Spatial distribution of drought levels in Bantimurung District, Maros Regency, South Sulawesi Province

Mina Senjani[1,*], *Eko* Kusratmoko[1], and *Yoanna* Ristya[2]

Department of Geography, Faculty of Mathematics and Natural Science, University of Indonesia, Depok 1624

Abstract. Drought is an event that almost occurs every year in several regions of Indonesia. Drought events are often associated with the El Nino phenomenon, namely the lack of rainfall over a certain period of time in a reasonably long time. In 2015, Indonesia experienced drought in several parts of Indonesia, one of which was Bantimurung District in Maros Regency, South Sulawesi Province. This study aimed to map the level of drought in Bantimurung District. Standardized Precipitation Index (SPI) based meteorological and Normalized Difference Vegetation Index (NDVI) were used to determine the spatial-temporal distribution of drought. Then, the NDVI values of weak (2014) and very strong (2015) El Nino year were correlated with SPI. The results show that Bantimurung District experienced drought in 2015 with near normal (July-September) to moderately dry (October-November) drought levels. In 2014, the drought was not so severe compared to 2015 because the level of drought was near normal and moderately wet. In 2014, the moderately wet area was located in the east district including Leang-leang and Kalabbirang villages. In 2015, villages Minasa Baji, Mattoangin, Alangtae, Baruga, Tukamasea, Mangeloreng, west of Kalabbirang and Leang Leang were located in western of the district have moderately dry drought level.

1 Introduction

Drought is an event that almost every year occurs in several regions in Indonesia. Drought is a naturally occurring event caused by a lack of rainfall over a long period of time [1]. One of the causes of drought is the El Nino phenomenon. The El Nino phenomenon has resulted in some regions in Indonesia experiencing a decrease in rainfall far from normal or a prolonged dry season [2]. Indonesia experienced intense heat and drought during the dry season of 2015, especially in the July-October [3]. In addition, previously, in 2014, Indonesia experienced the same phenomenon, but El-Nino this year was considered less strong [4]. The impact of El Nino can be seen in several regions in Indonesia, one of which is Maros Regency in South Sulawesi Province.

* Corresponding author: eko.kusratmoko@sci.ui.ac.id

This study examines the phenomenon of drought and maps the level of drought in years experiencing El-Nino symptoms, namely 2014 and 2015 in Bantimurung District. Determination of the level of drought is important to know before mapping. Determination of the level of drought aims to evaluate the climatological tendencies towards dry areas/drought level of an area, estimate irrigation water needs in a certain area, evaluate drought at a place locally, and report periodically the development of drought regionally [5].

In this study, Normalized Difference Vegetation Index (NDVI) and Standard Precipittaion Index (SPI) methods are used to determine the spatial distribution of drought levels in Bantimurung District. The study aims to determine the distribution of drought levels that occur in Bantimurung District. Monitoring and detection drought by using NDVI is based on the health of vegetation that is correlated to moisture condition [6]. The hypothesis for a strong SPI-NDVI relationship to agricultural land is that lack of rainfall often causes vegetation to experience stress or even death, with plants showing a decrease in near-infrared reflectance and increased red reflectance [7].

Bantimurung District has the largest paddy field in Maros Regency. According to data from the Central Statistics Agency in 2017, the area of paddy farming in Bantimurung District reached 3800.25 hectares and the agricultural sector is the main livelihood for the local population. In addition, Bantimurung District is one of the districts that support Maros Regency as a rice-producing region in South Sulawesi [8]. However, the phenomenon of drought that occurs in this district makes the existing agricultural land becomes less optimal.

2 Methodology

2.1 Study Area

The study was conducted in Bantimurung District, Maros Regency, South Sulawesi. Bantimurung District is located between Latitudes 4°54’30” and 5°4’30” S and the longitudes of 119°35’0” and 119°46’0” E. Bantimurung District is a plateau with flat topographic conditions, with an area of about 173.70 Km^2. Bantimurung District is divided into eight villages, namely: Baruga, Tukamasea, Leang-leang, Matoangin, Mangeloreng, Kalabbirang, Alangtae, and Minasa Baji. Bantimurung District has several types of land use such as agriculture, settlement, plantation, and forest. Agriculture is the widest type of land use in Bantimurung District as well as in Maros Regency with an area of 3.908 Ha. The agricultural sector, especially lowland rice, is the main livelihood for residents in the Bantimurung District.

