CASE STUDY PAPER

DROUGHT ANALYSIS USING EDI AND SPI METHOD TO MITIGATE DROUGHT DISASTER IN WONOGIRI DISTRICT

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Abstract

Drought is one of natural disaster that affects many life aspects such as agricultural and economic. One of areas that have a high risk of meteorological drought in Indonesia is Wonogiri District. This area tends to have less rainfall than other areas. In order to develop strategic plan and program activities related to draught disaster mitigation, the corresponding hydrological characteristics in this area have to be clarified through drought analysis.

Meteorological drought is a condition where the rainfall depth less than normal condition. Meteorological drought analysis in this study is done by using EDI and SPI methods. These methods use rainfall data as the input in the calculation i.e. monthly rainfall data. Rainfall data station that is used in this study is 15 rain gauges with 12 years data, from 1990 to 2001. The results of the drought analysis are then used for making a drought risk map in the Wonogiri District.

The results show that EDI method could describe drought condition in Wonogiri more efficient than SPI method, for both of short occurrence and long occurrence. Drought in the study area occurs in May up to October. The result of the mapping using GIS describes the area that affected by drought and its index. The result could be used as a parameter to mitigate drought disaster in Wonogiri District.

Keywords: meteorological drought, rainfall, GIS, drought risk map

INTRODUCTION

General Background

Drought is kind of slow onset disaster. Its mean that drought occurrence is slow process that occurs in a long period that affects many life sectors. The main cause of any drought is a deficiency of the precipitation in particular time and area. This condition is quite often causing the water storage condition become malfunction. Naturally, it will affect the function of the eco-systems and the human activities. The impact of the drought could be in many sectors such as economy and food security. Therefore, it is needed to study the drought condition and drought severity as a basis of drought mitigation in order to decrease the impact of this disaster.

The economic, social, and environmental damage due to drought in Indonesia is become more serious today. According to Badan Meteorologi, Klimatologi dan Geofisika in 2005 (Hasta, 2005 in Wahyudi, 2009), Wonogiri District is one of the 30 district in Java that has greater impact of drought. So, this study focusing to assess the drought severity in this area.

To assess the drought severity in this study, it is used two method, those are Standardized Precipitation Index (SPI) and Effective Drought Index (EDI). Both of the methods are using precipitation data for the input of the calculation. SPI has been used for assessing the drought condition all over the world, such as in Europe (Karavitis, et al., 2011, Lana, et al., 2001, Bordi, et al., 2001, Bonaccorso, et al., 2003, Tsakiris, et al., 2004, Fiorillo, et al., 2010, Santos, et al., 2010), America (Seiler, et al., 2002, Yamoah, et al., 2000, Wu, et al., 2007), Asia (Komuscu, 1999, Wu, et al., 2001, Sonmez, et al., 2005, Touchan, et al., 2005, Zhang, et al., 2009), Afrika (Agnew, 2000), and Australia (Khan, et al., 2008). Different with SPI, EDI is belong to new method. It has been used to assess drought condition in Iran (Morid, et al., 2006) and the result shows that EDI assess drought severity more effective than other method. Therefore, it is used SPI and EDI to assess drought severity in this study.

Literature Study

Standardized Precipitation Index (SPI)

SPI index is calculated by some following step. The first step of the calculation is preparation of the data i.e. continuous monthly precipitation data. Afterwards calculate the mean precipitation for the certain time scale. The time scale that is usually used is i = 3-, 6-, 12-, 24-, or 24-monthly (McKee, et al., 1993). SPI is calculated by the next equation:

$$Z_{ij} = \frac{X_{ij} - \overline{X}_i}{\sigma_i} \quad (1)$$

where

X_{ij} = mean precipitation for time scale i in year-j,

$\overline{X}_i$ = mean precipitation for time scale i,

σ_i = standard deviation of precipitation for time scale i.

Classification of the drought by SPI is given in the following table (McKee, et al., 1993).

Table 1. SPI drought classification

Drought classification	Category	Probabilitas (%)
Mild drought	$-0.99 \leq SPI \leq 0$	~24
Moderate drought	$-1.49 \leq SPI \leq -1.0$	9.2
Severe drought	$-1.99 \leq SPI \leq -1.5$	4.4
Extreme drought	$SPI \leq -2.0$	2.3

Lloyd-Hughes, et al., (2002) classified drought by SPI in eight classes as follows.

