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ANALYSIS OF CLIMATE VARIABILITY ON DROUGHT INDEX IN SLEMAN DISTRICT

Rayi Putri Anggraeni[1*], Jasruddin[2], Agus Susanto[3]
Universitas Negeri Makassar, Indonesia
anggraenirayi@gmail.com, jasruddin@unm.ac.id

ABSTRACT

Climate change occurs due to global warming, resulting in irregular seasonal shifts and ecological disasters such as floods or droughts that cause substantial losses. This research aims to determine the influence of climate variability on drought conditions by analyzing drought using the Standardized Precipitation Index (SPI) method. The data used consists of monthly rainfall over 40 years, from 1981 to2020, obtained from CHIRPS satellite and observation data located in SlemanDistrict. From the 40-year data divided into ten-year periods, severe droughts occurred in the second and fourth periods, specifically from 1991 to 2000 and from 2011 to 2020. The highest frequency of drought occurrences from the entire dataset also happened during the 1991-2000 period. Climate variability, based on the Schmidt-Ferguson climate types, shows climate changes by calculating the Q value. Initially, from 1981 to 1990, the Q value ranged from 33.3 to 60, categorized under type C climate. However, from 1991 to 2000, the Q value ranged from 33.3 to 100, with climate types categorized as C and D. Climate pattern changes have occurred from 2001 to 2010, with climate types ranging from B to D. Spatial analysis scale changes were observed from 2011 to 2020. These conditions indicate climate pattern changes in Sleman District over the 40-year period. The relationship between drought index and SPI method with climate variability (Q) values indicates a weak to moderate relationship with a significance level of 5%. This suggests climate change affects rainfall patterns and drought levels. The correlation coefficient values indicate a moderate relationship, with correlation coefficient values ranging from 0.3 to 0.5 highest during period II (1991-2000) and period IV (2011-2020).

Keywords: *Climate Variability, Precipitation, Drought, SPI, Pearson Correlation*

INTRODUCTION

Climate change has only been a global issue that has been widely discussed and solutions are still being sought. Climate can be defined as the average condition of air temperature, precipitation, air pressure, wind direction, air humidity, and other climatic parameters over a long period of time (Kebumian, 2010). Climate/weather information is an inseparable part of the activities of various development sectors such as agriculture, plantations, forestry, transportation, irrigation, environment, mining and energy, disaster mitigation and others. Therefore, climate/weather information has a very strategic value in decision-making related to the planning and evaluation of activities in various development sectors (Laimeheriwa et al., 2019).

Several publications write that Indonesia is at the top of the spectrum as a country that is most vulnerable to natural disasters, namely geological and climate disasters (Djalante & Thomalla, n.d.). Climate cannot be controlled on a meso to macro scale (for example, the scale of islands, archipelagos, countries and continents), so the steps that can be taken are through climate forecasting or forecasting. To predict when extreme climate conditions will occur, what is the level of change and the impact on an area/region, climate analysis and interpretation using long-term climate time-track data is needed.

Climate change occurs due to global warming that results in irregular seasonal changes and ecological disasters such as floods or droughts that come one after another causing real losses. One of the causes is the El Nino and La-Nina phenomena which cause a decrease and increase in rainfall in Indonesia, both annual and seasonal values. The difference in rainfall patterns between regions also causes differences in the changes in rainfall that occur (Sasminto & Tunggul, 2014). The longer dry season and shorter rainy season have led to a reduction in some water sources that come from springs. In tropical regions with warm temperatures and the sun shining all year round, the climate is constantly changing dynamically so it is necessary to estimate the possible availability of water for the foreseeable future.

Lack of water availability can lead to catastrophic droughts. Drought is a lack of rainfall in a long period, so in such a lack of water it causes a bad impact on vegetation, animals, and humans (Maxwell & Soulé, 2009). Drought is a factor that inhibits the growth of agricultural production, especially rice as a staple food, which further affects the local and national economy (Saidah et al., 2017). According to Wilhite and Glantz, drought can be categorized into 4 types of drought, namely meteorological drought, hydrological drought, agricultural drought, and socio-economic drought. In this study, what is studied is about meteorological drought, namely drought related to the level of rainfall below normal in one season, where rainfall is a fundamental factor in controlling the occurrence of drought conditions, but the value of evapotranspiration is also a significant variable (Ali et al., 2011). Meteorological droughts can be identified through several factors, namely the severity based on the drought index, the time of occurrence and duration, the area affected and the frequency of its occurrence (Nalbantis & Tsakiris, 2009).

