Monitoring of Drought Events in Gorontalo Regency

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Abstract. Gorontalo Regency is a region vulnerable to drought. Drought is one of meteorological disaster because it tends to bring negative impact on various sectors. This study used rainfall data from 1981 to 2016 (35 years). The research employed Standardized Precipitation Index (SPI) to monitor and calculate the level of drought from the duration, intensity, and frequency in different time scales. The SPI value was calculated using the DrinC and ArcGIS software is used to create drought spatial distribution maps. The mean intensity of drought simultaneously followed the drought magnitude in Bilato station. The peak of drought in SPI-3 occurs in 1982, 2009 and 2016. In 1982, about 76.5% of the stations showed that the peak of drought events for SPI-3 in October to December. Moreover, 94% of the stations reveals that the peak of drought events for SPI-6 occur in July to December 1982. This shows that drought in 1982 was more severe than other years in the last three decades. Linear trends of drought for the period of 1981 to 2016 in most stations show an increasing trend, hence, it can be concluded that Gorontalo Regency experienced an increase in the wet period. Changes in time-scale caused the tendency for a high number of dry period frequencies. Drought spatial distribution could be used to determine the priority plans in finding the solutions due to droughts that occur in drought-vulnerable areas. Drought analysis using SPI could contribute to the decision-making in the future as an effort to minimize the impact of drought.

Keywords: drought severity, spatial analysis, standardized precipitation index

1. Introduction

Gorontalo Regency is one of the regencies in Gorontalo Province with highest rice production with total rice production in 2015 is about 153.515 tons and maize production in the same year is about 142.863 tons [3]. Therefore, Gorontalo Regency is the largest food producer in the province. Furthermore, Gorontalo Regency is also vulnerable to drought. Drought is one of meteorological disaster because it tends to bring negative impact on various sectors, such as in social and economic sectors as well as in other areas. The potential drought area in Gorontalo Regency is about 172.894 hectares, whereas the possible environmental damage due to drought is about 59.311 hectares [2]. The impact of the drought is economically and socially felt by the people in this regency. Therefore, efforts to assess the level of drought hazard are needed. This effort can be made by utilizing the climate data to monitor the drought events. Hence, adaptation and mitigation of drought hazard can be done.

Monitoring of drought events needs an exact calculation to assess the severity classification of the drought. Assessing the severity classification and providing information for early drought warning can support adaptation and mitigation actions of the drought hazard. Therefore, tools to be used in evaluating the level of drought severity are needed. In the recent years, meteorological drought index has become a widely used index for assessing the severity of the drought. The often-used meteorological drought index are Standardized Precipitation Index (SPI), Standardized Precipitation Evapotranspiration Index (SPEI), Palmer Drought Severity Index (PDSI), Crop Moisture Index (CMI), Surface Water Supply Index (SWAZEE), and Reconnaissance Drought Index (RDI). SPI is highly valuable meteorological drought index used to estimate the hazard level of drought [10]. Also, SPI can monitor and measure the level of drought duration, intensity, frequency, and drought probability in various time scales [12].

SPI application in monitoring and measuring drought level is straightforward because SPI only needs monthly rainfall data. Hence, in detail, SPI detects rainfall deficit in giving period. The flexibility of the time scale becomes one of the SPI advantages in monitoring short-term and long-term drought. This study aims at (1) estimating the duration, magnitude, and intensity of the drought; (2) analyzing the frequency of wet, normal, and dry periods; (3) to consider spatial distribution of drought in Gorontalo Regency.

2. Materials and Method

2.1. Climate data

This study used rainfall data from 1981 to 2016 (35 years). Assessing the severity level of the long-term rainfall data was (≥ 30 years) [8,14]. Usage of rainfall data to produce drought characteristic is trusted, because the longer the data entry period, the more accurate the produced value. The SPI value was calculated using the DrinC (Drought Indices Calculator) software developed by the Laboratory of Reclamation Works and Water Resources Management of the National Technical University of Athens, Greece [20]. Monthly rainfall data were obtained from 17 stations located all around Gorontalo Regency and 2 stations located outside of Gorontalo Regency (Figure 1). The data were collected from the Balai Wilayah Sungai Sulawesi II (Watershed Agency of Sulawesi II, henceforth called as BWS), Meteorological Station of Meteorology, Climatology, Geophysics Agency (henceforth called as BMKG) and 0.25-degree data grid of BMKG, were obtained from the sacad.database.bmkg.go.id/grid/web/ website. The additional data were obtained from the iridl.ldeo.columbia.edu/SOURCES/NOAA/ website.