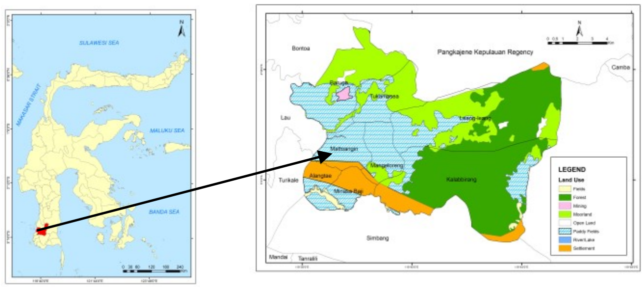

Fig. 1. Study Area

2.1 Data

The data used in this study are: monthly rainfall data for two years of 2014 and 2015 of 8 rain gage stations in Maros Regency obtained from *Balai Wilayah Sungai* (BWS) and 8 Landsat 8 Operational Land Imager (OLI) July – November 2014 and 2015 obtained from the USGS data portal.

2.2 Methods

Determination of the level of drought in this study uses the Standardized Precipitation Index (SPI) and Normalized Difference Vegetation Index (NDVI) methods. The SPI method was developed for drought monitoring, and only requires one input variable [9]. SPI is a probability index that has been widely used to represent meteorological drought. The SPI was calculated using Excel. The following is the SPI equation [10]:

$$SPI = (Xi - Xmean)/\sigma \qquad (1)$$

Where Xi is the precipitation of an investigated (i) period, X_{mean} is the long-term mean, and σ standard deviation of the measured precipitation [10,11]. SPI values are mapped with inverse distance weighting (IDW) using ArcGIS (vers. 10.1). In determining of the level of drought, SPI values are classified. In this study, the SPI classification made by [11] is used.

Landsat 8 is used to extract NDVI values for the period July-September 2014 and 2015. NDVI is a quantitative method based on the use of spectral values from satellite imagery to obtain information about vegetation health and biomass density [12]. NDVI pixel values range from -1 to +1. A high NDVI value indicates healthy vegetation and high humidity and a low NDVI value indicates the opposite condition [11]. Thus the NDVI results can be used as a drought index [7].

$$NDVI = (NIR - Red) / (NIR + Red) \qquad (2)$$

The results of SPI and NDVI for the period July-November in 2014 and 2015 were then correlated between SPI and NDVI. The correlation between NDVI and SPI is determined using Pearson Product Moment. The purpose of this correlation is to determine the effect of meteorological drought on the condition of vegetation and moisture on the surface.

3 Results and Discussion

3.1 Distribution of Drought Results of the SPI Values

The results of the 2014 and 2015 SPI mapping are shown in Figure 2 and Figure 3. The mapping results indicate the level of drought spatially based on the classification of SPI values. SPI mapping results show the similarities and differences in the level of spatial and temporal drought in July-November 2014 and 2015.

In July-September 2014, the level of drought in Bantimurung District was near normal. In October, the eastern part of Bantimurung District including Leang-leang Village and Kalabbirang Village was moderately wet. This condition shows that this region did not experience a meteorological drought. Whereas, in November the level of drought is nearing normal, which is distributed in all districts.

