Proceedings of the
1st International Conference on Environmental Health, Socioeconomic and Technology 2022
Lamongan, Indonesia, August 10-11 2022
Vol. 1, No. 1 (https://conference.unisla.ac.id/index.php/icehst/)

DROUGHT CHARACTERIZATION IN THE CORONG RIVER BASIN USING METEOROLOGICAL ANALYSIS

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ABSTRACT

East Java Province is the number one supplier of national rice production in Indonesia. Lamongan is one of the districts with the most rice production in East Java and ranks fifth nationally. The availability of national food is highly dependent on the availability of water in rivers, dams, and reservoirs. This study aims to characterize the drought in the Corong River Basin which is located between Lamongan Regency and Gresik Regency. These two districts are very prone to drought. The Corong watershed supplies water to the southern Lamongan area which is very prone to drought. This research method uses the analysis of The Standardized Precipitation Index (SPI). The parameters used are rainfall data from 2001-2020 in the Corong River Basin area from 3 rain stations, namely the Gondang, Lamongan, and Karangbinangun rain stations. From the results of the analysis of SPI-1, SPI-3, SPI-6, and SPI-12, the minimum drought occurred in 2007 with the lowest value of -3.6188 with the characteristics of a very dry drought.

KEYWORDS: *Drought; River Basin; Rainfall; The Standardized Precipitation Index*

1. INTRODUCTION

Drought occurs due to abnormal climatic conditions characterized by a decrease in water reserves (rainfall, afforestation, and soil moisture) (Nam et al., 2018) and increased evaporation (Hao et al., 2015; Woodcock et al., 2020). Droughts and other climate extremes (floods) are usually calculated using long-term rainfall records on specific timescales (Liu et al., 2020). For example, if the rainfall on a given time scale is significantly lower than the long-term average rainfall forecast on the same scale, drought is considered to have occurred over a certain period (Ayantobo et al., 2018). Drought results in significant economic losses in agricultural crop production (Kim et al., 2019). Determination of cropping patterns in sustainable agricultural production is very important to overcome the challenges posed by changes and extreme climate events such as floods and droughts, this greatly affects food production that is economically efficient, ecologically safe, and does not endanger the needs of future generations (Lesk et al., 2016).

Most studies over the last few decades have studied drought based on severity and magnitude using indices, such as the Standard Precipitation Index (SPI) (McKee et al., 1993), the Standard Precipitation Evapotranspiration Index (SPEI) (Vicente-Serrano et al., 2010), palmer drought severity index (PDSI) (Palmer, 1965) and so on. Among these indices, the SPI (McKee et al., 1993) is one of the most commonly used drought indices to monitor meteorological drought and its vulnerability over a time span (Ayantobo et al., 2018). The ability of rainfall-based drought indices (SPI, SPEI, and aSPI) to characterize agricultural drought is still not well understood (Ding et al., 2020;Wang et al., 2019). Quantitative evaluation of the meteorological and agricultural impacts of drought on food availability The future provides an important context for policymakers to make decisions to support sustainable crop production (Wang et al., 2020), but requires a comprehensive understanding of the relationship between spatiotemporal climatic variations, complex cropping systems, irrigation effects, and availability. water resources (Yao et al., 2020).

Lamongan Regency is an area that often experiences drought, especially in the southern part of Lamongan which is caused by uncertain climate change. This drought occurred in the months that should have entered the rainy season which resulted in a drought in Lamongan Regency that year (BPS,2018). The distribution of meteorological drought covers fifteen sub-districts spread over the central, southern, and eastern regions of Lamongan Regency. These sub-districts include Lamongan, Deket, Karangbinangun, Turi, Sukodadi, Kembangbahu, Glagah, Sukorame, Ngimbang, Blubuk, Modo, Kedungpring, tripe, Sekaran, and Laren sub-districts (Dewandaru, 2014). Lamongan Regency is one of the regencies located in East Java Province which has a fairly high level of potential disaster threat, especially the potential for floods and droughts. This is because the topography of Lamongan Regency is 50.17% at an altitude of 0-25 meters and the Lamongan Regency also has a relatively flat morphology, even in some areas there are many basins that are currently swampy (Andy Pratama, 2016).