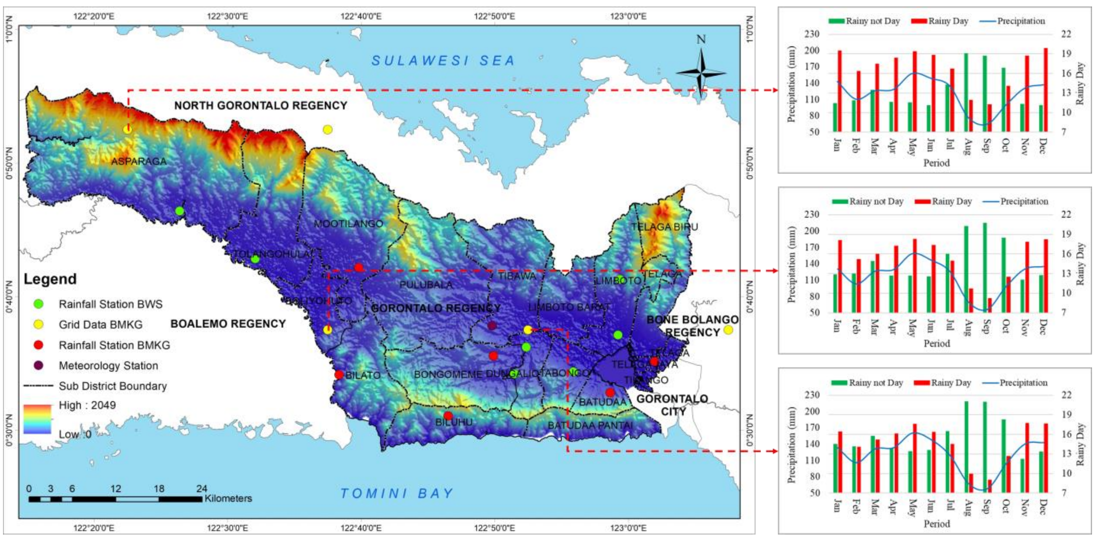

Figure 1. The administrative map of Gorontalo Regency and the station location (left), rainfall averages for the period of 1981 to 2016 at the Pangahu station (above), Motoduto station (middle), Isimu station (below).

2.2. Estimated monthly rainfall
Rainfall data obtained from some stations still contain missing data and data not available. The estimated rainfall data using Inverse Distance Weighting method (IDW), this method can be estimated as follows:

$$X_p = \frac{\sum_{i=1}^{n}\left(\frac{1}{d_i^2}.X_i\right)}{\sum_{i=1}^{n}\left(\frac{1}{d_i^2}\right)} \quad (1)$$

where Xp: the estimated value of rainfall, X_i: the value of rainfall at the nearest station in the same period, d_i: distance between the estimated station and the nearest station [13].

2.3. Calculating the SPI
SPI is calculated using DrinC, providing drought index calculation based on the method of the gamma distribution. The gamma distribution to fit well to the rainfall time series data [18]. Gamma distribution is a method to describe rainfall variability. Gamma distribution is a probability density function. The equations used are:

$$g(x) = \frac{1}{\beta^{\alpha}\Gamma(\alpha)} x^{\alpha-1} e^{-x/\beta}, \text{ for } x > 0 \quad (2)$$

where,

$$\Gamma(\alpha) = \int_0^{\infty} y^{\alpha-1} e^{-y} dy \quad (3)$$

where α and β are the shape and scale parameters, x is the amount of rainfall and Γ(α) is a gamma function. The parameters of α and β gamma probability density function of each station to estimate rainfall in the period a scale of 1, 3, 6, and 12 months.

The method used to estimate the value of the gamma distribution parameter is the maximum likelihood method is:

$$\alpha = \frac{1}{4A}\left(1 + \sqrt{1 + \frac{4A}{3}}\right), \beta = \frac{\bar{x}}{\alpha}, \text{ where } A = \ln(\bar{x}) - \frac{\sum \ln(x)}{n} \quad (4)$$

n= number of rainfall observations

The resulting parameters are then used to determine the cumulative probability value of the observed rainfall events in a month and the time period recorded on the observed station [6]. The gamma distribution is undefined (x=0) and rainfall distribution likely contains a zero value, the cumulative probability becomes:

$$H(x) = q + (1 - q)\, G\,(x) \quad (5)$$

where q is the probability of zero rainfall dan G(x) is the cumulative probability of the incomplete gamma function. If *m* is the number of zeros of the rainfall time series, then *q* can be estimated by *m/n*. The cumulative probability of H (x) is then transformed to a normal standard random variable Z with a mean value of zero and a variance of one [1]. Moreover, according to Edwards [6] the standard normal random variable Z which is also the SPI value is more easily obtained by using the approach proposed by [1] which converts the cumulative probability to the normal standard random variable Z (SPI):

$$Z = SPI = -\left(t - \frac{c_0 + c_1 t + c_2 t^2}{1 + d_1 t + d_2 t^2 + d_3 t^3} \right), t = \sqrt{\ln\left(\frac{1}{(H(x))^2} \right)} \qquad \text{for } 0 < H(x) \leq 0.5 \qquad (6)$$

$$Z = SPI = \left(t - \frac{c_0 + c_1 t + c_2 t^2}{1 + d_1 t + d_2 t^2 + d_3 t^3} \right), t = \sqrt{\ln\left(\frac{1}{(1.0 - H(x))^2} \right)} \qquad \text{for } 0.5 < H(x) < 1.0 \qquad (7)$$

with, c0 = 2.515517, c1 = 0.802853, c2 = 0.010328, d1 = 1.432788, d2 = 0.189269, d3 = 0.001308. Rainfall data recorded on the observation station is not normally distributed so that the transformation will follow basically normal distributed SPI values [19]. The calculation of the SPI values at different time scales are classified based on wet and dry as shown in Table 1.

Table 1. Drought classification according to SPI value.

SPI range	Drought category
2.0 or more	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
-2.0 or less	Extremely dry

2.4. Duration, magnitude, and intensity of drought

Drought is identified by looking at the number of months since the first month, where drought starts if SPI values show negative values up to -1, drought finished if the SPI values showed a positive value [12][16]. Based on these indicators can be determined longest drought period is referred to as the drought duration (DD) at any rainfall station. Drought duration since the beginning of the case until the finished of the drought can be calculated the amount drought magnitude (DM). DM is defined as the accumulation of SPI values in the events of drought duration [12], DM is formulated with:

$$DM = -\left(\sum_{i=1}^{n} SPI_{ij} \right) \qquad (8)$$

where n is the number of months with the occurrence of drought on the time scale j. Based on the value of DM and DD can be calculated the mean intensity value (MI). The mean intensity is the average accumulation of water deficit during the period of drought [15].

2.5. Frequency and spatial distribution of drought

Calculate the frequency of drought events using the equation $f = n/N$ x 100, where: n is a number of months with drought events (negative SPI), N is a number of total months [15]. Drought spatial distribution using Inverse Distance Weighted (IDW) method. For this purpose, ArcGIS software is used to create drought spatial distribution maps.

3. Results and Discussion

3.1. Description of rainfall in the research site

Gorontalo Regency is one of the areas in the equator, where convective clouds are developed. This phenomenon has caused Gorontalo Regency to receive abundant rainfall all year round. The average annual rainfalls in Pangahu, Motoduto, and Isimu stations for the period of 1981 to 2016 were 1449, 1397 and 1436 mm with two peak patterns of rainfall. The peak of rainfall occurs during April to June and November to January, whereas the lowest rainfall occurs in August to October (Figure 1). The same pattern also found in other weather observation stations in the Gorontalo Regency era. The number of the highest rainy day was at the Pangahu station with 17 days per month, whereas, in Isimu and Motoduto stations, the number of rainy days was 15 days per month.

3.2. Rainfall estimation result

The result of rainfall estimation data shows that IDW method had similarity with the data from observed rainfall, even though the estimation data showed higher or lower data than observed data on certain periods. In addition, stations density is one of the main factors in selecting the spatial interpolation data in estimating the rainfall [4]. The analysis reveals good correlation values were obtained from stations that are close to each other. The optimum distance between stations used in interpolation of rainfall data is ten to thirty kilometers [5]. In this study, the maximum distance between stations used was 20.5 km. Table 2 shows that observed monthly rainfall and rainfall estimated in Datahu, Talumelito and Pilolalenga stations show good results with correlations values of 0.84, 0.80, and 0.77 (high correlation). These correlation values ensure that estimated rainfall data using the IDW method could be used to monitor drought events in Gorontalo Regency.

Table 2. Correlation between the monthly rainfall observations and estimation.

