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Assessment of Duration and Frequency of Drought by Percent Normal Precipitation Index (PNPI) for Lombok Island

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Abstrak: Meteorological drought is a climatic condition categorized by a scarcity of rainfall. Understanding the drought characteristics is a significant step appointed uncertain climate conditions due to current global climate change. This study aims to assess the duration and frequency of drought using the Normal Precipitation Index (PNPI) method to identify drought characteristics in the study area. The PNPI revealed a spatial variation in percent value monthly rainfall to average rainfall across the island of Lombok that prolonged and severe droughts have occurred in entire study areas with varying duration and frequency. PNPI method in analyzing drought events in the island of Lombok showed that Sopak is the driest area and Sekotong is the wettest one.

Keywords: Meteorological drought; Drought duration; Drought frequency; Percent normal precipitation index

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INTRODUCTION

Drought is a phenomenon that occurs as a result of seasonal circulation under the influence of the global climate, which is characterized by the availability of water that is far from the water needs for life, agriculture and other activities. Droughts often do not show real symptoms as other natural disasters but slow on-set and significantly impact the environment and human life. The impact of a drought event can be severe and affect an extensive area. Drought is directly related to public health problems, usually from poor sanitation to disease outbreaks, and can broadly lead to poverty and underdevelopment.

Drought analysis is needed to support agricultural activities towards food security. Agriculture, especially rice, is the largest water consumer and vulnerable to drought. Drought analysis calculations usually produce an index that describes the severity of the drought. Drought indices are largely used in dryness hazard assessment and environmental management (Bouwer et al., 2014; Dabanli, 2018; Kim et al., 2015; Teague et al., 2021; Wilhite et al., 2014), to assess forest fire hazards (Littell et al., 2016; McEvoy et al., 2019; Vilchis-Francés et al., 2021), to predict crop yield (Liu et al., 2018; Parsons et al., 2019), to provide an early drought warning system (Lohani & Loganathan, 1997; Masinde, 2015; McEvoy et al., 2019; Sharafi et al., 2020; Sutanto et al., 2020).

Droughts are grouped into meteorological shortages, agricultural deficits, and hydrological droughts. Meteorological drought is related to rainfall under normal conditions in a season. Agricultural drought is

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related to reduced water content in the soil (soil moisture), and hydrological drought is related to reduced water supply from the earth.

Meteorological drought describes as reduced rainfall which is the first indication of drought conditions. There are many ways for detecting meteorological drought with various advantages and disadvantages. Among the methods that are widely used are SPI (Standardized Precipitation Index), PDSI (Palmer Drought Severity Index), Decile Index, Theory of Run, PNPI (Percent Normal Precipitation Index), WSI (surface water supply index), and many others.

This study aims to identify the characteristics of drought on the island of Lombok using the Percents of Normal Precipitation Index method, which determines the level of the deficiency based on the deviation of rainfall from its average rate. The advantages of this index are that simple to use and easy to calculate. A general audience can also easily understand, and it can be calculated for various time scales of interest (e.g., day, week, month, season, year). But usually, the time scales range from a single month to a couple of months, representing a particular season to an annual (Ndlovu & Demlie, 2020; Nikbakht et al., 2013).

METHOD

Study area

The study was conducted in four different dry areas on the island of Lombok, which is often got drought experienced.



Figure 1. Study Area

Lombok Island is one of the islands laid in West Nusa Tenggara province, Indonesia. Lombok Island is located between the islands of Bali and Sumbawa, at latitude $115^{\circ} 46' - 119^{\circ} 5'$ and longitude $8^{\circ} 10' - 9^{\circ} 5'$. Lombok Island's climate character is unique because Lombok is a transitional area from a wet climate in the west, namely Java, Bali, Kalimantan, and a dry climate in the East, namely the island of Sumbawa and Sumba island. The island of Lombok has a climatic zone that varies from dry to wet areas.

Data Collection

The data needed for the drought index analysis using the PNPI method is rain data. The rain data was collected from measurements recorded by several rain stations spread over the island of Lombok. Several rain stations involved in this study were selected in areas that frequently experience drought to represent the drought conditions in those places, such as Sekotong in West Lombok, Pringgabaya in East Lombok, Sopak in North Lombok, and Rembitan in Central Lombok.