One of the impacts of the drought is that the use and distribution of water in Lamongan Regency is disrupted and causes a lack of welfare in people's lives, especially in the agricultural sector. In this case, the profit from the agricultural sector decreases, because the farmers lack water to irrigate their rice fields. The total need for agricultural irrigation water in Lamongan Regency which has been calculated based on the area of drought risk is 3,320,905 L/month/m2. So that the area in the south or southeast of Lamongan Regency requires more irrigation networks, and the middle region with low and very low risk does not require irrigation. too many additional irrigation networks, just need to increase the existing irrigation (Wibisana, 2017)

In 2018 in Lamongan Regency a disaster occurred drought with a total area experiencing drought of 93,904 hectares that hit Modo District, Sarirejo District, Kembangbahu District, Sukodadi District, Bluluk District, Lamongan District, Sugio District, Tikung District, Kedungpring District, Sambeng District, Babat District and Brondong District. Almost all of the sub-districts that have been included in the drought-prone map are located in the southern region of Lamongan. Namely, District Tikung, Kembangbahu, Sarirejo, Modo, Kedungpring, Sugio, Sukodadi, Sambeng, Bluluk and Lamongan City Districts (Lamongan, 2019). Corong watershed is a watershed located in the southern Lamongan area so analysis of rivers is very useful for maintaining water availability in rivers and reservoirs (Waduk Gondang reservoir), determining cropping patterns, and disaster mitigation. This study aims to analyze meteorological drought using The Standardized Precipitation Index (SPI), this analysis uses rainfall variables at 3 rain stations, namely the Gondang reservoir rain station, Karangbinagun rain station, and Lamongan rain station. This study will analyze the characteristics of drought and drought duration

2. MATERIALS AND METHODS

2.1 Study Area

The Bengawan Solo River area is located between $110^{o}18'$ and $112^{o}\,45'$ east longitude and between $6^{o}\,49'$ and $8^{o}\,08'$ south latitude. River drainage area (DPS) ± 16,100 km2, located in the province of Java Central and East Java. Corong watershed is one of the major watersheds in the Bengawan Solo River Basin with an area of 8,304 km^2. The location of this research is located in the Corong River Basin, one of the largest watersheds in the Bengawan Solo River Basin.

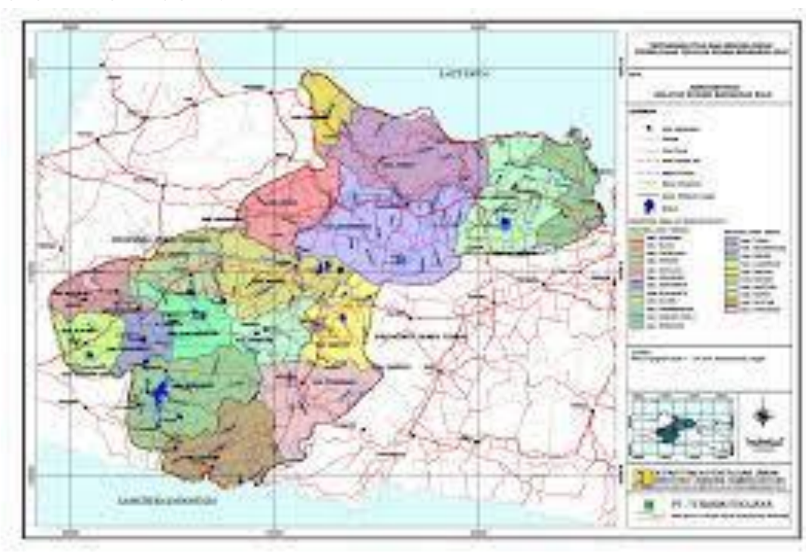

Figure 1. Bengawan Solo River Basin Administration Map
Source: Bengawan Solo River Basin Center, 2010

