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Research Paper

Drought Analysis Using Theory of Run Method (Case Study of Hulu Randugunting Watershed in Blora Regency, Central Java)

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ABSTRACT: *Drought is a prolonged scarcity of water periodically in various fields. Meteorological drought is caused by less rainfall than the average situation over a long time, which will lead to a decrease in the amount of groundwater and soil moisture. In this study, 5 stations of rainfall data were used for the last 10 years which were processed into regional rainfall data using Thiessen Polygons. Rainfall data in the Randugunting watershed area was analyzed for meteorological drought using the Theory of Run method. The purpose of this study was to obtain the longest drought duration and the largest number of droughts in the Randugunting watershed and determine the classification of drought levels and compare the Theory of Run drought with Southern Oscillation Index (SOI) data. The results of the analysis using the Theory of Run method are that the duration of the drought occurred for 9 months and the largest number of droughts was 555.40 mm. Based on the results of the drought classification, the normal level is 17.65% and the dry level is 82.35%. The results of the drought are then compared with Southern Oscillation Index (SOI) data which has suitability for the occurrence of drought and El Nino of 35%.*

KEYWORDS: *Droughout, Theory of Run, SOI, ENSO*

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I. INTRODUCTION

Several areas in Indonesia experienced drought, but the start time was irregular (Syahrial, 2017). The District of Blora has established a drought emergency response status in several areas. One of the areas experiencing drought is Japah District (BPBD Blora, 2021)

The study location used in this research is the Hulu Randugunting watershed. The area around the Upper Randugunting watershed is a fairly large agricultural area. The utilization is that community uses it as natural and agricultural resources for the Upper Randugunting watershed which is located in Japah District, Blora Regency. The Randugunting watershed flows through the Randugunting Dam which will irrigate irrigated land during the dry season in the dry area of Blora Regency.

Research by Sanjaya (2022) entitled "Study on the Utilization of GPM Satellite Monthly Rainfall in the Greater Bandung Area with Monte-Carlo Cross Validation" aims to evaluate the performance of satellite-based rain data (GPM IMERG) and correction using the Monte Carlo cross validation method in Greater Bandung. The results of the study with the lowest RMSE value of 75.38; NSE value = 0.86; KR = 0.03, and the value of R = 0.93 indicates that the GPM data can detect monthly rainfall patterns well.

Research using the Theory of Run method was applied to several areas, including analysis to identify the level of drought that occurred in the Ngrowo sub-watershed and serve as an early warning for future droughts (Pratama, 2014). Ciujung with return periods of 5, 10, 15, and 20 years. (Oktaviani, 2015).

The Theory of Run method uses rainfall data from a meteorological drought analysis as the first indication of drought conditions. The Theory of Run method can obtain the longest drought duration and the largest number of droughts. In this method, the deficit (negative run) and surplus (positive run) values are obtained from the difference between monthly rainfall and the monthly average. Based on the deficit and surplus values, the duration of the drought and the number of deficits or droughts can be obtained (Syahrial, 2017).

This study determined the longest drought duration and the largest number of droughts by using the availability of rainfall data in the Upper Randugunting watershed, then classifying the level of drought and comparing it with the El Nina Southern Oscillation (ENSO). This study can be used as a reference for dealing with disasters caused by drought.

II. THEORY

2.1 Drought

Drought is a periodic occurrence of prolonged drought and water scarcity in various areas (atmosphere, lithosphere, and hydrosphere) of the Earth system, designated as one of the most extreme climatic events. Extreme drought episodes are natural difficulties throughout the history of human evolution, and they mainly occur when different hydrometeorological variables become less than actual conditions (Kim, 2020).

These extreme climate events are classified into four categories such as hydrological drought, agricultural drought, meteorological drought, and socio-economic drought (Bhunia, 2019).