Table 1. The availability of rain data measurement

Area	Longitude	Latitude	Data availability
Sekotong	116 05 12	8 44 03	1990-2018
Pringgabaya	116 37 39	8 33 29	1995-2016
Sopak	116 25 09	8 16 29	1994-2017
Rembitan	116 12 23	8 49 30	1994-2017

The PNI formula for characterizing drought severity is defined by dividing the observed monthly rainfall (Pi) by the normal rainfall (P) and multiplying by 100%. The normal rainfall is typically considered a mean of 30 years precipitation. It can also be expressed by the following equation (1), while the classification category of the drought index is presented in Table 2.

$$PNPI = \frac{P_i}{P} \times 100\% \dots\dots\dots (1)$$

Where PNPI is Percent Normal Index, Pi is the observed monthly rainfall (mm), and P is the normal monthly (average) rainfall (mm).

Table 2. The PNPI drought Categories

Criterion (%)	Class Category
PNI > 80	Normal
70 < PNI < 80	Slightly drought
55 < PNI < 70	Moderately drought
40 < PNI < 55	Severely drought
PNI < 40	Extremely drought

Analyzing the characteristics of meteorological drought on the island of Lombok using the PNPI method, the parameters to be studied are the duration of the lack and the number of occurrences (relative frequency). Drought duration is the length of time from a drought beginning or from the beginning of a historical drought to its end. According to the WMO17 SPI User Guide in defining drought duration, a drought event starts when the SPI value equals -1 and ends when the SPI value changes to positive (Svoboda et al., 2012). Based on this definition, it can be interpreted that drought begins when it is categorized as moderate dry and ends when it turns into a mild or normal category. Similarly, the dry condition in this study starts when the PNPI number is less than 70% when the class is moderately dry.

RESULT AND DISCUSSION

This research was located throughout the island of Lombok, especially in areas that often experience drought. There are Sekotong in West Lombok, Rembitan in Central Lombok, Pringgabaya in East Lombok, and Sopak in North Lombok. These areas tend to have a dry climate characterized by a short duration of the rainy season and low annual rainfall. Deficiency almost always occurs every year In these areas, so the local government must provide clean water for the community's needs. The annual rainfall data is presented in Figure 2.

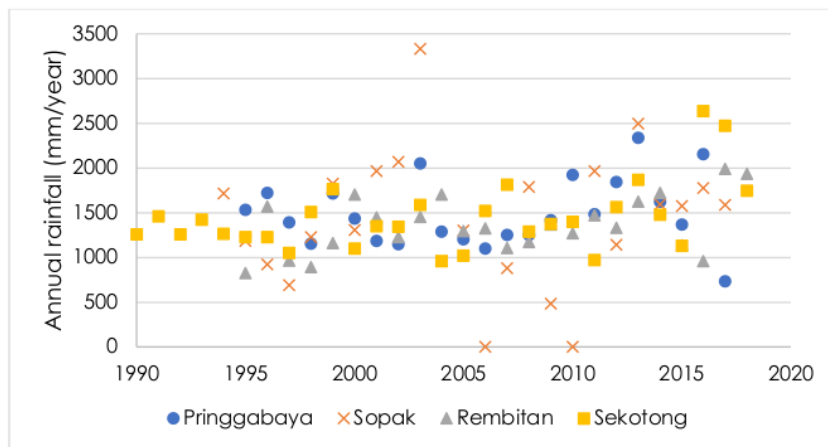


Figure 2. Annual rainfall in the study area

The drought characteristics in these areas were then carried out using the PNPI method for simplicity and reliability. PNPI method determines the drought index by calculating the percentage value of monthly

rainfall against normal monthly rainfall, defined as the rainfall accumulation observed in one month divided by the long-term average value and multiplied by 100%. The index is in percentage value. The smaller the percentage produced, the more severe the level of drought occurred.