Station	r_{value}	**Category**
Datahu	0.84	H
Talumelito	0.80	H
Pilolalenga	0.77	H
Batudaa	0.77	H
Tabongo	0.71	H
Mootilango	0.68	M
Biyonga	0.67	M
Hepuhulawa	0.62	M
Bilato	0.54	M

H = High correlation, M = Moderate correlation

3.3. Drought events from 1981 to 2016

Rainfall variability in Gorontalo Regency during 1981 to 2016 was influenced by El Nino Southern Oscillation (ENSO) phenomenon. This phenomenon has caused low rainfall in Gorontalo Regency. Hence, it triggered drought. In addition, drought had caused water deficit when the recorded data in one rainfall station had been below the standard for several months [7]. Drought analysis for the period of 1981 to 2016 had different duration, magnitude and drought intensity in various time scales. Drought duration, magnitude, and intensity identification were conducted in one, three, and six months' timescale. As shown in Table 3, the duration of SPI-1 was six to seven months, with the drought magnitude was found in Bilato station with the value of -22.2 and mean intensity of -2.3 (extremely dry). The mean intensity of drought simultaneously followed the drought magnitude in Bilato station. About 59% of the stations showed that the peak of drought in SPI-1 occurs in November 1984, regardless that in that year no El-Nino phenomenon that occurs. This indicates that SPI was able to identify below normal rainfall in short time-scale.

The SPI-3 analysis shows that the longest drought duration occurs in Tabongo and Talumelito with the value of drought magnitude in each station was -5.5 and -6.6, with a mean intensity of -1.4 (moderately dry) for Tabongo and -1.6 (severely dry) for Talumelito (Table 3). The duration of drought in Tabongo and Talumelito stations were not simultaneously followed by the magnitude and the intensity of the drought. This was because, in other stations, it was revealed that the drought

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Table 3. Duration, magnitude, intensity and peak of drought during the period 1981 to 2016 in Gorontalo Regency

Station	DD			DM			MI			P		
	SPI-1	SPI-3	SPI-6	SPI-1	SPI-3	SPI-6	SPI-1	SPI-3	SPI-6	SPI-1	SPI-3	SPI-6
Hepuhulawa	6	3	2	-17.2	-7.6	-2.2	-1.8	-2.5	-1.1	Feb-98	Jan-Mar 2016	Jul-Dec 1982
Biyonga	7	3	2	-16.9	-6.9	-2.7	-1.7	-2.3	-1.4	Des-15	Oct- Dec 1982	Jul-Dec 1982
Tabongo	7	4	2	-17.8	-5.5	-3.4	-1.7	-1.4	-1.7	Nov-84	Oct- Dec 1982	Jul-Dec 1982
Datahu	7	3	2	-17.5	-6.6	-5.5	-1.6	-2.2	-2.7	Feb-98	Oct- Dec 2009	Jul-Dec 1982
Pilolalenga	7	3	3	-18.4	-6.4	-4.8	-1.9	-2.1	-1.6	Nov-84	Oct- Dec 1982	Jul-Dec 1982
Lakeya	7	3	2	-20.6	-9.1	-2.1	-2.1	-3.0	-1.1	Nov-84	Oct- Dec 1982	Jul-Dec 1982
Mohiolo	7	3	2	-17.4	-6.6	-4.8	-1.7	-2.2	-2.4	Feb-98	Apr-Jun 2009	Jul-Dec 1982
Biluhu	6	3	3	-14.6	-6.3	-4.3	-1.6	-2.1	-1.4	Feb-98	Jul-Sep 1982	Jul-Dec 1982
Bilato	7	3	2	-22.2	-9.3	-4.8	-2.3	-3.1	-2.4	Jul-82	Jul-Sep 1982	Jul-Dec 1982
Talumelito	6	4	1	-16.0	-6.6	-3.8	-1.7	-1.6	-3.8	Nov-84	Oct- Dec 1982	Jan-Jun 2012
Mootilango	7	3	2	-20.7	-8.9	-4.9	-2.2	-3.0	-2.5	Nov-84	Oct- Dec 1982	Jul-Dec 1982
Bongomeme	7	3	2	-19.3	-8.3	-2.5	-1.9	-2.8	-1.2	Nov-84	Oct- Dec 1982	Jul-Dec 1982
Batudaa	6	3	5	-16.1	-5.9	-8.5	-1.7	-2.0	-1.7	Feb-98	Oct- Dec 1982	Jul-Dec 1982
Pangahu	6	3	2	-17.0	-7.9	-4.7	-1.8	-2.6	-2.3	Nov-84	Oct- Dec 1982	Jul-Dec 1982
Motoduto	7	3	2	-19.5	-7.6	-5.0	-1.8	-2.5	-2.5	Nov-84	Oct- Dec 1982	Jul-Dec 1982
Isimu	7	3	2	-21.3	-8.9	-2.8	-2.1	-3.0	-1.4	Nov-84	Oct- Dec 1982	Jul-Dec 1982
Djalaluddin	7	3	2	-16.7	-7.0	-2.4	-1.6	-2.3	-1.2	Nov-84	Oct- Dec 1982	Jul-Dec 1982