2.2 Rainfall

Rainfall is the amount of water that falls when it rains on the earth's surface for a certain period. Rainfall is measured and presented in millimeters on a horizontal plane. Indonesia is a country that often has a variety of rainfall because the area has different altitudes. One millimeter of rainfall can be interpreted as rain that falls over an area of one square meter with a height of one millimeter when the rainwater does not evaporate, seep or flow (Rahmawati, 2014).

2. Drought Index Analysis Method

According to Adidarma, et al. (2010) how to calculate drought is calculated drought based on monthly rainfall in one of the following ways:

1. Percentage against normal
2. Decile
3. Theory of Run
4. Standardized Precipitation Index (SPI)
5. Standardized Precipitation Evapotranspiration Index (SPEI)
6. Palmer Drought Severity Index (PDSI)

2.4 Method Theory of Run

The Theory of Run method was first developed by Yjevich in August 1967. The definition of Theory of Run is to compare the length of the water deficit and the amount of the water deficit. Drought analysis calculations related to the longest drought duration and the largest droughts can be done using the Theory of Run method (Pratama, 2014).

This method will obtain the deficit (negative run) and surplus (positive run) values , which are determined based on the monthly average. Based on the deficit and surplus values, the duration of the drought and the amount of the deficit or drought can be obtained

The general equation of the Theory of Run to determine the surplus and deficit run in equation 2.1, the duration of the drought as in equation 2.2, and the number of droughts are presented in 2.3 (Pratama, 2014):

$$J(m,n)=A(m,n)-B(n) \quad (2.1)$$

$$Ln=\Sigma I(m,n) \text{ in } n=1 \quad (2.2)$$

$$Dn=\Sigma J(m,n)I(m,n) \text{ in } n=1 \quad (2.3)$$

Where n denotes month, m represents the year, (m,n) means deficit and surplus values, (m,n) means monthly rainfall in n months of m years, (n) denotes average monthly rainfall in month n, Ln indicates the duration of drought, shows the number of droughts and (m,n) indicates an indicator of deficit or surplus value, when $(n)>A(m,n)$. The value 0 is called a surplus, when $(n)<A(m,n)$ value 1 is called a deficit.

2.5 Polygon Thiessen

The Thiessen Polygon method is used to calculate the average rainfall in the area. This method is used if the stations are spread unevenly in the research area. In the watershed area, rainfall is considered the same as the nearest station and can represent the area of the watershed. This method uses a minimum of 3 rain stations to perform calculations (Triatmodjo, 2013)

The calculation of the Thiessen Polygon method is presented in the following 2.4 formula (Triatmodjo, 2013):

$$A=(A1L1+A2L2+\cdots+AnLn)/(L1+L2+\cdots+Ln) \qquad (2.4)$$

Where, is regional rainfall, 1,$A2$,An is regional rainfall at station 1,2,n and 1,$L2$,Ln is station area 1,2,n which has an effect.

2.6 El Nino Southern Oscillation (ENSO)

The El Niño Southern Oscillation, also known as ENSO, is an interaction between the atmosphere and the oceans in the tropical Pacific that results in periodic variations in sub-normal and upper-normal sea surface temperatures and dry and wet conditions over several years.

The SOI measures large-scale air pressure changes between the western and eastern Pacific at the time of the ENSO event. This index calculates the difference in air pressure anomalies in Tahiti and Darwin, Australia, which are associated with changes in sea surface temperature in the eastern Pacific region.

III. METHODE

This study uses GPM-IMERG satellite rainfall data and SOI value data from the Australian Government Bureau of Meteorology. The rainfall stations are processed using Thiessen polygons to obtain the influential station area and determine regional rainfall. Regional rainfall is calculated by drought analysis using the theory of run. The results of the theory of run calculations are then classified as a drought. The theory of run calculation is compared with the SOI value.

IV. RESULTS AND DISCUSSION

4.1 Drought Analysis Theory of Run

4.1.1 Deficit dan Surplus Value

Based on the rainfall data, calculations were carried out to determine the surplus and deficit values every month for 10 years of observation. After the average value of all data for that month is obtained, rainfall data is reduced every month with the monthly average, which can be seen in the previous equation (2.1).