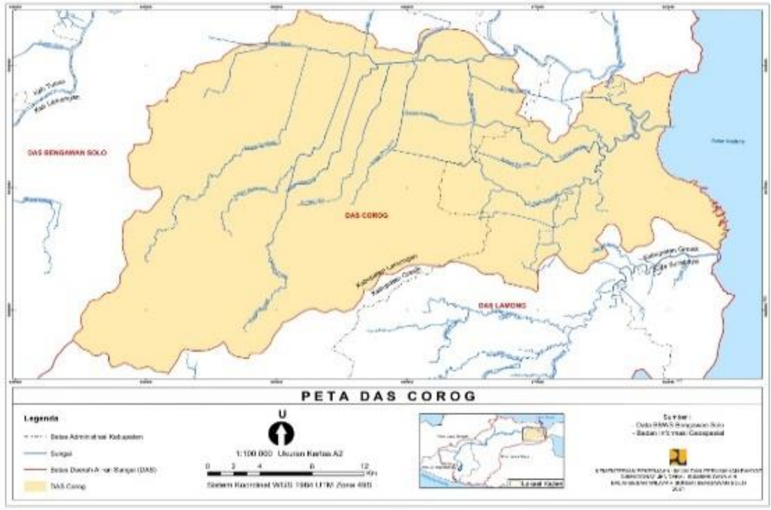

Figure 2. Corong River Basin Administration Map
Source: Bengawan Solo River Basin Center, 2020

2.2 Rainfall Data

Rainfall data used in this analysis Monthly rainfall data for 20 years (2001-2020). There are three rain stations used, namely Gondang Reservoir rain station, Karangbinangun rain station and Lamongan rain station. This study uses the Standardized Precipitation Index (SPI), a technique to determine the characteristics of drought using the main data of rainfall. The watershed map is used to see the extent of influence of each rain station and to determine the watershed area. Regional rain is normal precipitation throughout the perception region, not precipitation from a single point of perception. One sign of precipitation perception cannot overcome the volume of precipitation in one place. Strategies for calculating provincial rainfall from rain perception in several foci are separated into 5. Arithmetic strategies, Thiessen polygons, Ishoyet line techniques, dense line strategies, and elevation techniques (Sosrodarsono, 2003).

In this study, the Thiessen polygon was used because it is the most common inspection technique. This technique considers the weight of each station that handles the surrounding area. The Thiessen Polygon Strategy is used to calculate the provincial rainfall from each station that covers the surrounding area. In a space in the watershed, it is accepted that the rainfall has the same intensity that occurs at the nearest station so the recorded rainfall at a station leads to that area. (Triatmodjo, 2009).

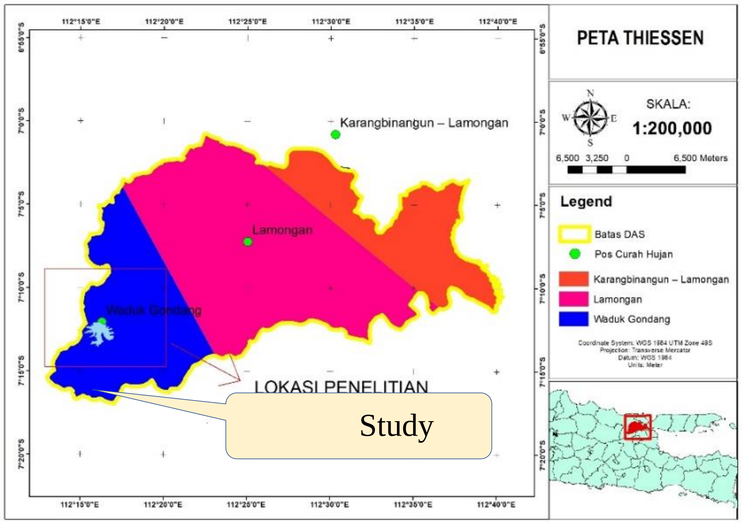

Figure 3. Thiessen polygon Corong River Basin
Source: Analysis results, 2021

2.3 The Standardized Precipitation Index (SPI)

The Standardized Precipitation Index (SPI) methodology is a rundown that is used to determine the deviation of rainfall from a run-of-the-mill in a wide area. To identify the strength of the dry season, as well as the standard of dry season occurrence in a certain period. The dry season time can be seen from the SPI value, assuming the SPI is -1 or less, this indicates that the dry season power has been reached and a positive SPI value indicates the end of the dry season. SPI and system grouping can be seen as follows:

Table 1. SPI Value and Classification

SPI Value	Classification
$\geq 2,00$	Extremely wet
1,50 s.d 1,99	Really wet
1,00 s.d 1,49	Pretty wet
-0,99 s.d 0,99	Close to normal
-1,00 s.d -1,49	Dry Enough
-1,50 s.d -1,99	Very dry
$\leq -2,00$	Extremely Dry

Source: (Hayes et al., 1999)

The general calculation formula with the SPI technique is as follows:

$$Z_{ij} = \frac{X_{ij-}X_j}{\sigma_j} \quad (1)$$

Where :

Z_{ij} = Variable Z, the year i to month j.
X_{ij} = monthly rainfall in i month of j month
X_j = rain month j, average
σ_j = monthly standard deviation.

2.4 Data Processing

The steps of data processing are described as follows:

1. Data Collection The required data are rainfall data and topographic maps obtained from BBWS Bengawan Solo. Rainfall data needed is from the nearest station.
2. Rain Data Processing steps:
   a. Input the observation rain data into monthly rain data in Microsoft Excel.
   b. Calculating the area of a rain station through ArcGIS.
   c. Calculating lost rainfall data with distance approach.
   d. Calculate the area's average rainfall with a Thiessen polygon. The data on the area of the rain station coverage area obtained from PU calculated the coefficients and searched for the regional average rainfall from the complete observations.
3. Calculation of Standardized Precipitation Index (SPI)

Calculation of the SPI value based on the number of gamma distributions with the following formula:

$$G(x) = x\int_o^x g(x)dx = \frac{1}{\beta^{\alpha} I(a)}\int_o^x t^{a-1}\ e^{\frac{-x}{\beta}}dx \qquad (2)$$

The values of and are estimated for each rain station using the following formula:

$$\alpha = \frac{X^2}{Sd^2} \qquad (3)$$

$$\beta = \frac{x}{\alpha} \qquad (4)$$

With:

$$A = \ln(\ddot{x}) - \frac{\sum \ln(x)}{n} \qquad (5)$$

n = amount of rainfall data

Since the gamma function is undefined for x=0, then the value of G(x) becomes:

$$H(x) = q + (1-q)G(x) \qquad (6)$$

With a value of q = m/n with a value of m is the number of 0 mm rain events in the rain data series.

Calculation of SPI value for $0 < H(x) \leq 0.5$,

$$Z = SPI = -(1- \frac{CO+C1t+C2t^2}{1+d1t+d2t^2+d3t^3}) \qquad (7)$$

And transform gamma distribution:

$$t = \sqrt{In\left[\frac{1}{(H(x))^2}\right]} \qquad (8)$$

Whereas for $0,5 < H(x) \leq 1,0$

$$Z = SPI = +(1-\frac{CO+C1t+C2t^2}{1+d1t+d2t^2+d3t^3}) \qquad (9)$$

with:

Co= 2.515517 d_1= 1.432788

C1= 0.802853 d_2= 0.189269

C3= 0.010328 d_3=0.001308

2.5 Drought Identification

From this SPI value, we can use it to classify drought within a certain range. The SPI is a popular meteorological drought index based on rainfall data. The classification of the SPI is: (1) Mild drought is classified when the SPI rainfall value is between 0 and -0.99, (2) Moderate drought has a value between -1.00 to -1.49, (3) Severe drought is described if the between -1.5 and -1.99 and, (4) Extreme drought is described as less than -2.00. This classification will allow us to compare drought severity between countries in the same region, as well as between regions. This will allow comparisons of drought severity between countries in the same region, as well as between regions.

3 RESULT AND DISCUSSION

3.1 Regional Rain Analysis

The information needed is in the form of monthly rainfall from several checkpoints of rain stations, each rain station is searched for the extent of its influence using Thiessen polygons. There are three rain stations, namely: Waduk Gondang Rain Station, Lamongan Rain Station, and Karangbinangun Rain Station. The area of the rain catchment area of each rain gauge station using the ArcGIS program.