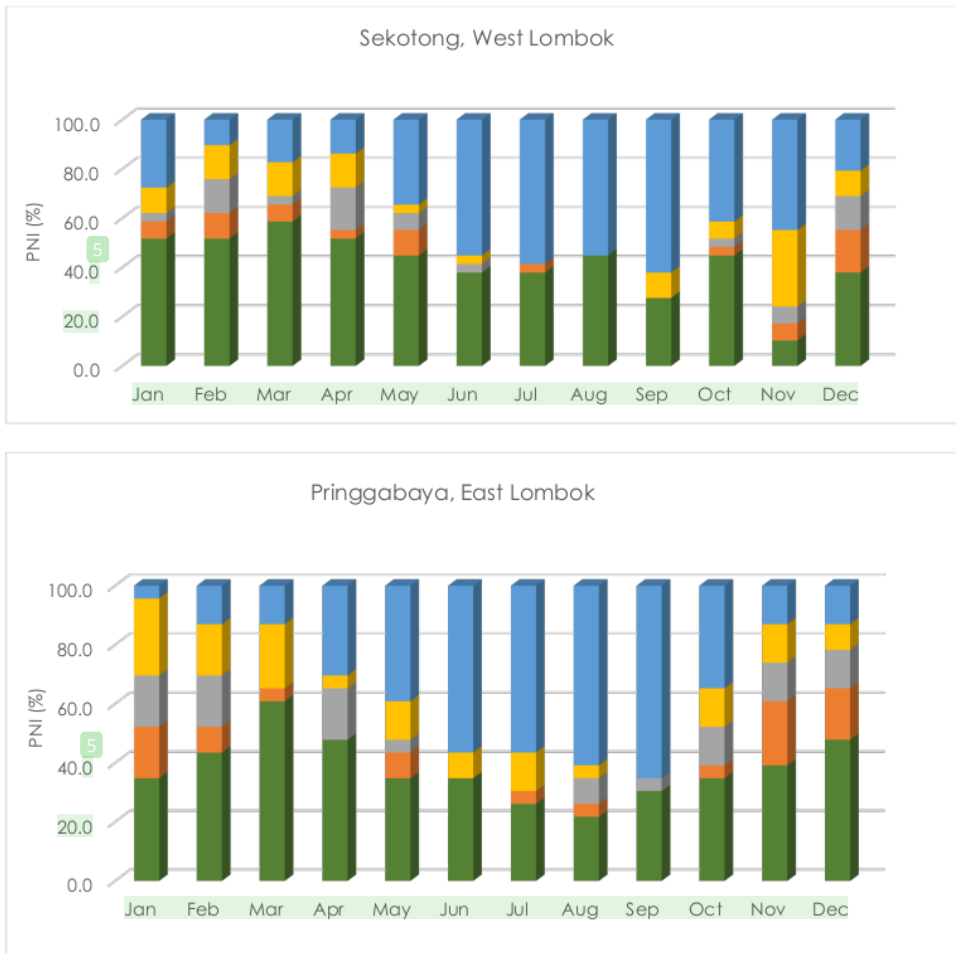
There is a variation in the PNPI drought index resulting from year to year over the island of Lombok, where some of the years are drier, and others are wetter. The spatial distribution of the PNPI drought Index across the island of Lombok from 1990 to 2018 is shown in table 3. This table shows the percentage of the number of months of drought events to the total number of months analyzed.

Table 3. Percentage of Drought Occurrence in categories based on PNPI result from 1990-2018 (%)

Site	N	SD	MD	SeD	ED
Sekotong	42	6	6	10	37
Pringgabaya	38	8	9	12	33
Sopak	32	4	4	5	55
Rembitan	36	3	6	11	43

Where: N=Normal, SD=Slightly Drought; MD=Moderate Drought; SeD=Severe Drought; ED=Extreme Drought.

Based on the WMO guides in categorizing a dry condition that the dry begins when it index categories as moderate dry (Svoboda et al., 2012), the number in table 3 shows that moderate to extreme drought in the study area has a higher frequency of occurrence than normal conditions. The results of the calculation of the drought index at each location are then presented in Figure 3.



