SPATIAL ANALYSIS OF DROUGHT IN GROBOGAN REGENCY USING STANDARDIZED PRECIPITATION INDEX (SPI)

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Abstract

Drought is a natural disaster caused by the phenomenon of weather irregularities. In certain conditions, the drought is not so dangerous, but in a severe drought, it could threaten human life in many sectors such as in agriculture, economic and social sectors. Grobogan is an area in Central Java province which always suffers from drought during the dry season. This study aims to determine the spatial distribution of drought in Grobogan using the Standardized Precipitation Index (SPI). The data used is secondary data of Grobogan rainfall for 21 years (1994-2014) at 21 rainfall stations. The results showed that the incidence of droughts lasted for five months, which is in May, June, July, August and September. Early drought occurred in May with a value of SPI -1.01 to -1.15 with the drought level of moderate in an area of 123494.97 ha or 62.50% of the area. Drought in June with SPI value of SPI -1.11 to -1.49 occures in the entire region with the drought level of moderate. Drought in July with SPI values between -1.29 to -1.77, consists of 71313.85 ha or 36.09% area in a moderate drought level and 126272.1 ha or 63.91% area in a severe drought level. The peak of the drought occurred in August with SPI value of -1.53 to -2.51, a region with extreme drought level covering 74394.37 hectares or 37.65% area and severe drought level covers 123,191.6 hectares or 62.35% area. In September drought was reducing with SPI value of -1.06 to -1.56 which consists of 123 495 ha or 62.50% area was in moderate drought level and 74091.03 ha or 37.50% area was in severe drought level.

Keywords: drought, SPI, spatial distribution

A. Introduction

Drought is a deficiency of precipitation over an extended period of time, usually a season or more, which results in a water shortage for some activity, group, or environmental sectors. However, in terms of typologies, droughts are commonly classified as meteorological, agricultural, hydrological, and socio-economic. (UN/ISDR, 2007). Drought is one of the most complicated and least understood natural hazards, affecting more people than any other hazards (Wilhite, 2003).

Unlike earthquakes, floods and cyclones, drought occurrence is a gradual process with long-lasting effect. The drought from 1980 to 2000 posed a threat to the food security and human mortality all round the world. On average, 28 % of the geographical area of India is vulnerable to drought. Meteorologically, ± 19 % deviation of rainfall from long-term mean is considered normal in India. Deficiency in the range 0f 20 to 59 % represents

"moderate" drought and more than 60% "severe" drought (Samra, 2004).

Intergovernmental Panel on Climate Change (IPCC, 2007) states that the world's vulnerability to drought is increasing within the last 25 years, and climate projections show will get worse in the future. Based on the data IRBI (Indonesia Disaster Risk Index), Grobogan including one district that is prone to drought (BNPB, 2014). Droughts are disasters that have broad impact on the community because it involves the need for water for domestic and agricultural.

Drought is one of the natural disasters that occur slowly (slow-onset disaster), lasting until the rainy season arrives, wide impact, and cross-sector. An example of the drought that hit California in 2015 (and has been for 4 years) has caused negative impacts in the agricultural sector causing huge economic losses, totaled $ 2.7 billion (et.all Howitt, 2015).

According to Partridge (2002), rainfall in Indonesia affected by the El Nino Southern Oscillation (ENSO). But the size of the effect varied from one place to another. Based on the results research of Manik, et. all (2014), a real decline in rainfall in Lampung province occurred in 1994 and 1996 in conjunction with the El-Nino phenomenon that in many studies are known to be closely related to the dry season in Indonesia. It is also similar to research results of Lilik Supriatin and Martono (2016) in Cilacap, it was recorded that in 1984 – 2013 there were four time occurrences of El Nino (1991, 1994, 1997, and 2002) and four time occurrences of La Nina (1989, 1999, 2000,and 2007). It found out the rainfall during El Nino years was lower while it was higher in La Nina years.

Map of Flood and Drought Prone Grobogan in 2011 showed that most of the area is prone to drought. This is confirmed by the data from the Map Index Precipitation Standardized (SPI) 3 Monthly in Central Java issued by BMKG Semarang Stations, in the period from December 2014 to February 2015 the area is classified as one of the districts most prone to drought with dryness most higher than other districts in Central Java. According to the Regional Development Planning Agency Grobogan (2014), from 19 districts in Grobogan, only two districts that do not suffer from drought at all. Such conditions should be wary because many local people who work in the agricultural sector so that the feared impact on socio-economic conditions of society.