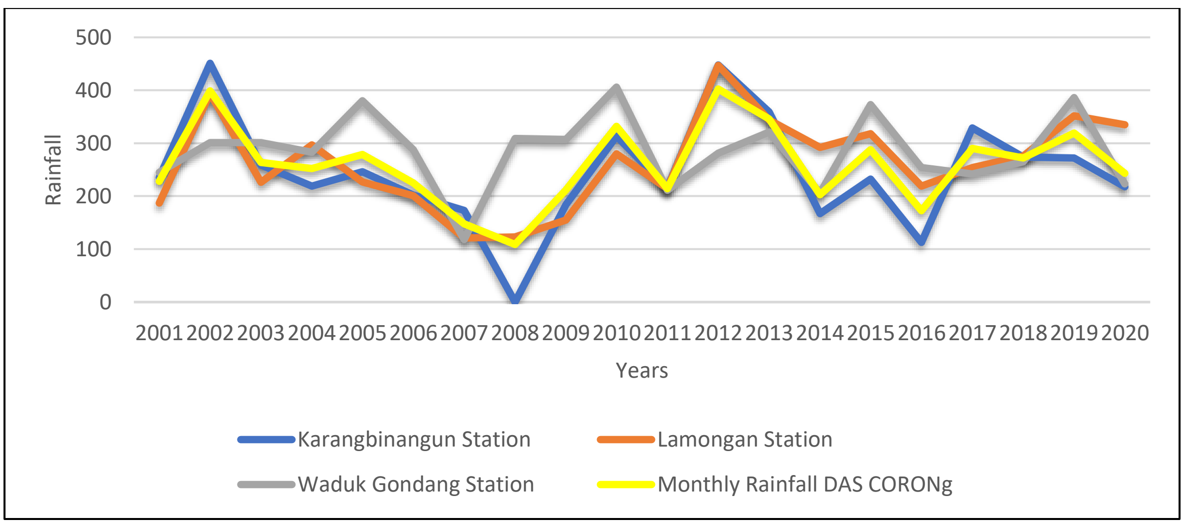

Figure 4. Monthly Rainfall Corong River Basin from 2001-2020
Source: Analysis results, 2021

3.2 Drought Duration Value For Each Deficit Period (SPI 1, SPI 3, SPI 6, and SPI 12)

After performing the Pride test and filling in the missing rain data, the effect of each rain station is calculated using a Thiessen polygon. Based on the calculation of the drought index using the SPI, the drought index value was obtained in all periods with the characteristics of wetness and drought deficit.