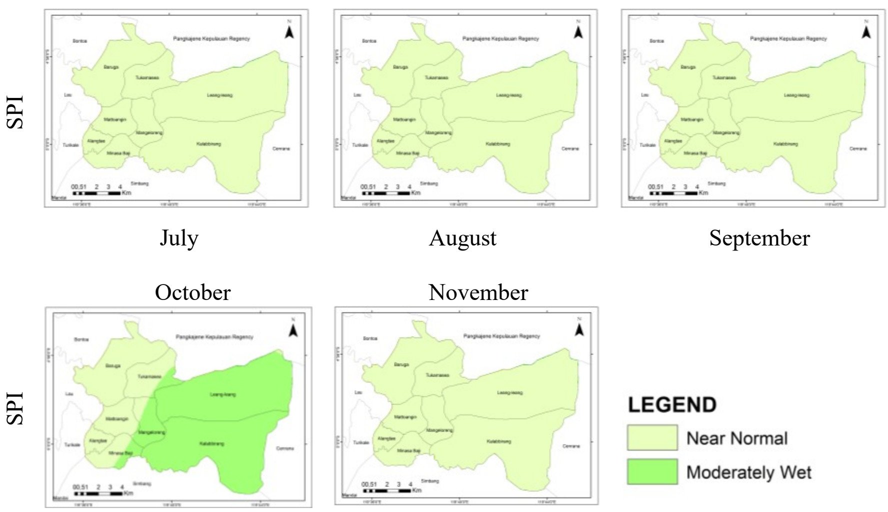

Fig. 2. Standard Precipitation Index (SPI) from July – November 2014

In July-September 2015, the level of drought in Bantimurung District was close to normal. The level of drought with near normal classification is homogeneously distributed in all villages. This drought level has a range of SPI values of -0.99 - 0.99. In October, the drought level in Bantimurung District became moderately dry in most areas and near normal in the eastern regions of Leang-leang and Kalabbirang villages. The level of dryness classified as moderately dry has a range of SPI values -1.00 - 1.49. On the other hand, in November the level of drought with a near-normal was distributed in most of the district areas and was moderately dry only in the western part of the district area including Baruga Village, Mattoangin Village, Alangtae Village, and a small part of Minasa Baji Village.

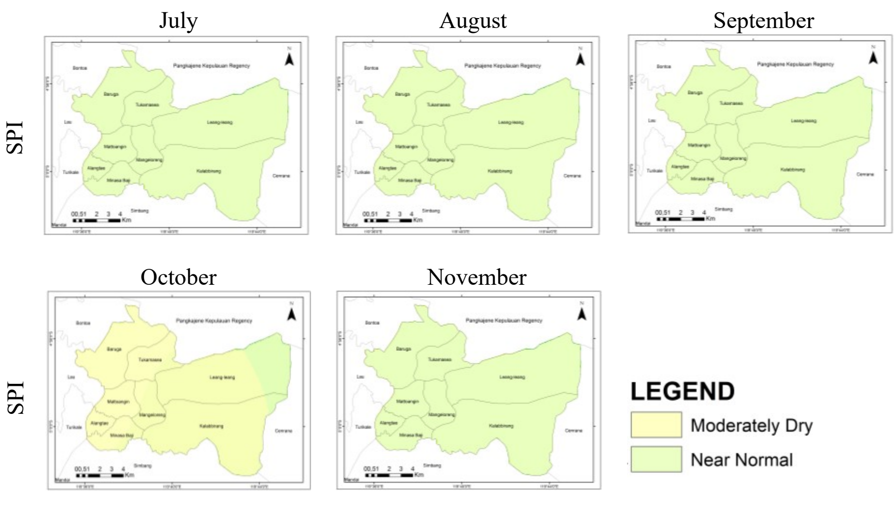

Fig. 3. Standard Precipitation Index (SPI) from July – November 2015

SPI mapping results in 2014 and 2015 show there are similarities in spatial and temporal drought levels. In both years, July-September had a level of drought with a near normal while the difference between the two was in October and November. October 2015 is drier compared to October 2014 and is not dry at all.

3.2 NDVI Distribution

Based on the results of NDVI processing, obtained information related to vegetation density in July-November 2014 and 2015 in Bantimurung District. NDVI results are shown in Figure 4 and Figure 5. In 2015 the smallest NDVI value was found in September with a value of -0.36, while the largest NDVI value was found in August with a value of 0.90. Whereas in 2014 the smallest NDVI value was in August with a value of -0.53 and the largest in the same month with a value of 0.88. Higher NDVI values indicate healthy vegetation and high humidity.