The study aims to calculate the drought index in Grobogan Regency using the

Standardized Precipitation Index (SPI). According to the World Meteorological Organization (2012), SPI method has been used to research more than 70 countries in the world, because it has several advantages, namely:

a. SPI can be calculated for different time scales
b. can provide early warning of drought
c. can help assess the severity of drought
d. SPI is simpler than the Palmer Drought Severity Index

Limitations (https://climatedataguide.ucar.edu/climate-data/standardized-precipitation-index-spi):

- As a measure of water supply only, the SPI does not account for evapotranspiration, and this limits its ability to capture the effect of increased temperatures (associated with climate change) on moisture demand and availability
- Sensitive to the quantity and reliability of the data used to fit the distribution; 30-50 years recommended
- Does not consider the intensity of precipitation and its potential impacts on runoff, streamflow, and

water availability within the system of interest

B. Research Method

Standardized Precipitation Index (SPI) is a method developed by McKee et al (1993). This method is a model for measuring the shortage / rain deficiency at various periods based on normal conditions. For analysis of drought using Standardized Precipitation Index (SPI) required monthly rainfall data with a longer period. For this study, analysis used rainfall data for 21 years (1994-2014) at 21 rain stations

SPI value calculation based on the number of gamma distribution is defined as a function of frequency or probability of the following events.

$$G(x) = \int_0^{\hat{} } g(x)dx = \frac{1}{\beta^\alpha \Gamma(a)} \int_0^{\hat{} } t^{a-1} e^{-x/\beta} dx$$

Values α and β are calculated for each rainfall station using the formula:

$$\alpha = \frac{1}{4A}\left(1 + \sqrt{1 + \frac{4A}{3}}\right)$$

$$A = \ln(\bar{x}) - \frac{\sum \ln(x)}{n}$$

atau

$$\alpha = \frac{\bar{x}^2}{s^2}$$

$$\beta = \frac{\bar{x}}{\alpha}$$

untuk $x > 0$

For x = 0, then the value of G (x) be:

$$H(x) = q + (1-q).G(x)$$

Note: q = number of rain events = 0 (m) / amount of data (n).

SPI value is the transformation of the gamma distribution (G (x)) into a normal standard with an average (mean) of 0 and a difference of 1, or using the following formula:

$$Z = SPI = -\left(t - \frac{c_0 + c_1 t + c_2 t^2}{1 + d_1 t + d_2 t^2 + d_3 t^3}\right)$$

$$Z = SPI = +\left(t - \frac{c_0 + c_1 t + c_2 t^2}{1 + d_1 t + d_2 t^2 + d_3 t^3}\right) \qquad untuk \ : 0 < H(x)$$

$$t = \sqrt{\ln\left(\frac{1}{(H(x))^2}\right)} \qquad untuk \ : 0 < H(x) \leq 0.5$$

$$t = \sqrt{\ln\left(\frac{1}{(H(x))^2}\right)} \qquad untuk \ : 0.5 < H(x) \leq 1.0$$

Note: c0 = 2.515517

c1 = 0.802853

c2 = 0.010328

d1 = 1.432788

d2 = 0.189269

d3 = 0.001308

The results of SPI calculation are classified according to criteria of the sharpness of the drought index according to WMO.

Table 1. Sharpness Drought Index SPI

SPI Value	Category
≥2.00	extreme moist
1.50-1.99	very moist
1:00 to 1:49	moderate moist
-0.99-0.99	mid range
-1.00- -1.49	moderate drought
-1.50- -1.99	severe drought
≤-2	extreme drought

Source: World Meteorological Organization (2012)

C. Results and Discussions

Based on drought index calculations by the SPI method in Grobogan at 21 stations using rainfall data for 21 years (1994-2014) can be seen that the drought lasted for five months from May to September

Table 2. Drought Index at Grobogan Regency (1994-2014)

No	Rain Stasiun	Jan	Feb	Mar	Apr	May	Jun	Jul	Agt	Sept	Okt	Nov	Des
1	SE 133 Godong	N	N	N	N	MD	MD	SD	ED	MD	N	N	N
2	SE 134 Gopeng	N	N	N	N	N	MD	SD	ED	MD	N	N	N
3	SE 135 Kepoh	N	N	N	N	N	MD	MD	SD	MD	N	N	N
4	SE 187 Kramat	N	N	N	N	MD	MD	MD	SD	MD	N	N	N

