Relationship Between Run-off and Drought Record Evaluated with Standardized Precipitation Index (SPI) in Kalimanten Sub-Watershed, Indonesia

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1. Introduction

Land degradation and drought are the major challenges for global society. Drought is a natural phenomenon that has been recurring at a regional scale throughout history. Drought is also considered as one of the major natural hazards with significant impact to environment, society, agriculture and economy. Extreme drought history occurred in a same time with anomalous surface temperatures of Pacific Ocean or wide known as El Nino – Southern Oscillation (ENSO) in 1982/1983, 1986/1987, 1991/1992, 1997/1998 and 2002/2003. Information acquired from BMKG (Badan Meteorologi dan Geofisika - Indonesian Agency of Meteorology, Climatology and Geophysics), East Java has quite high potential of drought disaster. About 20 districts are classified as drought-stricken areas such as Bangkalan, Sumenep, Madiun, Gresik, South Blitar and South Malang. Drought analysis must be performed to avoid all losses due to drought phenomenon. The identification and quantification of drought is not an easy task. It is recognized that there is no universally accepted definition of drought, because there is a wide variety of sectors affected by drought, its diverse spatial and temporal distribution and the demand placed on water supply by human-used systems (Heim, 2002).

Figure 1. Map of Kalimanten Sub Watershed

This study is located in Kalimanten Sub-Watershed, Malang, East Java as seen in **figure 1**. The purpose of this study is to know the characteristics of drought, such as the amount and the distribution and its correlation with runoff behavior in the study area. Result of this study can be used as a reference in preventing and mitigating drought phenomenon. Hazard level and mitigation efforts can be determined based on drought analysis of this study so that losses generated from the drought disaster can be minimalized.

2. Methodology

SPI (Standardized Precipitation Index)

The Standardized Precipitation Index (SPI; McKee 1993) is the number of standard deviations that observed cumulative precipitation deviates from the climatological average. It can be calculated for total precipitation for any duration. To compute the index, a long-term time series of precipitation data sets over the desired time scale are used to estimate an appropriate probability density function.

Drought category of SPI value (MC Kee at al., 1993) can be seen at table below:

Table 1. SPI Drought Classification

SPI Value	Drought Category	Time in Category
0 to -0.99	Mild Drought	34.1 %
-1.00 to -1.49	Moderate Drought	9.2 %
-1.50 to -1.99	Severe Drought	4.4 %
≤ -2.00	Extreme Drought	2.3 %

In this study, SPI was calculated using 25years monthly rainfall data from five rainfall gauges in the study area. In this paper, SPI calculation focused only on SPI 3 monthly (SPI3) because a 3-month SPI can reflects short to medium term moisture condition and provide a seasonal estimation of precipitation, primarily in agricultural region.

3. Result and Discussion

SPI Result

Precipitation in study area categorized as monsoonal precipitation where high rainfall intensity occurred in the beginning and end of the year, whereas in the middle of the year tends to be dry.

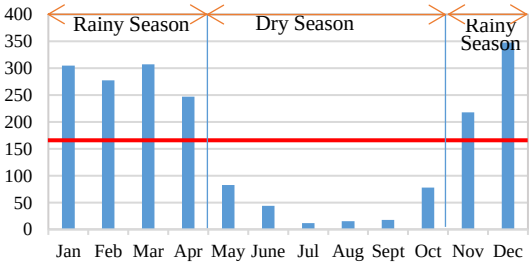

Figure 2. Graphic of Average Monthly Rainfall in Tangkilsari Rainfall Station Period 1990-2015

Rainfall data from 5 rainfall stations (1990-2015) were calculated using SPI (*Standardized Precipitation Index*) to find information about drought in the study area. Result of SPI calculation are as follows:

- **1997-1998**

Extreme drought occurred in May (Cumulative March-May) with SPI Index -1.57 until -2.53. Most extreme drought occurred in Tajinan Rainfall station. In December 1997 (cumulative October-December 1997) extreme drought occurred in Karangsuko, Tajinan and Blambangan while Bululawang and Tangkilsari had moderately drought. In January 1998 (cumulative November 1997-January1998), extreme drought occurred again in Blambangan and Karangsuko Rainfall Station, while the others tend to had moderate to severe drought.

- **2009-2010**

Extreme drought occurred in December (cumulative October-December 2009). 4 out of 5 station experiencing extreme drought. Tajinan, Bululawang, Blambangan and Tangkilsari had extreme drought with SPI index between -2.38 until -2.57 while Karangsuko rainfall station categorized

as normal. Drought occurred continuously until January 2010 where Bululawang and Blambangan had extreme drought while Tangkilsari and Tajinan had moderate to severe drought and Karangsuko rainfall station categorized as normal drought.