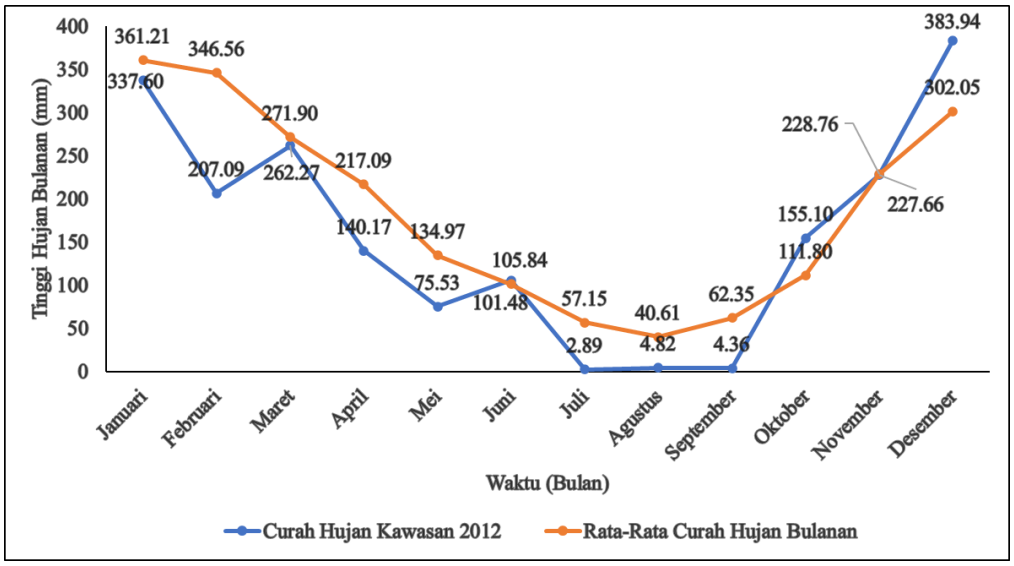

Figure 1: Nilai Defisit dan Surplus

The deficit and surplus values obtained in 10 years of observation are shown in Figure (4.2) to Figure (4.11). The largest deficit occurred in February 2012 at -139.47 mm. The largest surplus value occurred in January 2014 at 330.83 mm.

Based on the classification of rainfall, in 2012, January was a high rainfall. Based on the Theory of Run method in 2012, January is a dry month because the deficit value is obtained. This can happen because the

rainfall value is below the average monthly rainfall and is caused by the unstable, clay and rocky soil structure in Blora Regency. Store water so the monthly fall rainfall cannot be absorbed adequately and causes runoff (Dinas Lingkungan Hidup Kabupaten Blora, 2017).

4.1.2 Drought Duration

The duration of the drought indicates the occurrence of drought in the area. The calculation of the duration of the drought can be determined based on the value of surplus and deficit when the surplus value is assigned a value of (0) and when the deficit value is assigned a value of (1). If the value of one (deficit) is obtained in succession, then that value will be cumulative with the previous value until it is separated again by a zero value (surplus) and then recalculated from the beginning.