Table 2. SPI drought classification

Drought classification	Category	Probabilitas (%)
$SPI \geq 2.00$	Extremely wet	2.3
$1.50 \leq SPI \leq 1.99$	Severely wet	4.4
$1.00 \leq SPI \leq 1.49$	Moderately wet	9.2
$0.00 \leq SPI \leq 0.99$	Mildly wet	34.1
$-0.99 \leq SPI \leq 0$	Mild drought	34.1
$-1.49 \leq SPI \leq -1.00$	Moderate drought	9.2
$-1.99 \leq SPI \leq -1.5$	Severe drought	4.4
$SPI \leq -2.00$	Extreme drought	2.3

Effective Drought Index (EDI)

The EDI index is calculated by some step. The first step is calculating the effective precipitation (EP). The EP value is calculated by summing-up the amount of the precipitation, considered losses because of run off or evapotranspiration. The calculation of the EP is using the next equation:

$$EP_i = \sum_{i}^{n=1} \left[\frac{\sum_{n}^{m=1} P_m}{n} \right] \quad (2)$$

where: 365 is the period over which precipitation is summed, the most common precipitation cycle. Afterwards, calculate the mean precipitation (MEP) and DEP, which is the difference between the EP and MEP, as the next question:

$$DEP = EP - MEP \quad (3)$$

If the DEP give the negative value, indicating that this condition is drier than average. The last part of the calculation is dividing the DEP with the standard deviation (SD).

$$EDI = DEP/SD(DEP) \quad (4)$$

Drought classification by EDI is given in Table 3 (Byun, et al., 1999).

Table 3. Drought classification by EDI

Drought classification	Category
Mild drought	$-1.0 \leq EDI < 1.0$
Moderate drought	$-1.5 \leq EDI < -1.0$
Severe drought	$-2.0 \leq EDI < -1.5$
Extreme drought	$EDI < -2.0$

In this study, the EDI drought classification is modified into eight classes as follows so that it has similar classification as SPI.

Table 4. Modified drought classification by EDI

Drought classification	Category
Extremely wet	EDI ≥ 2.00
Severely wet	1.50 ≤ EDI ≤ 1.99
Moderately wet	1.00 ≤ EDI ≤ 1.49
Mildly wet	0.00 ≤ EDI ≤ 0.99
Mild drought	−1.0 ≤ EDI < 0
Moderate drought	−1.5 ≤ EDI < −1.0
Severe drought	−2.0 ≤ EDI < −1.5
Extreme drought	EDI < -2.0

Methodology

The study area of this study is Wonogiri District, Central Java, Indonesia. The data used for this study is precipitation data from 15 rain gauge stations shown in Figure 1.