According to data taken from the Central Statistics Agency (BPS), the harvested area of vegetable crops by sub-district filled the Sleman Regency area of 1,163 hectares, including 26 hectares of onion plants, 930 hectares of cayenne pepper plants, 187 hectares of spinach plants, and 20 hectares of tomato plants. Sleman Regency also has the largest area for its rice fields. According to data from the Indonesian Food Security Index (IKP) in 2018, Sleman Regency is ranked 11th out of 416 districts throughout Indonesia with a score of 83.49. This value shows that the Sleman Regency area has the best food security. From the data obtained, it is concluded that Sleman Regency is an important area in the agricultural and plantation sectors. Climate has a great influence on the sector, therefore research is needed in this region.

This study was conducted to find out the climate change that has occurred in Sleman district over the past 40 years to see the pattern of climate types and their classification over four periods, namely year I (1981-1990), year II (1991-2000), year III (2001-2010), and year IV (2011-2020). It is also associated with drought that occurs by calculating its drought index. Analysis of climate variability and drought index can provide a basis for the development of drought early warning systems. This can help governments and stakeholders to mitigate the adverse impact of drought on critical sectors such as agriculture, plantations, and the environment.

Based on the background described above, it can be identified that the formulation of the problem in the study is how the climate variability occurred in Sleman Regency during the last 40 years. What is the drought index that occurred in Sleman Regency during the last 40-year period. What is the drought index that occurred in Sleman Regency during the last 40-year period. What is the relationship between climate variability and drought index in Sleman Regency.

The purpose of this study is to analyze the climate variability that occurred in Sleman Regency during the last 40 years. Analyzing the drought index that occurred in Sleman Regency during the last 40-year span. Analyze the relationship between climate variability and drought index that occurs in Sleman Regency. The benefit of this study is that this research can improve scientific understanding of climate variability in a particular region. This involves understanding changes in temperature, rainfall patterns, and other factors that can affect drought conditions. Analysis of climate variability and drought index can provide a basis for the development of drought early warning systems. This allows authorities to plan and implement more effective risk management strategies. The findings of the study can be used to formulate adaptation and mitigation policies and strategies that are appropriate to local climatic conditions. This can help governments and stakeholders to mitigate the adverse impact of drought on critical sectors such as agriculture, fisheries, and the environment. With a better understanding of the impacts of climate change, this research can provide guidance for more sustainable management of natural resources. It involves managing water, soil, and ecosystems efficiently and effectively. By evaluating the impact of drought on the agricultural sector, this research can help in the development of more resilient agricultural practices to climate change. This can improve food security and reduce vulnerability to climate fluctuations.

METHOD

This study uses a type of quantitative descriptive research. According to (Sulistyawati et al., 2022), Quantitative descriptive research involves the process of describing, researching, and explaining an object or phenomenon without the intention of testing certain hypotheses by using data in the form of numbers to observe and draw conclusions from the observed phenomenon. Thus, the research focuses on the description, analysis, and explanation of the phenomenon by relying on the available quantitative data. This research aims to analyze climate variability and drought index and the relationship between the two. The data that has been collected is summarized and processed into an analysis to determine the classification of drought index and climate type that occurs in the area studied. Sleman Regency is geographically located between 110° 33′ 00" and 110° 13′ 00" East Longitude, 7° 34′ 51" and 7° 47′ 30" South Latitude (Ramadhani, 2023). This study took this location because Sleman Regency has a topography with different heights marked by the presence of several hills and rivers which indicates that this area has the potential for significant climate change. The region also has significant economic factors, especially in the agricultural sector. Fertile soil supports agricultural sustainability and the diversity of agricultural products produced.

