-1.642
6	96741	SPEI-1	2003	6	2003	-8.843	2010	-2.608
		SPEI-3	1997 - 1998	7	1997 - 1998	-9.481	2003	-2.322
7	96745	SPEI-1	2002	5	2002	-6.891	2014	-2.494
		SPEI-3	1997 - 1998	10	1997 - 1998	-13.056	2003	-1.760
8	96751	SPEI-1	1985	6	1985	-11.121	2003	-2.035

		SPEI-3	2002 - 2003	6	1985	-11.168	1985	-2.234
9	96753	SPEI-1	2010 - 2011	4	2010 - 2011	-6.460	2010	-2.135
		SPEI-3	2006	9	2006	-13.297	2001	-2.128
10	96783	SPEI-1	1991	4	1991	-6.249	2010	-1.906
		SPEI-3	2006	8	2006	-11.645	1991	-2.026
11	96835	SPEI-1	2014	3	2014	-3.688	1998	-2.003
		SPEI-3	1997 - 1998	7	1997 - 1998	-9.034	2007	-1.822
12	96925	SPEI-1	2014	3	2014	-4.589	2004	-2.129
		SPEI-3	2005	7	2005	-10.808	1997 - 1998	-1.997
13	96933	SPEI-1	2009	4	2009	-7.134	2014	-2.289
		SPEI-3	2009	8	2009	-11.083	2004	-1.899
14	96935	SPEI-1	2009	4	2009	-6.532	2010	-2.628
		SPEI-3	2008	9	2008	-12.434	2009	-1.675
15	96937	SPEI-1	2009	4	2009	-7.413	1991	-2.118
		SPEI-3	2006 - 2007	6	2006 - 2007	-8.779	2009	-1.898
16	96945	SPEI-1	2008	4	2008	-5.124	2007	-2.001
		SPEI-3	2006 - 2007	8	2006 - 2007	-11.647	1997	-1.699
17	96987	SPEI-1	1992	5	1992	-6.739	2005	-2.067
		SPEI-3	1991 - 1992	9	1991 - 1992	-14.909	1998	-1.708
18	97230	SPEI-1	1997 - 1998	5	1997 - 1998	-7.164	2001	-2.334
		SPEI-3	1997 - 1998	9	1997 - 1998	-14.934	1995	-1.969
19	97240	SPEI-1	2010	3	2010	-3.934	2000	-2.177
		SPEI-3	1997 - 1998	6	1997 - 1998	-10.283	2009	-2.485
20	97260	SPEI-1	2014	2	2014	-3.927	2005	-2.771
		SPEI-3	2004	6	2004	-8.090	2009	-1.916
21	97270	SPEI-1	2009	6	2009	-8.606	2010	-2.639
		SPEI-3	2009 - 2010	9	2009 - 2010	-16.509	1997	-1.856
22	97374	SPEI-1	2013	3	2014	-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

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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