DD = Drought duration, DM = Drought Magnitude, MI = Mean Intensity, P = Peak of Drought

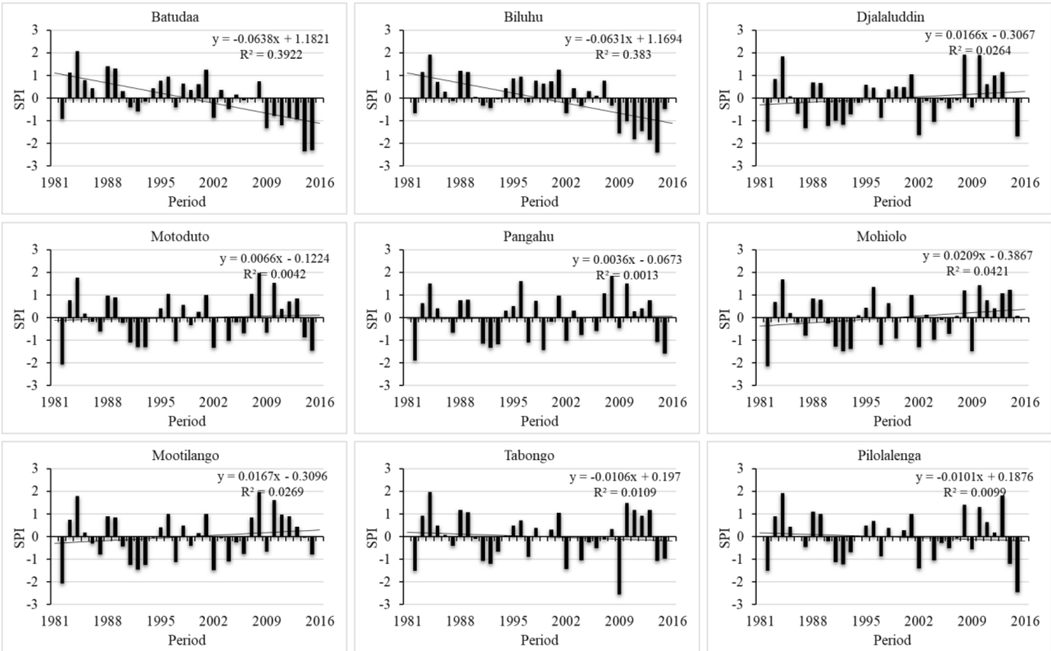

Figure 2. The linear trend of SPI-12 from 1981 to 2016

duration values were lower than those of Tabongo and Talumelito stations but the drought magnitude and drought intensity was higher. This indicates that the area with longer drought duration does not necessarily mean that the area is drier than other areas. As shown in Table 3, The peak of drought in SPI-3 occurs in 1982, 2009 and 2016. In 1982, about 76.5% of the stations showed that the peak of drought events for SPI-3 in October to December. Moreover, 94% of the stations reveals that the peak of drought events for SPI-6 occur in July to December 1982. This shows that drought in 1982 was more severe than other years in the last three decades. Also, based on the analysis, during 1982, all stations showed the value of SPI < -2 or within the extremely dry category.

The longest drought duration in SPI-6 occurs in Batudaa station during January 2014 to June 2016, whereas the drought magnitude of -8.5 and a mean intensity of -1.7 (severely dry). The shortest drought duration occurs in Talumelito station with the drought magnitude of -3.8 and mean intensity value of -3.8 (extremely dry), has the most severe impact on the area (Table 3). Description of duration, magnitude, and mean intensity of drought in SPI-1 and SPI-3 were different with SPI-6, where, the drought duration in SPI-6 tend to be longer whereas the drought magnitude SPI-6 tend to be lower than those in SPI-1 and SPI-3 (Table 3). These conditions indicate that rainfall accumulation would be bigger if the SPI time-scale is increased. Hence, it will influence the duration, magnitude, and intensity of the drought.