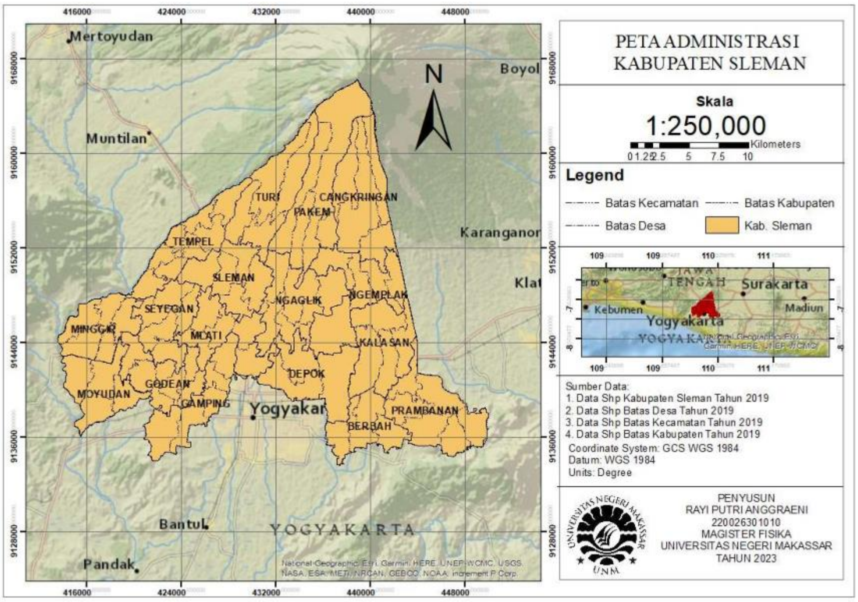

Figure 1. Sleman Regency Administration Map

The time taken in this study was 40 years which was divided into four periods, namely the first year period (1981-1990), the second year period (1991-2000), the third year period (2001-2010), and the fourth year period (2011-2020). This is to find out the changes that have occurred over the past 40 years in Sleman Regency. This study focuses on climate variability in rainfall parameters to determine the classification of climate types in the Schmidt-Ferguson method and analyzes meteorological drought by knowing the drought index with the SPI method by looking at the rainfall deficit that occurs in Sleman Regency.

The data used in this study is the Climate Hazards Group InfraRed Precipitation with Stations (CHIRPS) satellite rainfall data which is open access on the website: https://www.chc.ucsb.edu/data/chirps in the form of a grid data format with a resolution of 0.05° x 0.05°. The spatial resolution of CHIRPS satellite data is quite detailed (Dinku et al., 2018), So that the resulting analysis is expected to be more accurate. There are 20 grid distribution points in Sleman Regency with the name of the grid and its coordinates explained in table 1.

Table 1. The name and location of the grid on the CHIRPS Satellite.

Grid	Longitude	Latitude
823291	110,525	-7,825
821805	110,225	-7,775
821806	110,275	-7,775
821807	110,325	-7,775
821808	110,375	-7,775
821809	110,425	-7,775
821810	110,475	-7,775
820325	110,225	-7,725
820326	110,275	-7,725
820327	110,325	-7,725
820328	110,375	-7,725
820329	110,425	-7,725
820330	110,475	-7,725
818847	110,325	-7,675
818848	110,375	-7,675
818849	110,425	-7,675
818850	110,475	-7,675
817368	110,375	-7,625
817369	110,425	-7,625
815889	110,426	-7,575

Source: CHIRPS Satellite

Rainfall observation data from 6 rain observation posts in the Sleman Regency area from 1981 to 2020 taken from the Yogyakarta Climatology Station.