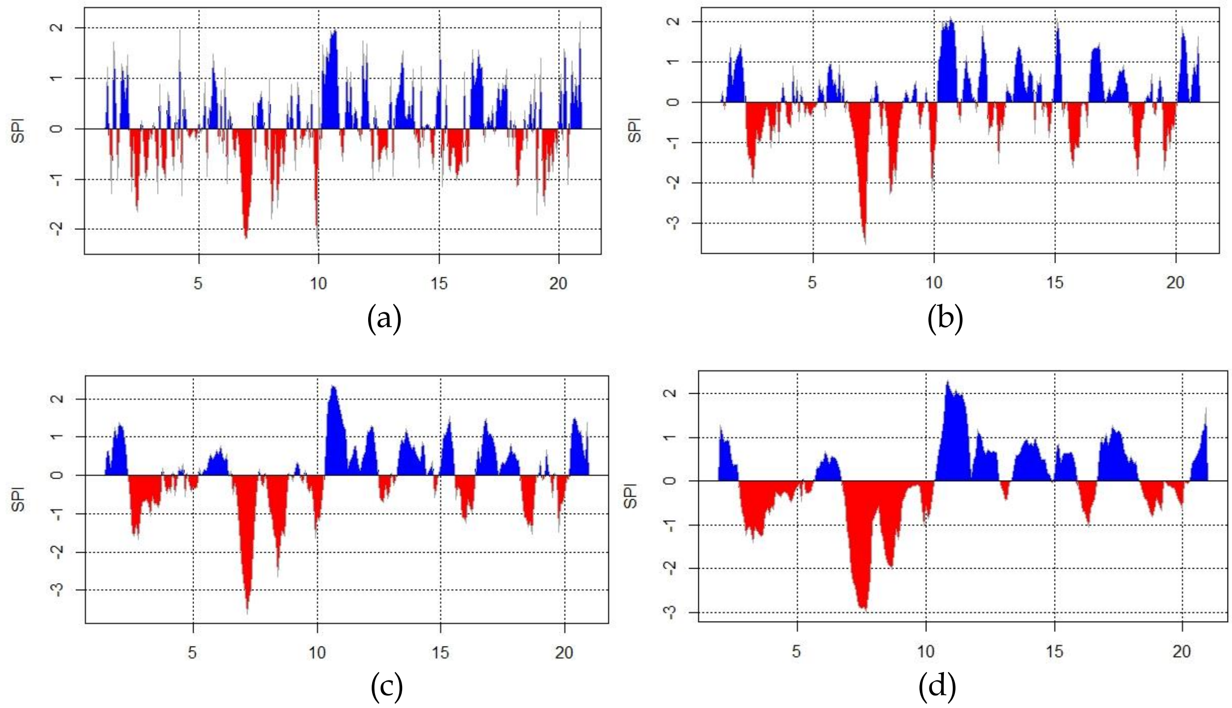

Figure 5. SPI In Different Time Scales (a) SPI-1 (b) SPI-3 (c) SPI-6 and (d) SPI-12
Source: Analysis results, 2021

From **Figure 5** Drought for 1 month deficit period or SPI-1 occurred in 2006 in December with a drought index value (-2.1905) and the smallest in 2009 in December (-2.3106) as shown in Figure 5 (a). 3 months deficit period or SPI-3 (-3.5318) in 2007 March Figure 5 (b), deficit period of 6 months or SPI-6 (-3.6188) in 2007 in March Figure 5(c), and period of 12 month deficit or SPI-12 (-3,0004) in September 2007 Figure 5(d).

Table 2. Drought Classification from 2001- 2020

	SPI 1				SPI 3				SPI 6				SPI 12			
Years	**Extreme**	**Heavy**	**Currently**	**Σ**	**Extreme**	**Heavy**	**Currently**	**Σ**	**Extreme**	**Heavy**	**Currently**	**Σ**	**Extreme**	**Heavy**	**Currently**	**Σ**
2001	-	-	2	2	-	-	-	-	-	-	-	-	-	-	-	-
2002	-	1	3	4	-	2	4	6	-	3	2	5	-	-	-	-
2003	-	-	2	2	-	-	1		-	-	1	1	-	-	9	9
2004	-	-	1	1	-	-	-	-	-	-	-	-	-	-	-	-
2005	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2006	1	1	2	4	1	1	1	3	1		1	2	-	1	-	1
2007	1	1	2	3	3	-	1	4	5	1		6	10	-	1	11
2008	-	2	1	3	2	2	1	5	1	4	2	7	1	4	4	9
2009	1	1	-	2	1	-	-	1	-	1	-	1	-	-	2	2
2010	-	-	-	-	-	-	1	1	-	-	2	2	-	-	-	-
2011	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2012	-	-	-	-	-	-	1	1	-	-	-	-	-	-	-	-
2013	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2014	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2015	-	-	2	2	-	1	3	4	-	-	2	2	-	-	-	-
2016	-	-	-	-	-	-	-	-	-	-	1	1	-	-	1	1

2017	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2018	-	-	2	2	-	1	3	4	-	1	4	5	-	-	-	-
2019	-	2	2	4	-	1	2	3	-	-	1	1	-	-	-	-
2020	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
∑	3	8	19	29	7	8	18	32	7	10	16	33	11	5	17	33