The drought magnitude and the length of drought duration were heavily influenced by the rainfall recorded in observation stations, the low rainfall intensity for an extended period of time will trigger a drought with a long duration. Figure 2 shows a number of events and level of drought severity in nine observation stations from 1981 to 2016. Analysis of drought dynamic in SPI-12 showed four drought events in Batudaa station, where two of the events was categorized as extremely dry. In Biluhu station there were six drought events recorded, one of them has been registered as extremely dry. Moreover, in Mootilango and Pilolalenga stations, there were seven drought events recorded for each station, and one of them was categorized as extremely dry, in 1982 for Mootilango station and extremely dry in 2015 for Pilolalenga station. In addition, Motoduto, Mohiolo, and Tabongo stations each recorded eight drought events, with only one drought events recorded as extremely dry for each station, namely in 1982 for Motoduto and Mohiolo stations and in 2009 for Tabongo station. Further, in Pangahu and Djalaluddin stations there were many drought events recorded, eight drought events for Djalaluddin station and nine events for Pangahu station. However, there was no drought categorized as extreme drought in these two stations from 1981 to 2016.

In general, the drought events varied in each observation station in Gorontalo Regency. Based on the SPI-12 analysis, most of the stations show that drought occurs in 1982, 1991, 1992, 2002 and 2015, with most of the station reported extremely dry events in 1982. From 1981 to 2016, the number of the dry years was more than the number of wet years. Therefore, the drought events potential for Gorontalo Regency in average was two to three times in each decade, with reference to a number of drought events in SPI-12. Nevertheless, the number of drought events depended on global warming that caused changes in rainfall and long-term climate change [21]. Linear trends of drought for the period of 1981 to 2016 in most stations show an increasing trend (Figure 2), hence, it can be concluded that Gorontalo Regency tends to increase in the wet period.

3.4. Frequency of drought

Drought frequency was identified in SPI-3, SPI-6 and SPI-12 time-scale. SPI-3 analysis showed that the wet period frequency in Djalaluddin, Motoduto, and Pangahu stations were 13, 14 and 16% whereas the dry periods were 12, 11 and 15%. The normal period for SPI-3 in Djalaluddin and Motoduto stations was 75%, whereas for Pangahu station was 69%. Overall, the wet period frequency was higher than the dry period. SPI-6 time-scale showed that the dry period frequency in Motoduto and Pangahu station was higher with the percentage of 17% (Figure 3). Also, the SPI-12 analysis indicates that frequency for all wet period in Djalaluddin and Motoduto stations were 18% whereas for Pangahu station was 15%. In reverse, the incidence for the dry period in Djalaluddin and Motoduto stations were 23%, while for Pangahu station was 26%. The condition for a normal period in Djalaluddin, Motoduto and Pangahu stations show the similar frequency of 59% (Figure 3). Drought events changes as timescale changes [11].

The results are shown by SPI-3, SPI-6, and SPI-12 indicate that the longer time-scale used the higher the dry period compared to the wet period. However, the short time-scales usage (SPI-3 and SPI-6) were able to identify the level of drought more clearly and able to indicate the influence of seasonal rainfall influence toward the drought distribution. Therefore, short time-scale SPI can be used to monitor short-term drought for the agricultural sector. One of the drought characteristics was the change in drought frequency along with the change in time scale [21]. Changes in time-scale, for the short-time scale to

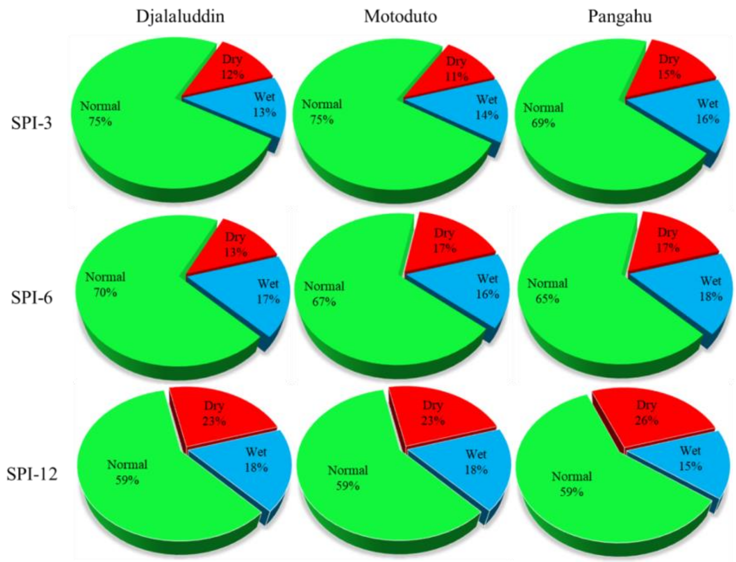

Figure 3. Frequency of wet, normal and dry period of SPI-3, SPI-6 and SPI-12.