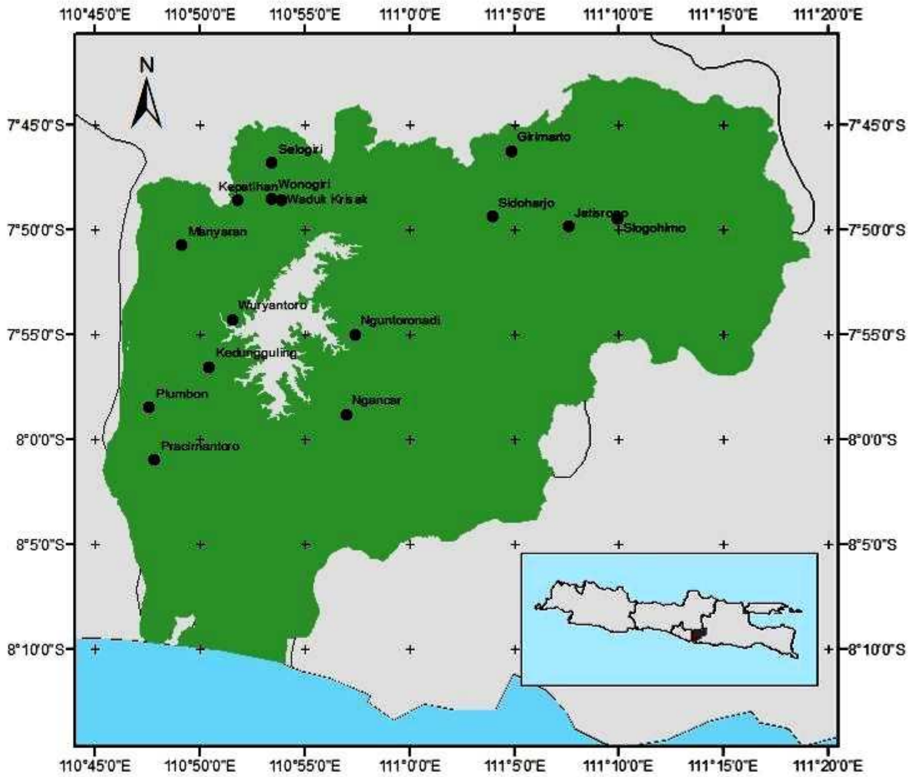

Figure 1. The region under study and the selected rain gauge stations.

Drought for the area was calculated using SPI equation (1). In this study, the SPI drought classification is based on Table 2, whereas the EDI classification is based on Table 4. To assess the area that affected by drought is carried out by mapping drought condition over the area. Mapping was done by Arc.Gis.

RESULTS AND DISCUSSION

Based on the monthly precipitation data, Wonogiri District has drought season in May-October with monthly average precipitation 56,4 mm on May; 49,8 mm on June; 25,5 mm on July; 20,1 mm on August; 13,7 mm on September and 98,5 mm on October. Monthly average precipitation in Wonogiri is depicted in Figure 2.

Station with the lowest precipitation is Selogiri, Pracimantoro and Plumbon. The results of the drought assessment using EDI, SPI 1-, 3-, 6-, 12-, and 24-month for the Selogiri station are shown in Figure 3.