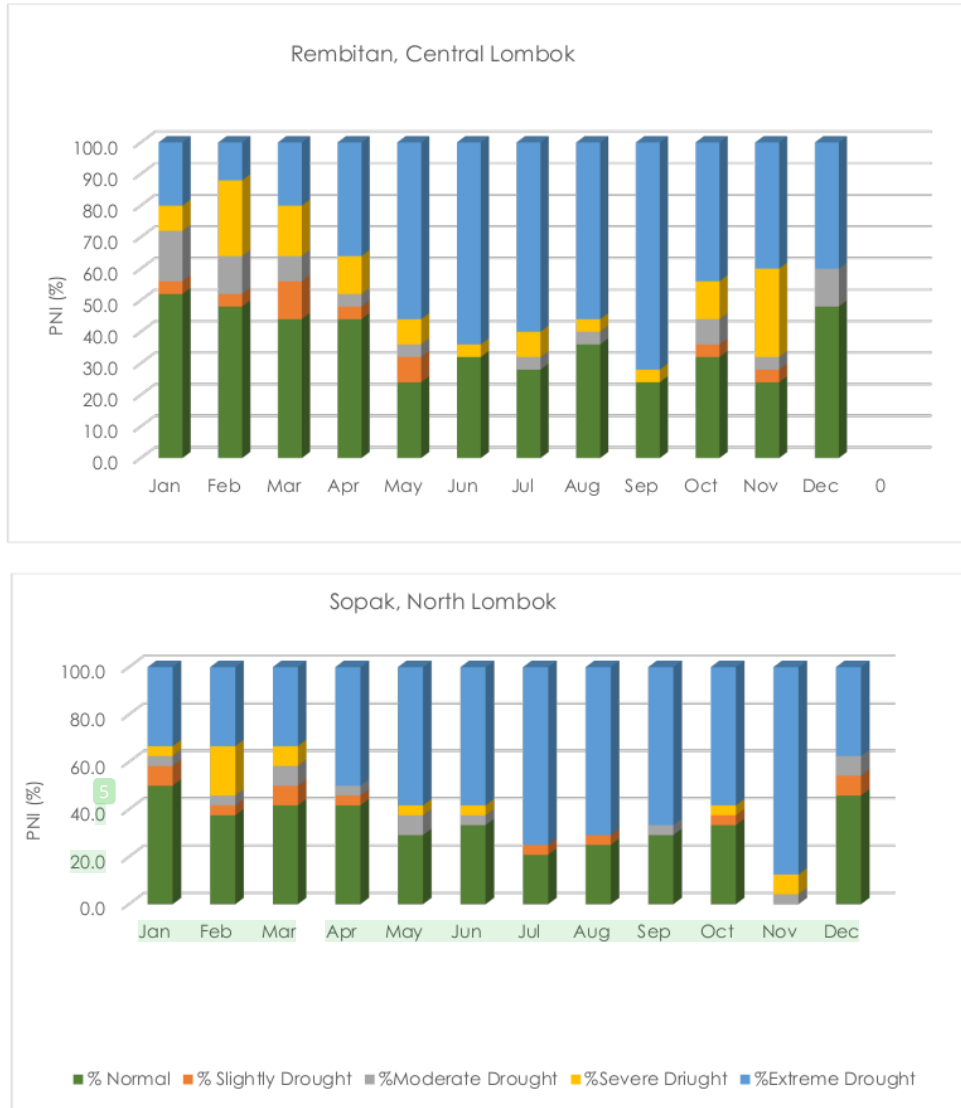


Figure 3. Frequency of drought occurrence

The calculation result of the drought index using the PNPI method shows that extreme dry events have occurred in all months from January to December. However, there are differences in the distribution of extreme dry events. In the Sekotong, and Pringgabaya areas, more extreme dry events occurred between April and October and peaked in July. But in Rembitan and Sopak, the extreme dry events peaked in September and November, respectively.

The frequency of drought presented in Table 3 only describes the number of drought events during the study year and does not describe the drought length for each event. Drought duration is essential to consider because it provides information about the duration of drought stress and its severity. The following analysis calculates the duration of each drought event at each location.

The calculation of drought duration begins when the drought index shows moderate drought and ends when conditions are normal or slightly dry. An illustration of calculating drought duration is shown in Figure 4 using data from 1990-1992 for the Sekotong area.

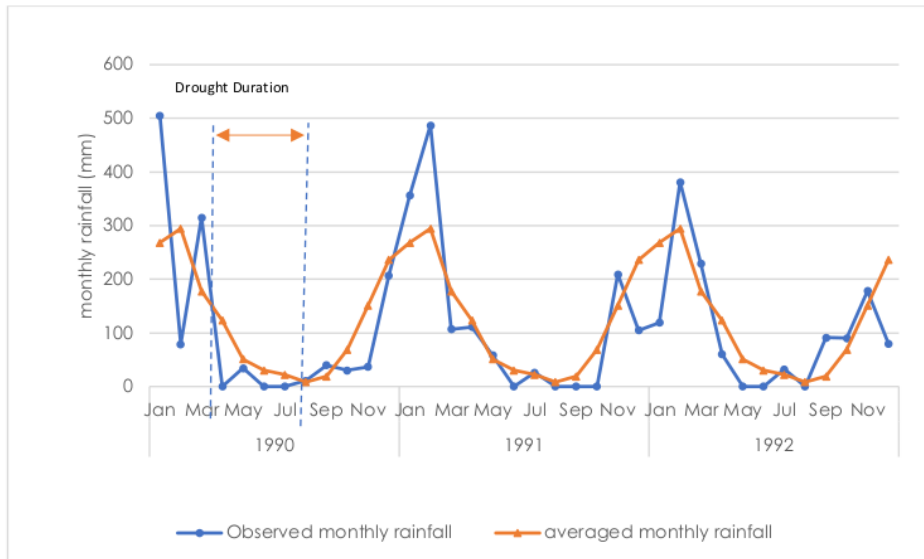


Figure 4. The illustration of the Drought Duration calculation

The calculation result of drought duration to frequency for all locations is presented in figure 5.