Table 2. Name and location of the Rain Post

Rain Post	Lintang	Bujur
Banjarharjo	07o 40' 39.0" LS	110o 27' 41.1" BT
Beran	07o 42' 39.0" LS	110o 21' 42.0" BT
Kebonagung	07o 43' 44.3" LS	110o 14' 38.3" BT
Ledoknongko	07o 38' 41.0" LS	110o 21' 27.9" BT
Patukan	07o 47' 52.6" LS	110o 19' 13.0" BT
Trukan	07o 48' 05.5" LS	110o 29' 20.6" BT

Source: Yogyakarta Class IV Climatology Station

Administrative map of DIY and Sleman Regency in .shp obtained from BIG (Geospatial Information Agency). The stages carried out in analyzing the data in this study are as follows:

1. **Drought Index using the SPI method**

   The corrected data was used in calculating the drought index using the SPI method and using the SCOPIC application. There are 4 classifications, namely 1, 3, 6, and 12 monthly to see the rainfall deficit data that occurred in Sleman Regency in 4 predetermined periods. Drought analysis obtained from statistical data obtained from the calculation of the previous stage was carried out in accordance with each period and its spatial analysis to see changes in each specified period of the year.

2. **Climate variability on rainfall parameters**

   In the corrected data for each grid in Sleman Regency, the number of wet and dry months was calculated according to the criteria in one year with the criteria that have been described in chapter II of the Schmidt-Ferguson method. This is done in all four specified year periods. Based on the calculation of the number of Wet Months (BB) and Dry Months (BK) per year for each grid, then the average value of BB and BK is calculated with equation (2.8) to calculate the comparative value (Q) using equation (2.9). Furthermore, the classification of regional climate types is carried out based on the comparative value (Q), calculated for each corrected rainfall data grid. Then statistical analysis of a data based on tables and graphs is carried out as well as spatial analysis using ArcGIS software version 10.8 to describe the data to be more concise and easy to understand.

3. **Relationship between drought index and climate variability**

   The results of the drought and climate variability analysis were carried out using the Pearson Correlation method. This is used to see the relationship between the two variables that have been analyzed.

RESULTS AND DISCUSSION

A. Standardized Precipitation Indeks (SPI)

Satellite rainfall data inputs are used to measure the drought index of the SPI index. The SPI method is used as an instrument used to measure drought levels based on rainfall data in a certain period of time. From 1981 to 2020, SPI results showed significant variations in drought levels in different regions. The results of the analysis of the drought index of the SPI method in the Sleman Regency area show a very close relationship pattern with climate influences both on a local, regional and global climate scale. Based on the internal calculations that are differentiated for each 10-year period, the results are obtained that severe drought values occurred in the second and fourth periods that occurred in the period 1991 – 2000 and the period 2011 – 2020, where in that period there was a strong El Nino phenomenon that greatly affected the level of drought in Indonesia, especially the island of Java, namely in 1997 and 2015 (Dwipayana & Suryana, 2023) (Iskandar et al., 2019). This condition is supported by other studies put forward by (Febrianti & Norman, 2022) which researched the drought index in the Banten Province area which stated that in the year El Nino was strong from October to December 1997 with a drought index that varied in the normal to very dry category.