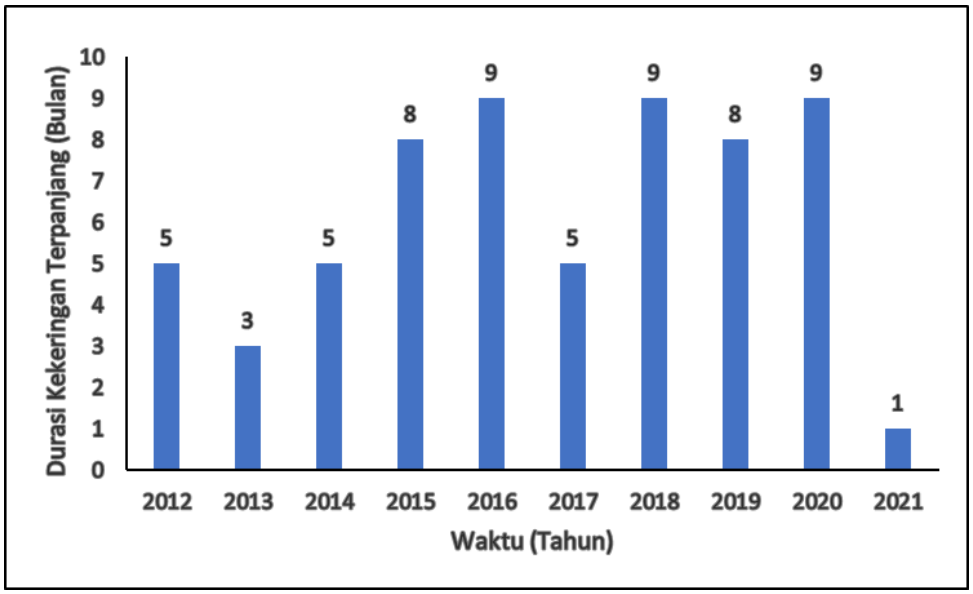

Figure 2: Drought Duration

As seen in Figure 2, the longest drought duration in 10 years of observation occurred for 9 months.

4.1.3 Number of Drought

After calculating the duration of drought, then calculate the number of droughts. The calculation of the number of droughts is based on the calculation of the duration of the drought. The amount of drought can be calculated using equation (2.3). The number of droughts is the accumulation of rainfall that experiences a sequential deficit.

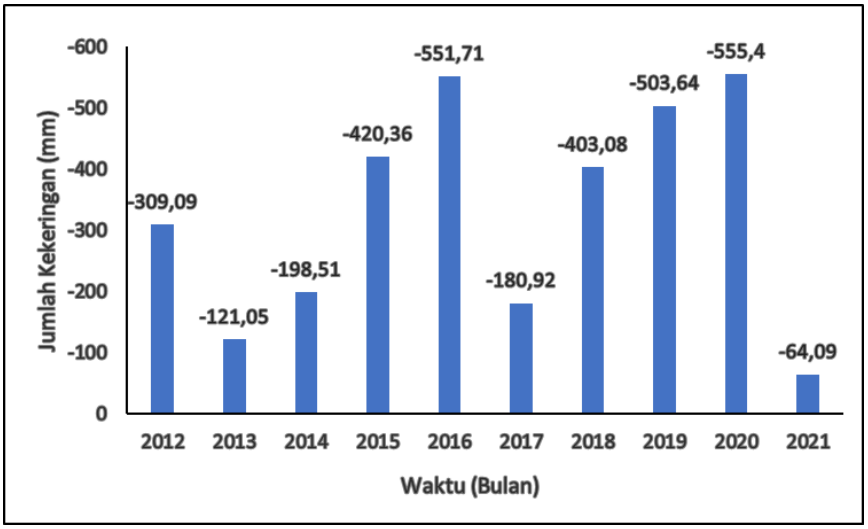

Figure 3: Jumlah Kekeringan

As seen in Figure 3, the largest number of droughts in the 10 year is -555.40mm, which occurred in 2020.

4.2 Drought Classification

This analysis was conducted to determine the level of drought that occurs every year in the Randugunting watershed. For this analysis, normal rainfall values are needed, obtained from the average value of rain for a month in the entire year of observation. Calculation of the classification of the level of drought by comparing the value of monthly rainfall with normal rainfall.