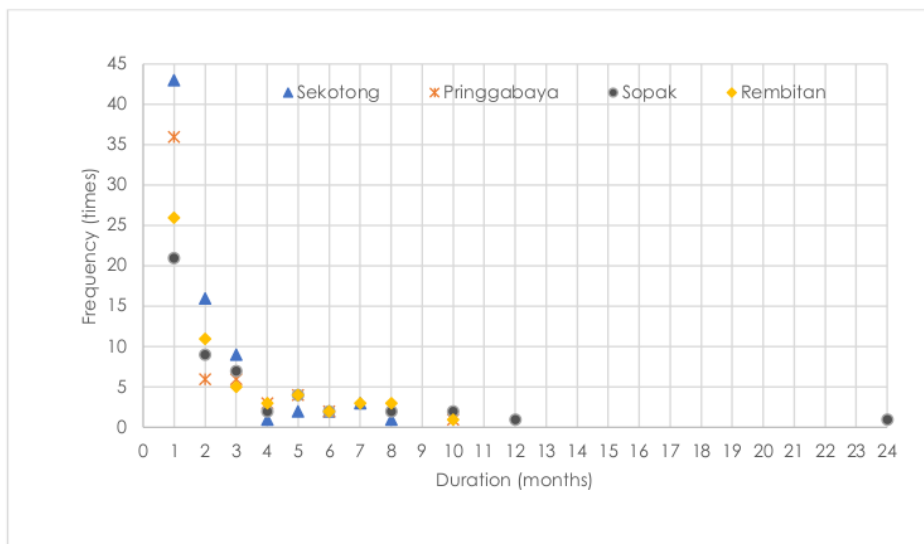


Figure 5. Drought duration to frequency for the Island of Lombok, 1990-2018

The longest severe to extreme droughts were recorded in 2005-2007 for Sopak, the northern part of Lombok, from September 2005 to August 2007 (24 months), and the second one also noted in Sopak from May 2003 to April 2004 (12 months). Meanwhile, the longest severe to the extreme drought that occurred in other areas was nine (9) months in 2017 in Pringgabaya, the eastern part of the island of Lombok. Rembitan, the island's central region, recorded the longest extreme drought of 8 months in 2002, while Sekotong recorded the longest extreme drought of 6 months in 2002, 2004, 2006, and 2015. When a prolonged drought hits an area, in general, other areas also experience extreme drought in varying duration and generally shorter. However, the long dry season in 2002 was evenly distributed in all locations in this island, which is noted by the Meteorological, Climatological, and Geophysical Agency (BMKG) also happening throughout Indonesia influenced by the El Nino phenomenon (Indonesian Agency for Agricultural Research and Development, 2002).

Drought monitoring is critical for risk management and impact management in reducing the adverse effects of drought events (Sharafi et al., 2020). Therefore, it is crucial to understand the drought characteristics in an area to improve drought disasters mitigation and preparedness. The PNPI method can determine the severity of drought by the index produced. But this index cannot compare the drought conditions over spatial or temporal. Because the average rainfall for the different places is will be varied and never be the same, and so do for the different periods (Quiring, 2009).

This condition is in line with the most prolonged drought event in Sopak during 2005-2007, which is the longest drought recorded that occurred on the island of Lombok. Several studies stated that 2006 was when the El Nino and positive Indian Ocean Dipole coincided (Fadholi, 2013), which caused many drought events in various regions in Indonesia. However, PNPI resulted for the other areas of Lombok did not experience as severe and prolonged a drought as experienced in Sopak at the time. The PNPI shows more months of severe to extreme drought conditions spread over the entire time study, even in a short period. Periods dominated by normal conditions represent the occurrence of above-normal rainfall. The percentage of drought occurrence figured out in Figure 3 implied that Sekotong is the wettest area, and Sopak is the driest one.

CONCLUSION

The spatial distribution of the PNPI revealed a spatial variation in percent to normal rainfall across the island of Lombok and that wet and dry conditions are not peculiar to one region. The prolonged and severe droughts have occurred in entire study areas with varying duration and frequency. The duration and frequency analyses using PNPI showed that Sopak is the driest area and Sekotong is the wettest one.

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