longer time-scale, will be followed by the change in frequency. Changes in time-scale caused the tendency for a high number of dry period frequencies. However, the magnitude of the drought will wear off due to the increasing accumulation of rainfall in longer time-scale. Drought monitoring through SPI in different time-scale can assist in planning efficient water resource usage for farming and hydropower [21].

3.5. Spatial distribution of drought

The value of SPI in all stations in Gorontalo Regency indicated severe drought in 1982 and 1992. July to September 1982 period which showed that drought occurs in all areas of Gorontalo Regency with extremely dry category (Figure 4). The 1982 drought is one of the most severe droughts that occur not only in Gorontalo Regency but also all over Indonesia. From April to June 1997 all area in Gorontalo Regency experienced the dry condition, the same condition also occurs in 1982. However, the 1997 drought magnitude was lower than the one in 1982. In April to June 1997, 67% of the area was in the extremely dry category, and 33% of the area was in several dry and moderately dry condition (Figure 4). The dry condition for July to December 2009 and January to June 2014 was more varied, from moderately wet to extremely dry. The normal condition in 2009 covered 53% of the area, whereas 47% of the area was in dry condition. The normal condition in 2014 covered 58% of the area, whereas 40% of the area was in dry condition and 2% in wet conditions. Spatial analysis approach provides additional information to assess the drought characteristics [9].

In general, based on the spatial drought analysis in 1982, 1997, 2009 and 2014, it shows that the drought events varied for all area in Gorontalo Regency. Seasonal drought events due to the seasonal rainfall variability need to be anticipated. Hence, it can be concluded that SPI for July to December indicates the high severity of drought due to the variability of seasonal rainfall. Other evidence to back this up is the drought peaks in the last three decades mostly occur in July to December. One of the main factors in the severity of the drought is the El Nino phenomenon that occurs periodically. The impact of this El Nino phenomenon is different for every area depending on the local climate characteristics. For Gorontalo, for instance, the high drought risk due to El Nino occurs in March to April and in July to October [17]. On those months, the observed drought events for the period of 1981 to 2016 was in line with the El Nino events. Thus, the SPI in the month could help assess the drought impact, especially in the agricultural sector in Gorontalo Regency. Also, it could increase the capacity in risk management due to the El Nino events [17]. Spatial drought analysis assists in identifying and describing the areas that are vulnerable to drought [14].