The calculation results show that the rain that occurred in January was 92% below normal rain, so it was classified as "Normal". The results of the classification calculations above are presented in Figure 4

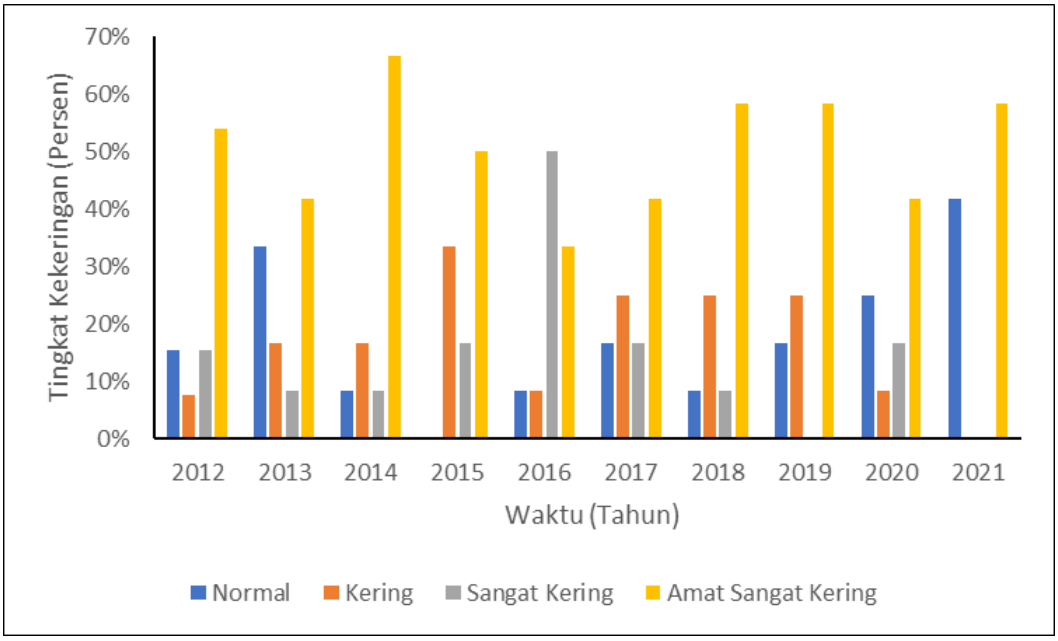

Figure 4: Drought Classification

It can be seen from Figure (4.16) above that the classification level in the Randugunting watershed is the normal level of 17.65% and the dry level of 82.35% because the Randugunting watershed is located in Blora Regency, which is traversed by the northern Kendang mountains or limestone mountains and the geographical conditions are mainly in the form of karst which has a type of arid limestone which causes drought.

4.3 El Nino Southern Oscillation (ENSO)

The results of the Theory of Run drought calculation method can be compared with El Nino events using Southern Oscillation Index (SOI) data. Based on the classification according to the Australian Government Bureau of Meteorology SOI values continuously above +8 indicate La Nina events, SOI values continuously below -8 indicate El Nino. The results of the recapitulation of the Theory of Run drought comparison with SOI values can be seen in Figure 5.