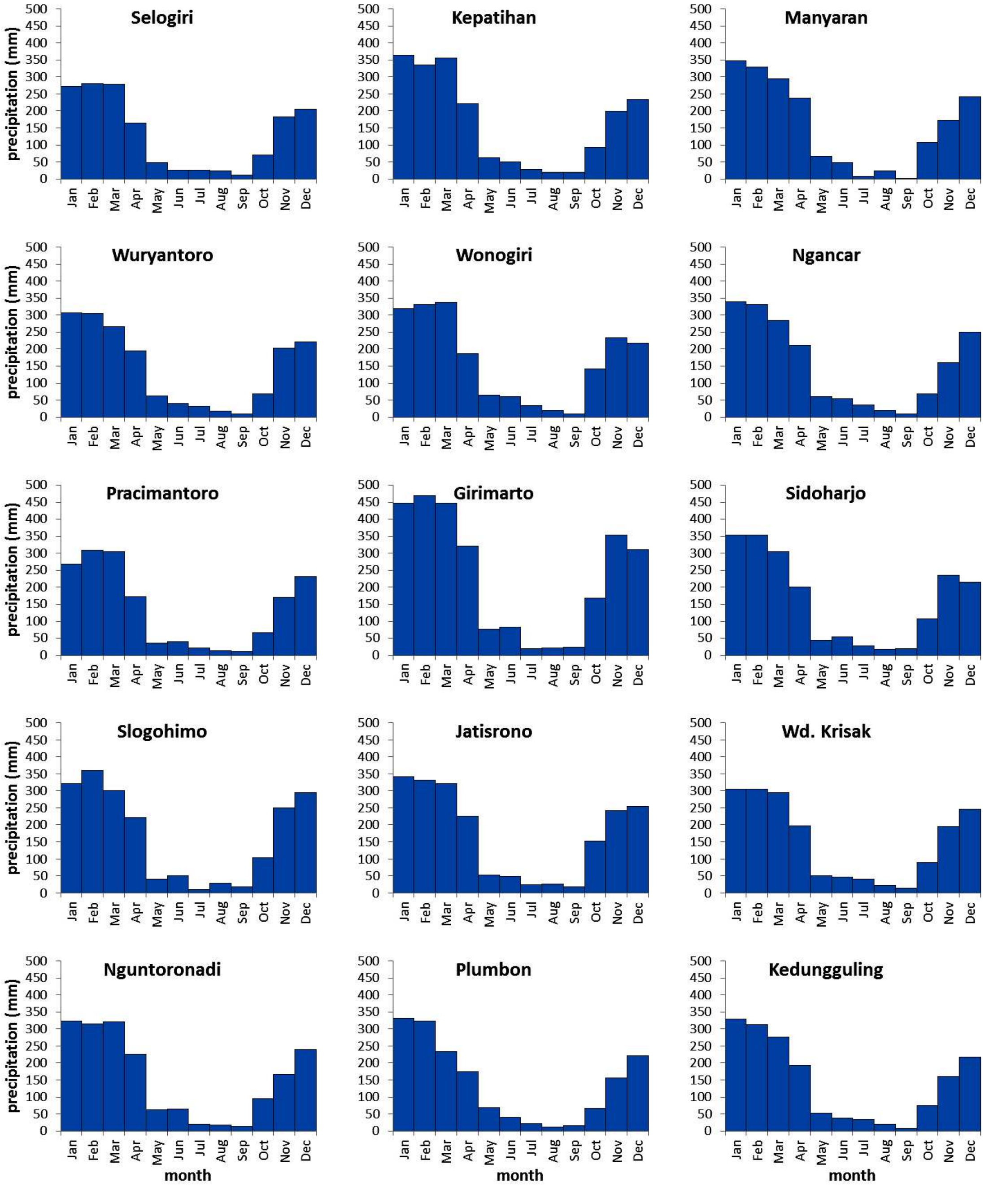

Figure 2. Monthly average precipitation in Wonogiri

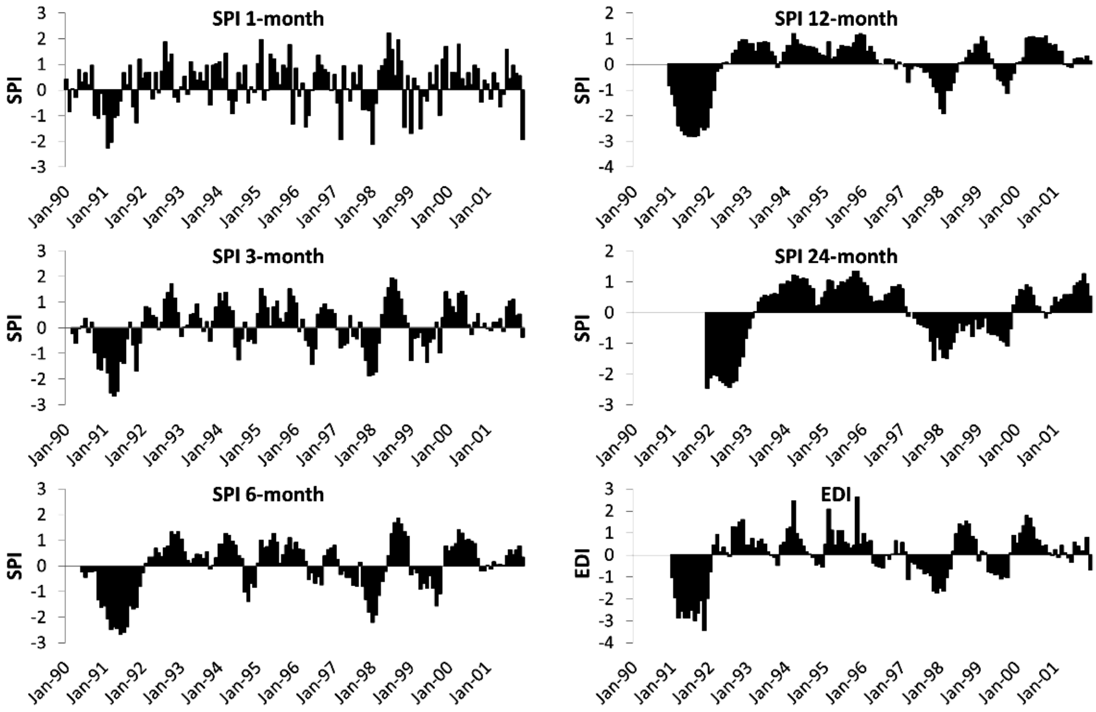

Figure 3. Drought index by EDI and SPI 1-, 3-, 6-, 12-, and 24-month for Selogiri station.

The SPI values vary among the duration. The fluctuation of SPI value for SPI 1-month is the highest one. It is because the SPI 1-month is based on 1-month precipitation data that has more fluctuation than other data durations. Different with SPI 1-month, EDI index has the same characterization with SPI 12-month. Those two indexes have the same onset time and duration of the drought. Based on this result, it seems that each method has different purpose in drought assessment. SPI with short time scale such as 1-month and 3-month is proper to assess soil moisture that needed to assess agricultural drought. In other side, EDI and SPI with long time scale are proper to assess water availability.