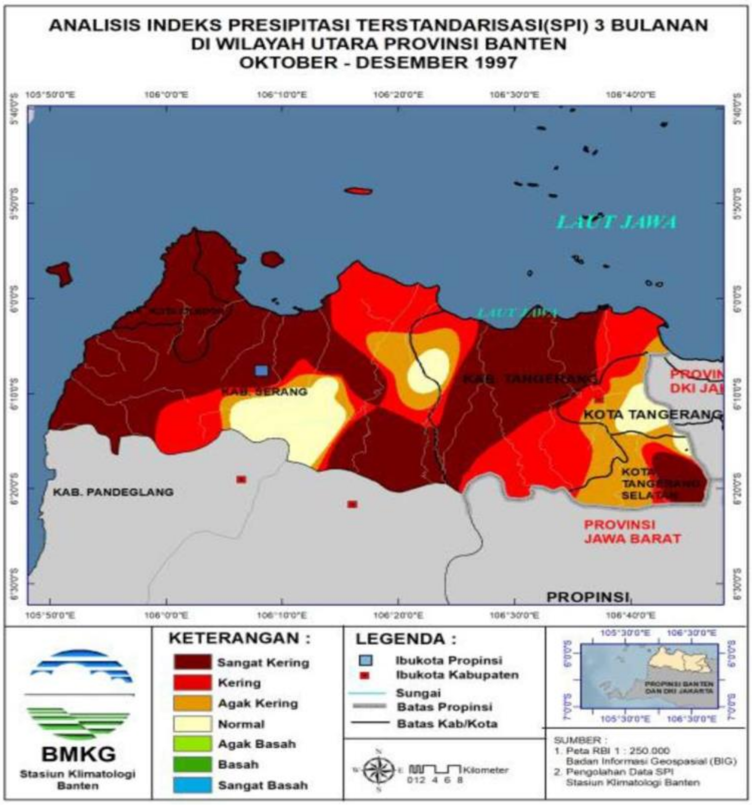

Figure 1. Map of Drought Index with SPI Method for 3 Monthly Period October-December 1997 in Banten Regency Source: (Yuningsih, 2017)

From the overall drought index research data in Sleman Regency, the average drought incidence in the period of Year II (1991-2000) has the highest frequency of occurrence. This is supported by the research of Yuningsih (2017) which stated that the phenomenon of strong El Nino (ONI index >+2) and IOD (>+1) in 1997 resulted in extreme drought in the Northern region of Banten. The research of Tjahyono (2017) also said in his study that a negative SOI value of less than -7 which lasts for a long time (greater than 3 months) indicates the occurrence of a long El Nino. This resulted in the occurrence of conditions in the dry to extremely dry category in 1997.

The calculation of Sleman Regency obtained that the frequency of drought levels is calculated on a monthly basis, there is an increase from periods I to IV, this condition is due to the influence of climate change that occurs. The influence of climate change that occurs globally has made cases of extreme climate events such as floods and droughts increase as happened in the Sleman Regency area (Rajendra, 2020) (Supari et al., 2017). This is marked by the occurrence of cases of the frequency of drought events that occur within 10 years. From the results of the percentage of drought frequency with the category of "very dry", the dominant occurred in the second period, both the SPI values of 1 monthly, 3 months, 6 months, and 12 months. This condition makes one of the indications of climate change is the El Nino phenomenon that has an impact on the case of drought disasters that hit the monsoon tropical climate area in Sleman Regency (Narulita et al., 2020).

Similar research on the SPI index calculated using satellite data was also proposed by (Ratri et al., 2016; Siswanto et al., 2022) which calculates the drought index using the SPI method by utilizing remote sensing technology, namely satellite. Similar to research that has been conducted using satellite data, it can be used to predict rainfall patterns as long as it is objective and must be verified using existing rainfall post data (Aprilina et al., 2023; Mamenun et al., 2014). With the results of the SPI index being able to be used for mitigation information and regional mapping, several regions experiencing a significant drought tendency by calculating SPI for different time scales, such as 3, 6, 12, and 24 months, we can determine the severity and duration of drought events (Kubicz, 2018).

B. Climate Type Change

The results of processing rainfall trends by calculating the difference in the amount of monthly rainfall for 10 years found that there was a decrease in the second period resulting from the difference in the amount of annual rainfall. In the third and fourth periods, there was an increase in the amount of rainfall compared to the second period. This indicates that in the second period there is a significant reduction in rainfall compared to other periods. In the results of the climate variability level data used as an indicator by calculating the value (Q) of climate type according to Scmidt-Ferguson in a period of 10 years, findings were obtained, including climate change which is characterized by changes in patterns and climate in the Sleman Regency area. Based on the calculation, there was a change in the value of Q in the period 1981-2020, which initially in 1981-1990 the Q value was 33.3 – 60 which all climate types were classified in C, but in the period 1991 – 2000 was the Q value between 33.3 – 100 in climate types C and D.

As a climate indicator, there has also been a change in climate patterns in the period 2001 – 2010 which is classified as a climate type in category B – D which has changed in the spatial analysis scale in 2011 – 2020. This condition has caused changes in climate patterns in the Sleman Regency area within 40 years. One of the reasons for this climate change is that rainfall patterns in Indonesia also experience changes in seasonal rainfall patterns (Gao & Jin, 2022; Tarmizi et al., 2019). Climate change, which is characterized by climate type patterns, also occurs in several regions in certain periods, this is corroborated by research from (Anwar et al., 2019). In the Bengkulu area, there is also a change in climate patterns seen from the Scmidt-Ferguson method, in his research comparing the rainfall patterns in the normal period 1971-1990 and 1981-2010. This condition is also corroborated by its spatial analysis which shows changes in climate patterns in Bengkulu Province. Other research (Aljawarneh & Lara Torralbo, 2021; Ridwan et al., 2023; Sudibyakto, 2015) who analyzed climate patterns with the same method showed a pattern of changes in climate variability over time.