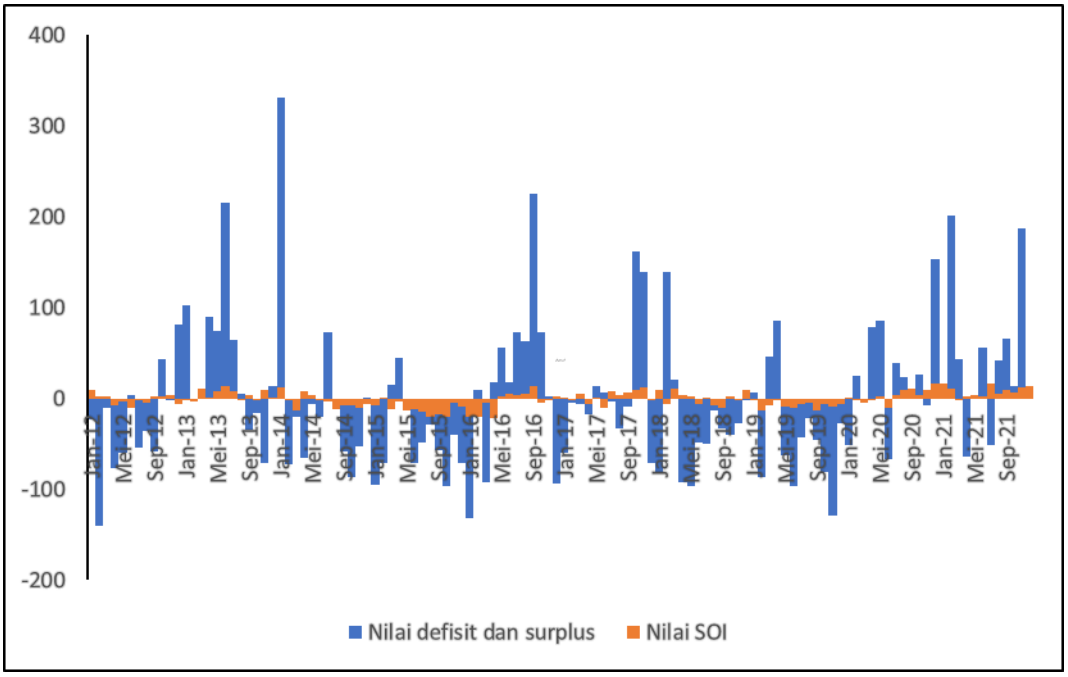

Figure 5: Perbandingan Nilai Defisit Surplus dengan Nilai SOI

Based on Figure 4.17, it can be seen that there is a relationship between the deficit and surplus values on the SOI value. When there is a deficit, the SOI is negative, and when there is a surplus, the SOI is positive. In 2015, the deficit value occurred for several months, as well as the SOI, which showed a negative value.

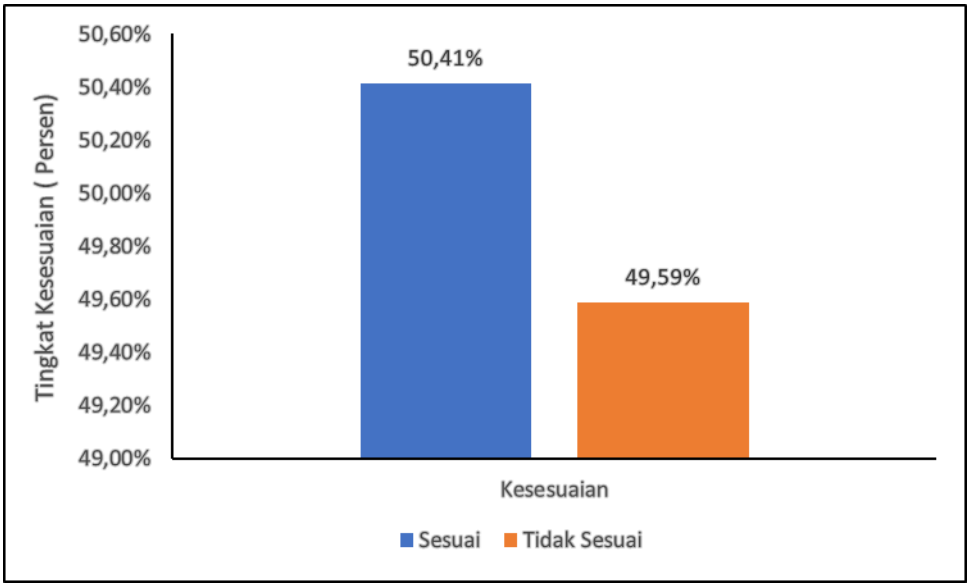

Figure 6: Rekapitulasi Perbandingan Kesesuaian Nilai Defisit Surplus dengan Nilai SOI

Figure 4.18 shows the recapitulation of the suitability of drought with El Nino of 50.41%, while the other 49.59% is influenced by other factors not discussed in this study.

V. CONCLUSION

The research that has been done has concluded that the largest number of droughts in the Randugunting watershed is -555.40 mm, while the longest duration is 9 months. The results of the classification analysis of the Theory of Run method in the Randugunting watershed are the normal state of 17.65% and the dry state of 82.35%. The results of the comparison of the Theory of Run drought with the SOI value have a suitability of drought occurrence with El Nino of 50.41%.

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