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The Effects of El Nino Southern Oscillation on Rainfall in the Karst Area of Maros, National Park Bantimurung Bulusaraung South Sulawesi and its Impact on Flood Disasters

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ABSTRAK

Penelitian ini bertujuan untuk mendeskripsikan profil curah hujan, menganalisis pengaruh *El Nino Southern Oscillation* (ENSO) terhadap curah hujan dan dampak ENSO pada bencana banjir di Kawasan Karst Maros TN Babul. Data yang digunakan berupa data sekunder tahun 2011-2020 yang terdiri dari data bulanan parameter ENSO berupa data *Oceanic Nino Index* (ONI) yaitu Indeks Nino 3.4 yang diperoleh dari *website* resmi NOAA (*National Oceanic and Atmospheric Administration*) dan *Southern Oscillation Index* (SOI) yang diperoleh dari *website* resmi BoM (*Bureau of Meteorologi*) dan data bulanan curah hujan Kawasan Karst Maros TN Babul yang diperoleh dari Stasiun Klimatologi Maros. Teknik analisis data yaitu dengan analisis grafik dan persamaan regresi linier sederhana menggunakan *Software Microsoft Excel 2010* serta pembuatan peta menggunakan *Software ArcGIS*. Hasil analisis menunjukkan profil curah hujan Kawasan Karst Maros TN Babul periode 2011-2020 memiliki pola curah hujan monsun dengan curah hujan tertinggi pada bulan Desember, Januari, dan Februari sedangkan curah hujan terendah terjadi pada bulan Juni, Juli, dan Agustus. Besar pengaruh ENSO terhadap curah hujan di Kawasan Karst Maros TN Babul periode 2011-2020 termasuk dalam kategori sedang dengan nilai koefisien korelasi ONI sebesar 0,521 dan SOI sebesar 0,465. Besarnya kontribusi pengaruh ENSO terhadap curah hujan sebesar 25,9-33,1%. Dampak ENSO pada terjadinya bencana banjir di Kawasan Karst Maros TN Babul periode 2011-2020 yaitu berdampak pada Kecamatan Bantimurung, Tompobulu, Camba, dan Simbang. Frekuensi bencana banjir terjadi pada bulan Januari dan Desember dengan intensitas curah hujan pada kategori curah hujan tinggi hingga sangat tinggi.

Kata kunci: Banjir, Curah Hujan, El Nino Southern Oscillation, Karst Maros

ABSTRACT

The aims of this study were to describe rainfall profiles, to analyze the effect of the El Nino Southern Oscillation (ENSO) on rainfall and its impact on flood disasters in the karst area of Maros, National Park Bantimurung Bulusaraung South Sulawesi. The data used were monthly data of ENSO parameters and monthly data on rainfall of Karst Maros TN Babul area in the range of 2011-2020. The monthly data of ENSO parameters consist of Oceanic Nino Index (ONI) data, namely Nino Index 3.4 and Southern Oscillation Index (SOI) obtained from the official website of NOAA (National Oceanic and Atmospheric Administration) and from the official website of BOM (Bureau of Meteorology), respectively. Whereas, the monthly data of rainfall of Karst Maros TN Babul area was obtained from Maros Climatology Station, South Sulawesi. The data was analyzed (i.e. graph analysis and simple linear regression) using Microsoft Excel 2010 Software and ArcGIS Software for map creation. The results showed that the rainfall profile of the karst Maros TN Babul region for the period 2011-2020 has a monsoon rainfall pattern with the highest rainfall in December, January, and February, while the lowest rainfall occurs in June, July, and August. The significant effect of ENSO on rainfall in the Karst Maros TN Babul Area for the period 2011-2020 was categorized as a moderate with an ONI correlation coefficient value of 0.521 and SOI of 0.465. The effect of ENSO on rainfall is in the range from 25.9 to 33.1% which result in flood disasters in the karst Maros TN Babul area such as Bantimurung, Tompobulu, Camba, and Simbang districts. The flood disasters mostly occur in January and December with rainfall intensity from high to very high category.

Keywords: Flooding, Rainfall, El Nino Southern Oscillation, Karst Maros

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1. Introduction

Indonesia is a tropical country located in the Southeast Asia region, most of which is an ocean which is very influential on global weather and climate. Indonesia's geographical position is very strategic because it is crossed by the equator, between the continents of Asia and Australia as well as the Pacific and Indian Oceans (Surinati, 2013; Dewanti et al., 2018; Lestari et al., 2018). Indonesia is also located between the confluence of two mountain ranges, namely the Pacific Circum and the Mediterranean Circum (Surinati, 2013) and three interacting plates, namely the Pacific plate, the India-Australia plate and the Eurasian plate (Arsyad, 2016).