Spatial drought assessment was done with drought mapping. By the drought map, the wide of the area that affected by drought could be assess. For example, the drought occurrence is in 1997-1998. EDI result shows that onset time in 1997 drought is on March and become larger until April. After that, the magnitude of the drought decrease slowly. It is different with the SPI 24-month that the peak of the drought is on November 1997. Therefore, for this reason, EDI method is more effective to be used for drought assessment than SPI.

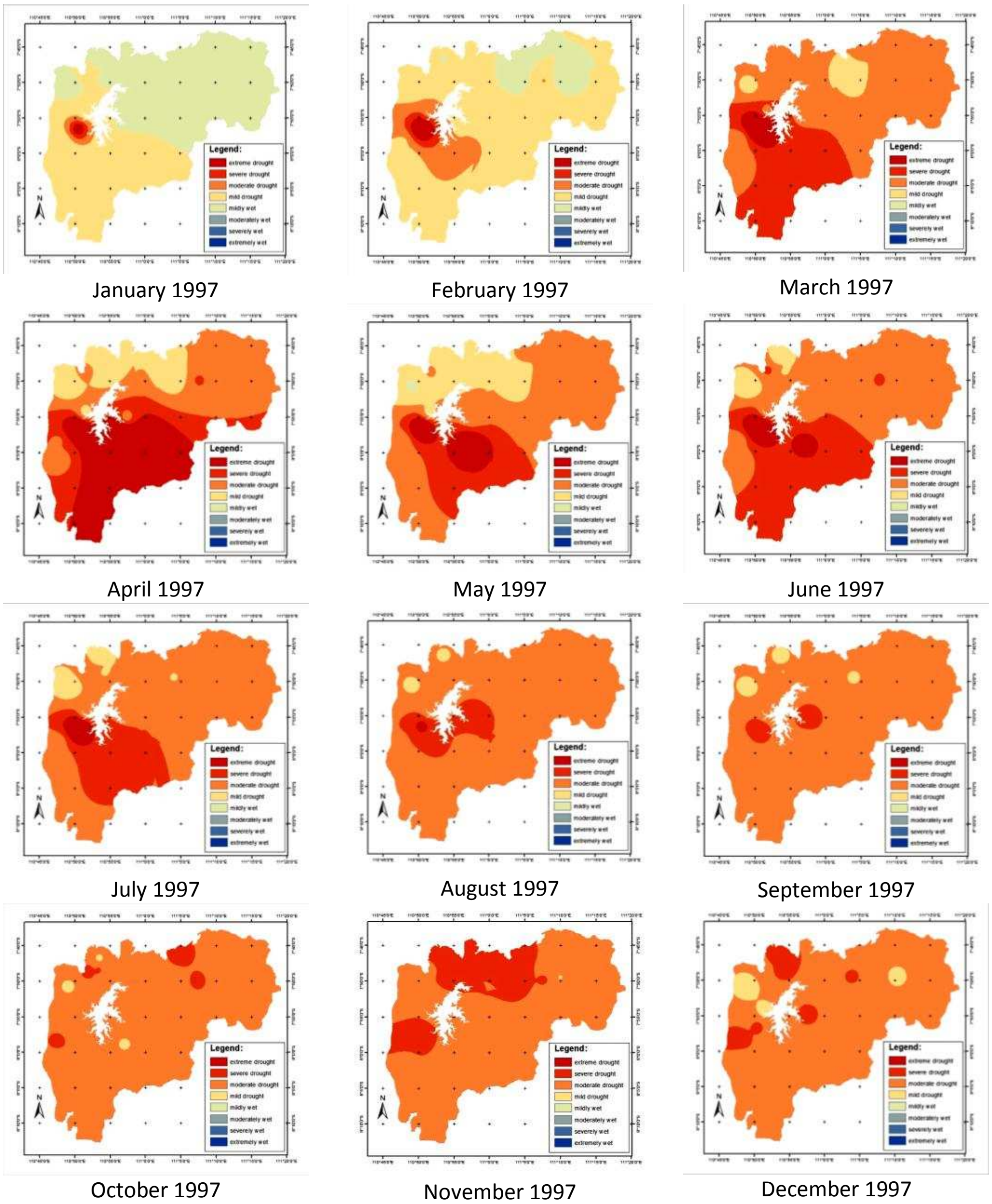

Figure 4. Drought assessment of 1997-1998 drought in Wonogiri using EDI