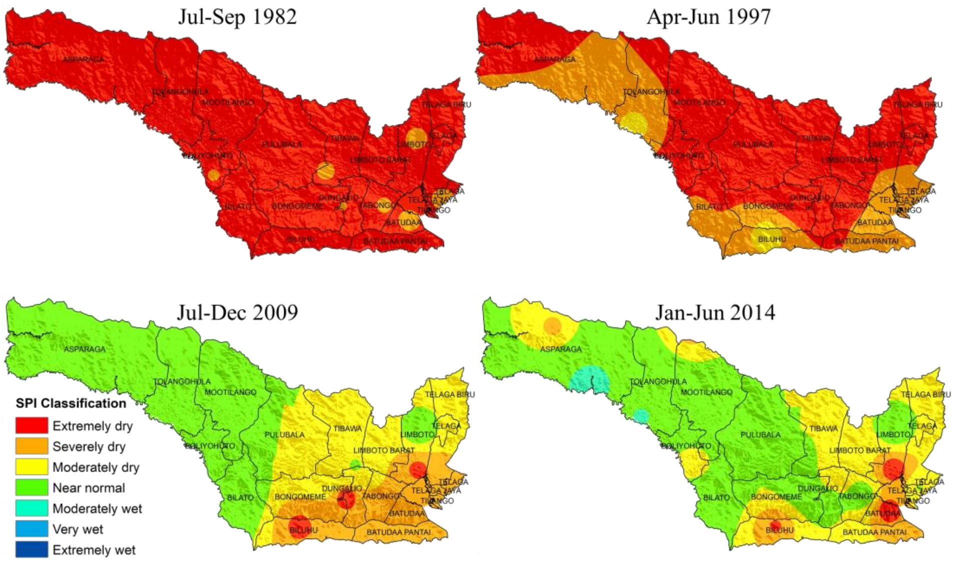

Figure 4. Spatial distribution of SPI-3 in 1982 and 1997, SPI-6 in 2009 and 2014

4. Conclusions

Monitoring of drought events in Gorontalo Regency used the monthly rainfall data during the period of 1981-2016. SPI was recommended to measure the severity level of drought because it is simple and it is flexible in observing drought in different timescale [8]. The result showed that rainfall lower is the main factors for the drought events. In addition, the duration and magnitude of drought were heavily influenced by the accumulation of rainfall in each time scale. The droughts that occur in Gorontalo Regency was also heavily determined by seasonal climate variability. For instance, droughts with the longest durations which occurred in 1982, 1986, 1997 and 2015 and the wet conditions that took place in 1984, 2001, 2008, 2010 and 2013, was closely related to El Nino Southern Oscillation (ENSO) phenomenon that periodically occur. Moreover, drought events frequency also related to the frequency and the strength of ENSO.

Drought monitoring using SPI in various time-scales was critical to be done to formulate mitigation plans. In addition, it also provided effective early warning information based on the severity of the drought [21]. Drought spatial distribution could be used to determine the priority plans in finding the solutions due to droughts that occur in drought-vulnerable areas. Therefore, drought analysis using SPI could contribute to the decision-making in the future as an effort to minimize the impact of drought in Gorontalo Regency. This study is an initial step in assessing the characteristics of drought in Gorontalo Regency. Hence, advance drought analysis needs to be done to determine the extent of ENSO influence toward the drought severity level in Gorontalo Regency.

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References

[1] Abramovitz M and Stegun I A 1964 Handbook of mathematical functions *National Bureau of Standards. Washington D C*

[2] [BNPB] Badan Nasional Penanggulangan Bencana 2015 Kajian Risiko Bencana Gorontalo 2016-2020 *Deputi Bidang Pencegahan Dan Kesiapsiagaan* 10-15

[3] [BPS] Badan Pusat Statistik 2016 Prov. Gorontalo Dalam Angka *BPS Prov. Gorontalo* 161-163

[4] Camera C, Bruggeman A, Hadjinicolaou P, Pashiardis S and Lange M A 2014 *J. Geophys. Res. Atmos.* 119 693

[5] Chen F W and Liu C H 2012. *Paddy Water Environ.* **10** 209

[6] Edward D C 1997 Characteristics of 20th century drought in the united states at multiple time scales *Thesis Graduate School, Colorado State University. Colorado.*

[7] Gocic M and Trajkovic S 2014 *J. Hydrol*. **510** 110

[8] Hayes M J, Svoboda M D, Wilhite D A and Vanyarkho O V 1998 *Bull. Am. Meteorol. Soc.* **80** 429

[9] Hughes B L 2012 *Int. J. Climatol.* **32** 406

[10] Keyantash J and Dracup J A 2002 *Bull. Am. Meteorol. Soc.* **83** 1167

[11] Labedzki L 2007 *Irrig. And Drain.* **56** 67

[12] McKee T B, Doesken N J and Kleist J 1993 *Proceedings of the 8th Conference on Applied Climatology* **17-12** 179

[13] Mello C R, Lima J M, Silva A M, Mello J M and Oliveira M S 2003 *R. Bras. Ci. Solo.* **27** 925

[14] Rahman M R and Lateh H 2016 *Environ. Earth Sci.* **75** 1

[15] Saravi MM, Safdari AA and Malekian A 2009 *Hydrol. Earth Syst. Sci.* **6** 1347

[16] Spinoni J, Antofie T, Barbosa P, Bihari Z, Lakatos M, Szalai S, Szentimrey T and Vogt J 2013 *Adv. Sci. Res.* **10** 21

[17] Supari, Muharsyah R and Sopaheluwakan A 2016 *AIP Conf. Proc.* **1730** 07000-1

[18] Thom H C S 1958 *Mon. Weather Rev.* **86** 117

[19] Tigkas D, Vangelis H and Tsakiris G 2014 *Earth Sci. Infor.* **8** 697

[20] Tsakiris G, Tigkas D, Vangelis H and Pangalou D 2013 DrinC-Drought Indices Calculator. Getting Started Guide, Version 1.5 1-7

[21] Wagan B, Zhang Z, Baopeing F, Wagan H, Han S, Ahmad I and Kabo-Bah A T 2015 *Outlook Agr.* **44** 235