NDVI values for July-November 2014 in Bantimurung District are in the average range of 0.6 - 0.8 which are characterized by light green on the map. NDVI values vary in August where there is a range of the highest values of 0.8-1 and the lowest of -0.53 - 0.2. The lowest average NDVI range per month is found in the northwestern part of Bantimurung District, precisely in Baruga Village.

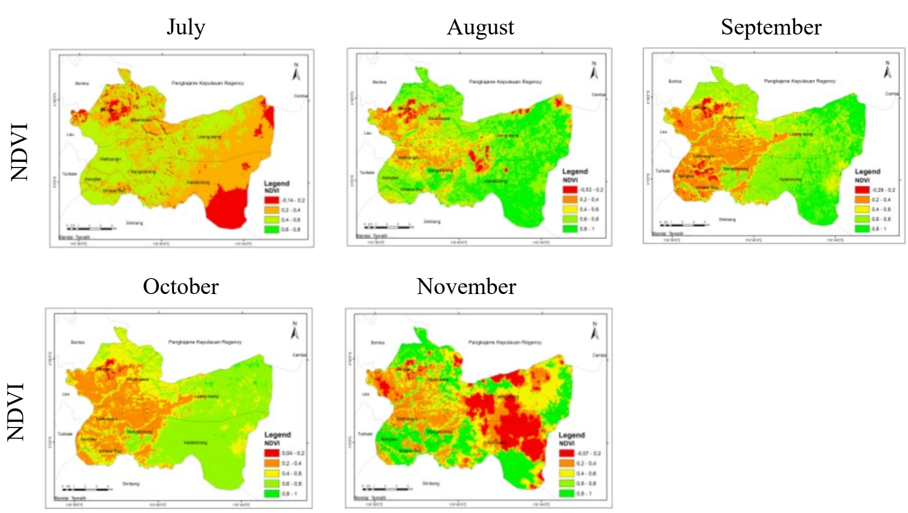

Fig. 4. Normalized Difference Vegetation Index (NDVI) from July – November 2014

NDVI values for July-November 2015 in Bantimurung District are in the average range of 0.6 - 0.8 and 08-1 that are characterized by light green and green in Figure 3a. Areas that have NDVI values are in the central to eastern regions, except in July covering almost all of Bantimurung District. The areas with the lowest NDVI values range almost every month are in the northwest and southwest of Bantimurung District, precisely in the Villages of Baruga and Alangtae.

https://doi.org/10.1051/e3sconf/202015302008

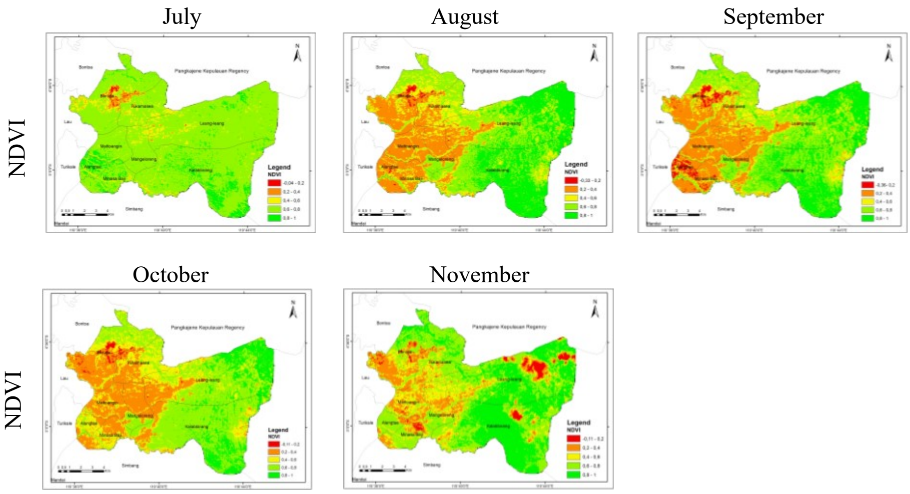

Fig. 5. Normalized Difference Vegetation Index (NDVI) from July – November 2015

NDVI July-November 2015 and 2014 have similarities and differences spatially and temporally. The NDVI equation in the two years is the lowest average NDVI range every month in the northwest region precisely in Baruga Village. This shows that the area has a low vegetation density. The difference in NDVI in the two years is found in the lowest and highest NDVI values. In August 2014, NDVI values were lower than in 2015.