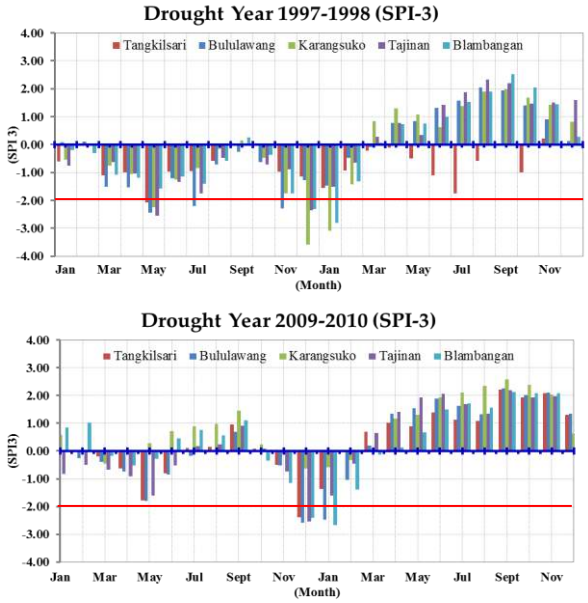

Figure 3. SPI Index During Drought Period, (a) 1997-1998, (b) 2009-2010

SPI-Discharge Comparison

Discharge data from 2 AWLR (*Automatic Water Level Recorder*) were used to know the conformity between SPI3 calculation and water amount available in the study area. AWLR Sengguruh is located at the downstream end of the study area while AWLR Gadang observes the discharge from the upper stream of the study area, so that the difference of the discharge represents the runoff from the entire study area.

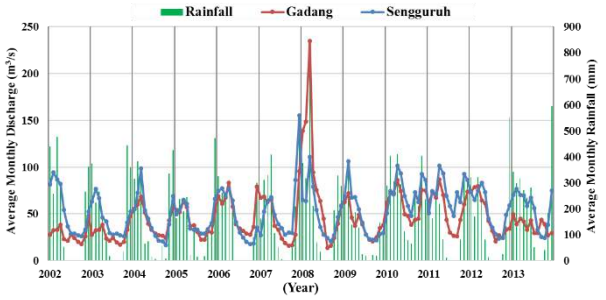

Figure 4. Comparison Between Average Discharge and Rainfall in Kalimanten Sub Watershed

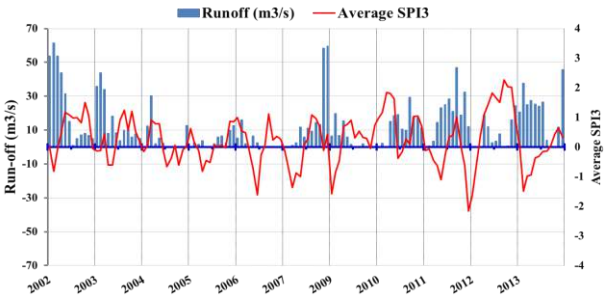

Figure 5. Average SPI3 Versus Runoff Between AWLR Gadang and AWLR Sengguruh

As seen in figure 5, in the end of 2002 until 2003, on average 30-40 m^3/s water flowing from upstream to downstream. At that period, average SPI3 is positive (no drought). Meanwhile in 2009-2010, when the runoff is close to zero, average SPI3 is negative (drought). The small value of runoff between two points means at that time just a very few water flow from entire watershed. This condition is an indication of drought that occurred in entire watershed. Contrarily, when the difference is high between 2 AWLR, indicates that there is no drought occurred in the watershed.

SPI - SOI (Southern Oscilliation Index) Comparison

El-Nino is one of the causes of drought in tropical areas such as Indonesia. Therefore, in this study, SPI3 analysis will be linked to the time of the El-Nino. El Nino is detected when SOI values negative, while La Nina detected while SOI values positive. In 1990-2015, strong El-Nino occurred in 1991-1992, 2002-2003 and 2009-2010 and very strong El-Nino occurred in 1997-1998.

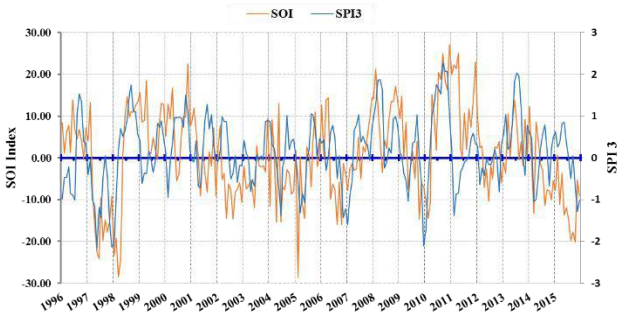

Figure 6. Comparison Between SPI3-SOI

SPI3 indicate that in 1997, drought reach its peak in May which is value of 3-months period of drought (March-May). This correspond to the value of El-Nino index. From **figure 6**, moderate El-Nino began on March and become stronger until reach its peak in June (-24.1). When a very strong El-Nino occurred again in January 1998 (-23.5), SPI3 also indicates that extreme drought occurred in the Kalimanten Sub-Watershed. This behavior indicates that there is strong relationship between El-Nino and drought in the study area.

4. Conclusions

Based on drought analysis during 1990-2015, the worst drought occurred in 1997-1998. In May 1997, all of the station has extreme drought status. At the end of 1997 until early 1998, moderate to extreme drought occurred in all of the station. This result has conformity with run off behavior in study area. Small value runoff occurred during drought periods of SPI3, which mean there are very limited water available in the watershed at that period or can be categorized as drought. SPI3 result also have correlation with SOI. Drought peak in May 1997 occurred during very strong El Nino from March to June 1997. Generally, SPI3 drought occurred during the time of El-Nino whether its moderate, strong or very strong El-Nino. Based on the analysis of the factors mentioned above, it can be concluded that SPI3 can be used as a measure to monitor the drought in Kalimanten Sub Watershed.

5. Reference

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