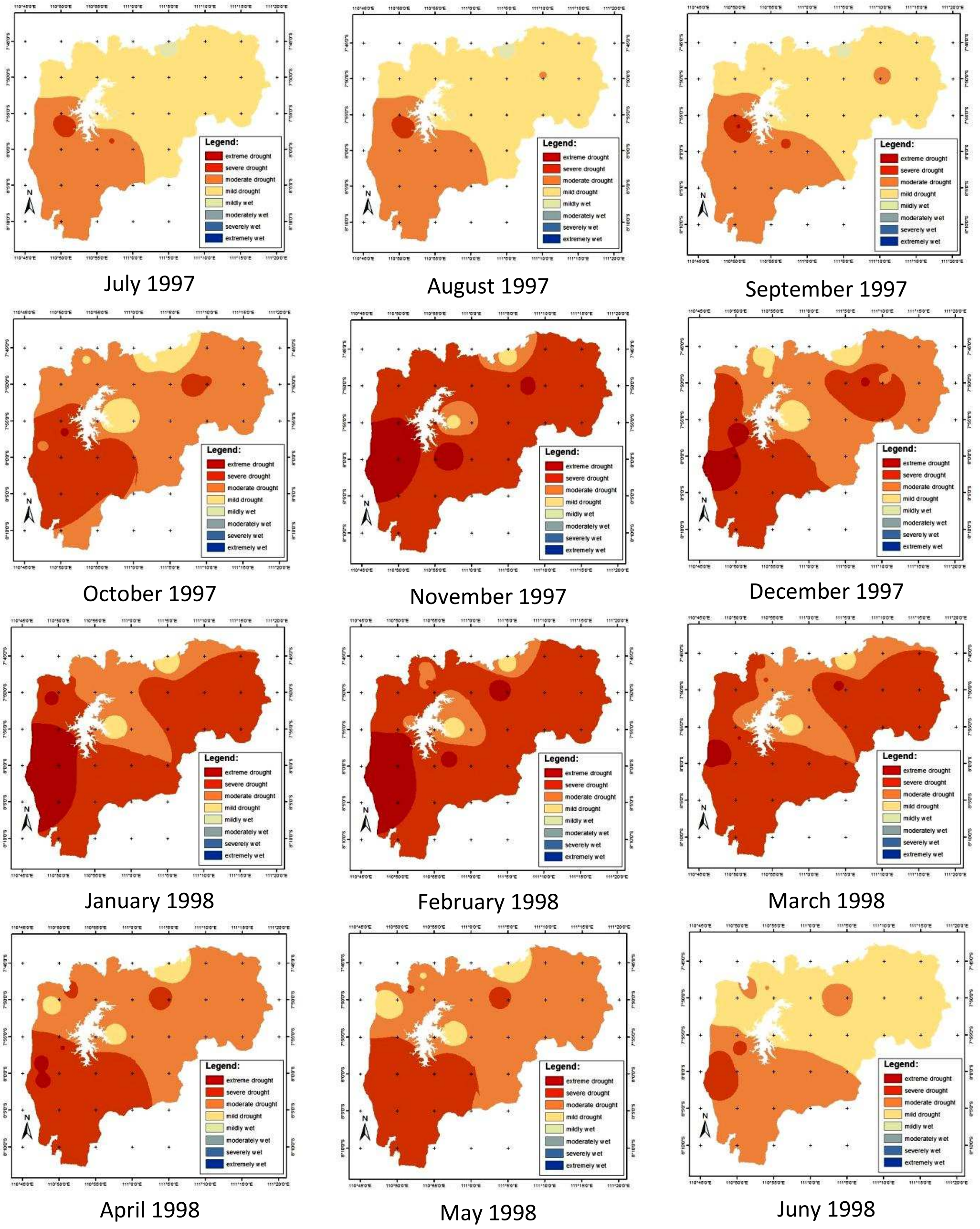

Figure 5. Drought assessment of 1997-1998 drought in Wonogiri using SPI 24-month

CONCLUSION AND RECOMMENDATION

Both of EDI and SPI methods could be used for drought meteorological assessment in the Wonogiri district. Each of the method has different characteristic. SPI with short time scale is fit to assess agricultural drought, whereas EDI and SPI with long time scale is fit to assess hydrological drought. Based on the drought mapping for all of the methods, the area with the highest vulnerability to drought is the South-West region of the Wonogiri district.

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