3.3 Correlation between SPI and NDVI

SPI and NDVI are the approaches used to determine drought. SPI is used to determine meteorological drought while NDVI is used to determine surface drought conditions. October 2015 was the month that had the worst drought level compared to other months in the same year and 2014. In analyzing the correlation between meteorological drought and land surface conditions in Bantimurung, Pearson Product Moment analysis was performed.

Pearson correlation coeffiecients between NDVI and SPI is -0,256, which means NDVI is not significantly correlated with SPI and has negative correlation. In most cases, precipitation in one month does not strongly affect vegetation in that month, but the response in notable over periods longer than one month [13]. This shows that meteorological drought has no effect on the health and humidity of vegetation on the surface. Based on the results of interviews, this is because agriculture in Bantimurung District is mostly irrigated rice fields so low precipitation does not really affect the irrigation. Agricultural land is still irrigated by irrigation originating from the Batubassi Dam.

3.3 Conclusions

Bantimurung District experienced a drought in 2015 with the level of drought near normal (July-September) to moderately dry (October-November). In 2014 the drought was not so severe compared to 2015 because from July-November it had a near normal level and was moderately wet. The moderately wet area in 2014 was in the east of the village and moderately dry in 2015 was in the western part of the district including the villages of Minasa Baji, Mattoangin, Alangtae, Baruga, Tukamasea, Mangeloreng and west of Kalabbirang and Leang-Leang.

The correlation between NDVI and SPI in October 2015 is not significantly correlated. This indicates that impact of low precipitation on vegetation does not strongly effect. This because vegetation is still irrigated by irrigation system from Batubassi Dam.

The author would like to thank the University of Indonesia through International Publication Grants Indexed 9 (PIT 9) Number: NKB-0025/UN2.R3.1/HKP.05.00/2019 that has facilitated these activities. Special thanks to Dr. rer. Nat. Eko Kusratmoko for the suggestions during writing this paper.

References

1. L. Ahmad, S. Parvaze, M. Majid, R.H. Kanth, Pakistan J. Met **13,** 25 (2016)
2. R. Bramawanto, R.F. Abida, J. Kelaut. Nas. **12**, 91–9 (2017)
3. A.D. King, D.J. Karoly, G.J. van Oldenborgh, Bull Am Meteorol Soc. **97**, 113–7 (2016)
4. Golden Gate Weather Services (2019) *El Niño and La Niña Years and Intensities.* URL: https://ggweather.com/enso/oni.htm
5. C.E Hounam, Burgos J.J., M.S. Kalik, W.C Palmer, J. Rodda, W. Met. Org. (1975)
6. L. Ji, A.J. Peters, Remote Sens. Environ **87**, 85–98 (2003)
7. E. Ozelkan, C .Ormeci, Remote Sens. a Chang. Eur. IOS Press, 53–60 (2009)
8. Badan Pusat Statistik Kabupaten Maros, BPS Kab. Maros, *Kecamatan Bantimurung*, 107 (2016)
9. T.B. McKee, N.J. Doesken, J. Kleist, The relationship of drought frequency and duration to time scales in *Proceedings of the 8th Conference on Applied Climatology,* 179–83 (1993)
10. E. Ozelkan, G. Chen, B.B. Ustundag, Int. J. Appl earth Obs. Geoinf **44,** 159–70 (2016)
11. M.J. Hayes, M.D. Svoboda, D.A. Wiihite, O.V. Vanyarkho, Bull Am Meteorol Soc **80,** 429–38 (1999)
12. B.M. Dodamani, R. Anoop, D.R. Mahajan, Int. J. Environ. Sci. Dev, *Agricultural drought modeling using remote sensing*, **6,** 326–31 (2015)
13. F. Parmiggiani, G. Quarta, G.P. Marra, D. Conte, NDVI fluctuations from 1995 to 2006 in South Italy and North Africa: a search for a climate change indicator in *Proceedings of SPIE The Int. Soc. for Optical Engineering* (2006)