Changes in rainfall patterns, both climate types and spatial analysis, also occur in several regions in Indonesia, not only in Sleman Regency. In previous research, it occurred in the Lampung region (Ridwan et al., 2023), Papua, especially in Manokwari Regency (Rakhim & Pattipeilohy, 2022) and the area in Padang West Sumatra (Wilis & Nugroho, 2017) and many other areas that have been proven by climate change. This climate change and variability information can then be used to inform policies and mitigation measures for extreme climate disaster management, both floods and droughts, and can be used for early warning systems (Nugroho & Habiballoh, 2023; Rakhim & Pattipeilohy, 2022).

C. Relationship between Drought Index and Climate Variability

Scientifically, the relationship between drought index and climate variability is based on how changes in climate patterns, including changes in temperature and rainfall, can affect the tendency and intensity of drought in a region. The results of the stastiti-mathematical calculation show that the relationship between the drought index and the SPI method with the climate variability value (Q) shows a weak to medium relationship with a significance level of 5%. This condition indicates that there is climate change that affects rainfall patterns and drought levels. The highest correlation value was in period II (1991-2000) and period IV (2011-2020) with a value of 0.3 – 0.5. This condition is quite significant from the results of the calculation of the drought index of the SPI method which occurs drought due to the El Nino phenomenon which makes a pattern of changes in rainfall variability in Sleman Regency (Aditya et al., 2021; Supari et al., 2018).

The relationship between climate variability change and drought index, which is only in the range of 30-50%, is because it is influenced by other variables such as the influence of local rainfall patterns and in regional categories as well as other activities such as the interaction between land and ocean (Johnson, 2012; Qian et al., 2013). This condition is supported by previous research that examined the influence of climate indicators with drought indices using the SPI method in West Sumatra which has a correlation index in the medium to strong category with a value of 0.4 - 0.8 (Sari, 2018). The strong influence of climate variability values with drought indices allows for continuous monitoring of climate elements, especially rainfall, as an early warning of drought hazards (Hidayat, 2023).

CONCLUSION

Based on the results and discussions that have been described, it can be concluded that the analysis of the drought index of the SPI method based on the calculation differentiated for each 10-year period, the results are obtained that the severe drought value occurred in the second and fourth periods that occurred in the period 1991 – 2000 and in the period 2011 – 2020. The highest frequency of the overall average drought event data also occurred in the period of Year II (1991-2000). The processing of climate variability level data was used as an indicator by calculating the value (Q) of climate type with the Scmidt-Ferguson method in a 10-year time period it was found that there was a change in the Q value in the period 1981-2020, which initially in 1981 – 1990 the Q value was 33.3 – 60 which all climate types were classified in C, but in the period 1991 – 2000 was a Q value between 33.3 – 100 in climate types C and D. As a climate indicator, there has also been a change in climate patterns In the period of 2001 – 2010 which was classified as a climate type in category B – D there was a change in the spatial analysis scale in 2011 – 2020. This condition has caused changes in climate patterns in the Sleman Regency area within 40 years. The relationship between the drought index and the SPI method with the climate variability value (Q) shows a weak to medium relationship with a significance level of 5%. This condition indicates that there is climate change that affects rainfall patterns and drought levels. The value of the correlation coefficient with the relationship in the medium category is indicated by the value of the correlation coefficient. The highest correlation value was in period II (1991-2000) and period IV (2011-2020) with a value of 0.3 – 0.5.

Suggestions for further research are that further research should be carried out on drought conditions based on other parameters in order to have more detailed results on the drought conditions that occur. Research is needed with a longer time to describe the climate change that occurs and increase the area so that the changes can be seen properly. It is necessary to use other methods to describe the relationship between the two variables to strengthen the theory produced.

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