138

No	Rain Station												
5	SE 196 Brati	N	N	N	N	N	MD	MD	SD	SD	N	N	N
6	SE 198 Wolo	N	N	N	N	MD	MD	MD	SD	MD	N	N	N
7	SE 199 Gending	N	N	N	N	MD	MD	MD	ED	MD	N	N	N
8	SE 200 Wedoro	N	N	N	N	MD	MD	SD	ED	MD	N	N	N
9	SE 201 Pengkol	N	N	N	N	MD	MD	SD	ED	MD	N	N	N
10	SE 202 Sedadi	N	N	N	N	MD	MD	SD	SD	MD	N	N	N
11	SE 204 Purwodadi	N	N	N	N	MD	MD	SD	ED	MD	N	N	N
12	SE 205 A Sanggeh	N	N	N	N	N	MD	SD	SD	MD	N	N	N
13	SE 205 B Semen	N	N	N	N	MD	MD	SD	SD	MD	N	N	N
14	SE 211 Tambakselo	N	N	N	N	MD	MD	SD	ED	MD	N	N	N
15	SE 212 wirosari	N	N	N	N	MD	MD	MD	SD	MD	N	N	N
16	SE 213 Tawangharjo	N	N	N	N	MD	MD	SD	SD	SD	N	N	N
17	SE 214 A Pojok	N	N	N	N	N	MD	SD	SD	MD	N	N	N
18	SE 216 Nglangon	N	N	N	N	N	MD	MD	SD	MD	N	N	N
19	SE 217 A Butak	N	N	N	N	N	MD	MD	SD	MD	N	N	N
20	SE 217 Simo	N	N	N	N	N	MD	MD	SD	MD	N	N	N
21	SE 220 Ngaringan	N	N	N	N	MD	MD	MD	SD	MD	N	N	N

Sourcer : secondary data analysis, 2016
Note: N = Normaly, MD = Moderate Drought, SD = Severe Drought, ED = Extreme Drought

1. Drought in May

May is the beginning of the dry season in Grobogan. This month has an average of 101.00 mm of rain. Based on the analysis SPI drought index with most of the rainfall stations began to suffer from drought, but still in the category of a bit dry. This drought has a value of -1.01 to -1.15.. Drought occurred in 13 rainfall stations by category rather dry area of 123494.97 ha (62.50%) covers 12 subdistricts, namely Kedungjati, Tanggungharjo, Tegowanu, Gubug, Godong, Klambu, Brati, Grobogan, Geyer, Pulokulon, Kradenan and Gabus. In eight other stations measuring 74091.03 ha (37.50%) classified as normal includes District Karangrayung, Penawangan, Purwodadi, Toroh, Tawangharjo, Wirosari and Ngaringan.

Table 3. SPI Drought Index at Grobogan Regency in May

No	Rain Station	May	
		SPI	Criteria
1	SE 133 Godong	-1.06	MD
2	SE 134 Gopeng	-0.80	N
3	SE 135 Kepoh	-0.91	N
4	SE 187 Kramat	-1.12	MD
5	SE 196 Brati	-0.89	N
6	SE 198 Wolo	-1.04	MD
7	SE 199 Gending	-1.03	MD

8	SE 200 Wedoro	-1.15	MD
9	SE 201 Pengkol	-1.15	MD
10	SE 202 Sedadi	-1.04	MD
11	SE 204 Purwodadi	-1.01	MD
12	SE 205 A Sanggeh	-1.00	N
13	SE 205 B Semen	-1.09	MD
14	SE 211 TambMDselo	-1.03	MD
15	SE 212 wirosari	-1.02	MD
16	SE 213 Tawangharjo	-1.10	MD
17	SE 214 A Pojok	-0.98	N
18	SE 216 Nglangon	-0.76	N
19	SE 217 A ButMD	-0.87	N
20	SE 217 Simo	-0.88	N
21	SE 220 Ngaringan	-1.13	MD

Source: secondary data analysis, 2016

2. Drought in June

In June Grobogan has an average rainfall of 56.79 mm. Based on the analysis of drought index, degree of dryness that occurs in the category somewhat dry with SPI value of -1.11 to -1.49. This means all areas experiencing drought Grobogan.