Source: Analysis results, 2021

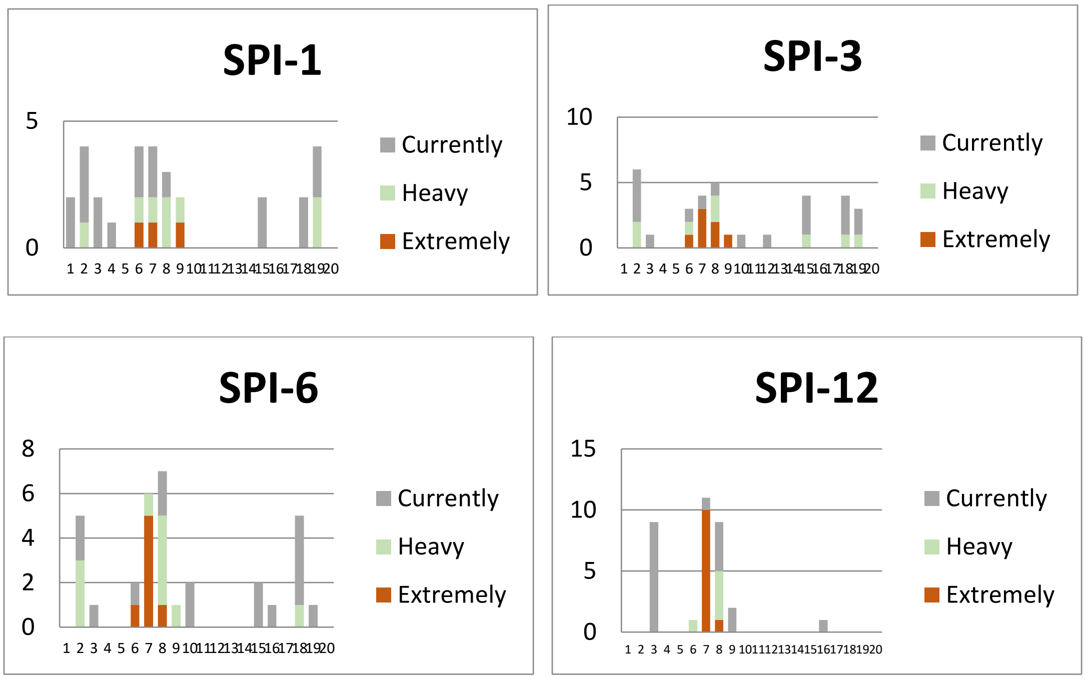

Figure 6. SPI Drought Characteristics, SPI-1, SPI-3, SPI-6 and SPI-12
Source: Analysis results, 2021

Table 2 and figure 6, a show the classification of droughts with different time durations. For the monthly SPI-1 period, extreme drought events only occurred 3 times in 2006, 2007, and 2009. For the monthly SPI-3 period, extreme drought events increased to 7 extreme events in 2006-2009. For the SPI-6-month period, extreme drought events tended to be almost the same in 2006, 2007, and 2008. For the SPI-12-month period, extreme drought events occurred for a longer duration. The results show that rainfall is the main driver of drought, is influenced by the duration of time and has different characteristics.

4. CONCLUSION

Corong watershed is one of the most important watersheds because it supplies water to the southern region of Lamongan which is very prone to drought. So drought analysis in this watershed is very necessary to characterize the drought conditions that occur using the Standardized Precipitation Index (SPI) method. The parameters used are rainfall data for 2001-2020 in the Corong watershed from 3 rain stations, namely Gondang, Lamongan, and Karangbinangun rain stations. Drought for 1-month deficit or SPI-1 occurred in 2006 in December with a drought index value (-2.1905) and the smallest in 2009 in December (-2.3106) with Extreme Drought characteristics. 3 months deficit period or SPI-3 (-3.5318) minimum index condition in March 2007 with Extreme Drought characteristics, 6 months deficit period or SPI-6 (-3.6188) minimum index condition in March 2007 with Extreme Drought characteristics, and period 12 months deficit or SPI-12 (-3,0004) in September 2007 with extreme drought characteristics

ACKNOWLEDGEMENT

The author expresses his deepest gratitude for the contribution of the Ministry of Education and Culture of the Republic of Indonesia through the Domestic Postgraduate Education Scholarship Grant (BPPDN) and the Research, Development Center of the Islamic University of Lamongan through the Doctoral Grant, Bengawan Solo River Basin Center Indonesia, Meteorology Climatology and Geophysics Council Indonesia.

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