Tabel 4. Indeks Kekeringan Bulan Juni Kabupaten Grobogan

| No | Stasiun CH | Juni | |
		SPI	Kriteria
1	SE 133 Godong	-1.44	AK
2	SE 134 Gopeng	-1.31	AK
3	SE 135 Kepoh	-1.26	AK
4	SE 187 Kramat	-1.37	AK
5	SE 196 Brati	-1.27	AK
6	SE 198 Wolo	-1.40	AK
7	SE 199 Gending	-1.19	AK
8	SE 200 Wedoro	-1.45	AK
9	SE 201 Pengkol	-1.49	AK
10	SE 202 Sedadi	-1.37	AK
11	SE 204 Purwodadi	-1.43	AK
12	SE 205 A Sanggeh	-1.17	AK
13	SE 205 B Semen	-1.25	AK
14	SE 211 Tambakselo	-1.33	AK
15	SE 212 wirosari	-1.11	AK
16	SE 213 Tawangharjo	-1.38	AK
17	SE 214 A Pojok	-1.33	AK
18	SE 216 Nglangon	-1.22	AK

19	SE 217 A Butak	-1.29	AK
20	SE 217 Simo	-1.38	AK
21	SE 220 Ngaringan	-1.38	AK

Sumber: Analisis Data Sekunder 2016

3. Drought in July

In July Grobogan Regency has an average rainfall of 37.76 mm. Based on the results of the analysis of the SPI drought index all area at Grobogan Regency experiencing drought. The level of drought varyng from moderate drought to severe drought with SPI value between -1.29 to -1.77.

Drought in categories of moderate drought occurred in 10 rainfall stations 71313.85 ha (36.09%) including Godong, Klambu, Brati, Kradenan, Cork, partly Ngaringan and partly Pulokulon District. While another 11 rainfall stations were category in severe drought of 126272.1 ha (63.91%) includes Tegowanu, Tanggungharjo, Kedungjati, Gubug, Karangrayung, Penawangan, Purwodadi, Toroh, Geyer, Grobogan, Tawangharjo, partly Wirosari, partly Ngaringan, partly Pulokulon District.

Tabel 3. Indeks Kekeringan Bulan Juli Kabupaten Grobogan

| No | Stasiun CH | Jul | |
		SPI	Kriteria
1	SE 133 Godong	-1.77	SD
2	SE 134 Gopeng	-1.56	SD
3	SE 135 Kepoh	-1.34	MD
4	SE 187 Kramat	-1.39	MD
5	SE 196 Brati	-1.37	MD
6	SE 198 Wolo	-1.39	MD
7	SE 199 Gending	-1.46	MD
8	SE 200 Wedoro	-1.54	SD
9	SE 201 Pengkol	-1.67	SD
10	SE 202 Sedadi	-1.57	SD
11	SE 204 Purwodadi	-1.58	SD
12	SE 205 A Sanggeh	-1.71	SD
13	SE 205 B Semen	-1.66	SD
14	SE 211 Tambakselo	-1.59	SD
15	SE 212 wirosari	-1.39	MD
16	SE 213 Tawangharjo	-1.53	SD
17	SE 214 A Pojok	-1.64	SD
18	SE 216 Nglangon	-1.29	MD
19	SE 217 A Butak	-1.40	MD
20	SE 217 Simo	-1.43	MD
21	SE 220 Ngaringan	-1.47	MD

Source: SPI drought index at Grobogan Regency 2016
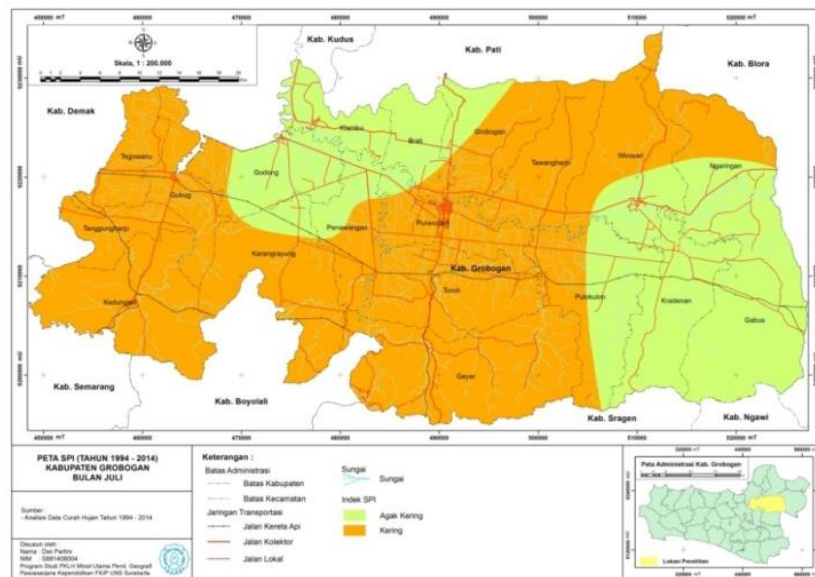
Picture3. Map of SPI drought index in July

4. Drought in August

In August Grobogan has an average rainfall of 19:40 mm. When compared with the average rainfall in other months the average rainfall in August was the lowest. The results of the analysis of the entire SPI drought index with rainfall stations experiencing drought. Drought including severe drought category to extreme drought with SPI values between -1.53 to -2.51.

Tabel 5. Indeks Kekeringan Bulan Agustus Kabupaten Grobogan

No	Stasiun CH	Agustus	
		SPI	Kriteria
1	SE 133 Godong	-2.39	SK
2	SE 134 Gopeng	-2.10	SK
3	SE 135 Kepoh	-1.69	K
4	SE 187 Kramat	-1.95	K
5	SE 196 Brati	-1.82	K
6	SE 198 Wolo	-1.94	K
7	SE 199 Gending	-2.46	SK
8	SE 200 Wedoro	-2.14	SK
9	SE 201 Pengkol	-2.51	SK
10	SE 202 Sedadi	-1.96	K
11	SE 204 Purwodadi	-2.20	SK
12	SE 205 A Sanggeh	-1.72	K
13	SE 205 B Semen	-1.79	K
14	SE 211 Tambakselo	-2.03	SK
15	SE 212 wirosari	-1.69	K
16	SE 213 Tawangharjo	-1.80	K
17	SE 214 A Pojok	-1.61	K
18	SE 216 Nglangon	-1.53	K
19	SE 217 A Butak	-1.78	K
20	SE 217 Simo	-1.75	K
21	SE 220 Ngaringan	-1.67	K

Sumber: Analisis Data Sekunder 2016

The level of extreme drought category occurred in 7 rainfall stations with area 74394.37 ha or 37.65% includes the Kedungjati, Tanggungharjo, Gubug,

Tegowanu, Karangrayung, Penawangan, Purwodadi, most of the Brati, Wirosari, Geyer District. The level of severe drought category occured in 14 rainfall stations with area 123191.6 ha or 62.35% includes the District Godong, Klambu, Brati, Grobogan, Tawangharjo, Toroh, Geyer, Pulokulon, Tawangharjo, Wirosari, Kradenan, Cork and Ngaringan District. If compared with the previous month, drought in August has drastically increased. Distribution of drought in August can be seen on the following map
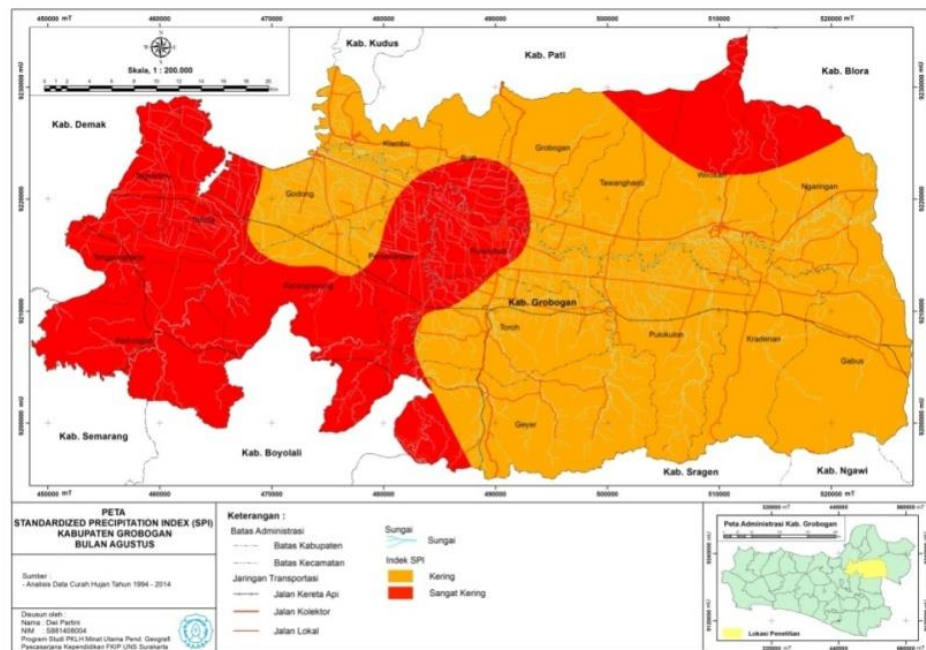
Picture 4: SPI drought index at Grobogan Regency in August

5. Drought in September

In September Grobogan has an average rainfall of 52.42 mm. SPI analysis shows that all rainfall stations experienced drought events by category of moderate drought to severe drought with SPI value of -1.06 to -1.56. This indicates that the drought will end this month.

Tabel 6. Indeks Kekeringan Bulan September Kabupaten Grobogan

No	Stasiun CH	Sept	
		SPI	Kriteria
1	SE 133 Godong	-1.30	AK
2	SE 134 Gopeng	-1.06	AK
3	SE 135 Kepoh	-1.43	AK
4	SE 187 Kramat	-1.34	AK
5	SE 196 Brati	-1.51	K
6	SE 198 Wolo	-1.33	AK
7	SE 199 Gending	-1.19	AK
8	SE 200 Wedoro	-1.22	AK
9	SE 201 Pengkol	-1.24	AK
10	SE 202 Sedadi	-1.19	AK
11	SE 204 Purwodadi	-1.42	AK

12	SE 205 A Sanggeh	-1.27	AK
13	SE 205 B Semen SE 211	-1.35	AK
14	Tambakselo	-1.41	AK
15	SE 212 wirosari SE 213	-1.36	AK
16	Tawangharjo	-1.56	K
17	SE 214 A Pojok	-1.47	AK
18	SE 216 Nglangon	-1.17	AK
19	SE 217 A Butak	-1.46	AK
20	SE 217 Simo	-1.37	AK
21	SE 220 Ngaringan	-1.17	AK

Sumber: Analisis Data Sekunder 2016

Most of the area is categorized as moderate drought in 19 stations rainfall or with an area of 123 495 ha or 62.50% includes 17 subdistrict Kedungjati, Tanggungharjo, Tegowanu, Gubug, Godong, Penawangan, Karangrayung, Geyer, Toroh, Purwodadi, Klambu, Brati, Pulokulon, Kradenan, Cork, Wirosari, Ngaringan. Only two stations belonging rainfall severe drought area of 74091.03 ha or 37.50% includes the District Grobogan and Tawangharjo.
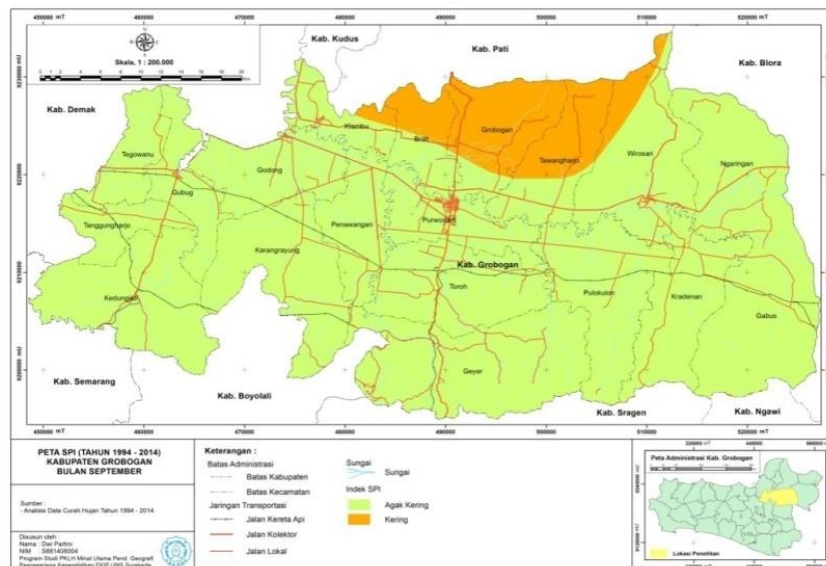
Picture 5. Maps of SPI drought index at Grobogan Regency in September

D. Conclusion and Recommendation

The results of drought index calculation in Grobogan Regency with SPI method based on rainfall data for 21 years (1994-2014) at 21 rainfall stations showed the drought for five months, starting from May until October, and the peak of the drought occurred in August, with 14 rainfall stations (123191.6 ha or 62.35%) belongs

to the category of severe drought and seven stations (74394.37 ha or 37.65%) belongs to the category of extreme drought. The highest drought index values also occur in August is -2.51 at Pengkol station.

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