Indonesia is one of the most convectively active regions in the world (Trismidianto and Satyawardhana, 2018). It is located at the core of the strongest monsoon region in the world and its regional climate strongly influences the Hadley and Walker Circulation (Qian, 2007). Walker circulation greatly affects the tropical climate in Indonesia. The Pacific region also has a global influence, as can be seen from the rainfall patterns in many parts of the world. This global relationship is caused by the annual interaction of the Indonesian Ocean and the Pacific Ocean, namely the Indian Ocean Dipole (IOD) in the Indian Ocean and ENSO in the equatorial Pacific Ocean (Lestari et al., 2018). Rainfall in Indonesia is closely related to ENSO.

ENSO is a phenomenon that occurs due to the interaction of the oceans and the atmosphere in equatorial region of the middle and eastern parts of the Pacific Ocean. ENSO takes place in the Pacific Ocean and affects the intensity of rainfall in Indonesia (Reggono, 2011; Surinati, 2013; Yuggotomo & Ihwan, 2014; Vitri & Marzuki, 2014; Nur'utami & Hidayat, 2016; Narulita, 2017; Hidayat et al., 2018). ENSO consists of three phases, namely the hot phase when El Nino occurs, the cold phase when La Nina occurs and the neutral phase (Dewanti et al., 2018). El Nino can be identified through the increase in sea surface temperature in the Equatorial Pacific waters, while La Nina is the opposite condition in the same region. El Nino can cause a decrease in sea surface temperature in Indonesian waters and La Nina tends to increase sea surface temperature in Indonesian waters (Aldrian et al., 2011; Fitria & Pratama, 2013; Wang et al., 2017). Changes in sea surface temperature can have an impact on the intensity of rainfall in Indonesia.

Several studies on ENSO and its effect on rainfall in Indonesia have been done. It was revealed that ENSO affects the variability of rainfall in several regions in Indonesia, including Koto Tabang, West Sumatra; Cerucuk watershed, Belitung Island; West Java; Semarang City and North Sumatra Province (Vitri & Marzuki, 2014; Nabilah, 2017; Narulita, 2017; Safril, 2018; Hidayat et al., 2018; Irwandi et al., 2018). Yuggotomo & Ihwan (2014) stated that ENSO has a low effect on rainfall in Ketapang Regency. This is in line with the work done by Dewanti et al., (2018). They haven't found any effect of ENSO on rainfall at four stations (Siantan, Supadio, Ketapang and Nangapinoh) in West Kalimantan.

Maros Regency is located in the western part of South Sulawesi Province, which has a varied topography, ranging from flat to mountainous areas, with an altitude of 0-1000 meters above sea level. Most of this area is dominated by karst area. The karst area of Maros, National Park Bantimurung Bulusaraung South Sulawesi has a specific karst topography including karst towers, stalactites, and stalagmites as well as high hills formation e.g. steep hillsides, rounded hilltops (Arham et al., 2015; Sulselprov, 2018).

The Maros Karst area of Babul National Park has abundant natural resources, both above the surface (epikarst) and below the surface (endokarst). The Maros Karst area has 18 caves that form cave ornaments, such as stalactites, stalagmites and flowstones. These caves store rainwater so that the karstification process goes well (Arsyad et al., 2016b). The karstification process takes a relatively long time with a sufficient rainfall. Rainfall has a very important role in the process of karst formation (Arsyad et al., 2017).

High rainfall during rainy season causes flooding in some areas in the Maros Karst Area of Babul National Park, especially in the areas with low topography (Badwi et al., 2020). The highest rainfall occurs in December, January and February (Pabalik et al., 2015; Arsyad et al., 2016a). Meanwhile, the lowest rainfall takes place around June, July and August (Pabalik et al., 2015; S. Sri et al., 2015).

Rainfall in the Maros Karst Area of Babul National Park is influenced by many factors, both regionally and globally. Regional factors can be caused by the Asian-Australian Monsoon which promotes dry and rainy season. Seasonal and inter-seasonal rainfall in this region can be affected by the global climate phenomenon, namely the El Nino Southern Oscillation (ENSO).

Based on the descriptions above, this research is very important to do. Case studies were conducted in the 2011-2020 period. The ENSO phenomenon can be demonstrated by the ONI (Oceanic Nino Index) and SOI (Southern Oscillation Index) parameters. The purpose of this study was to describe the rainfall profile, analyze the effect of El Nino Southern Oscillation (ENSO) on rainfall and the impact of ENSO on flood disasters in the Karst Region of Maros, Babul National Park. The data used is in the form of secondary data for 2011-2020 which consists of monthly ENSO parameter data in the form of Oceanic Nino Index (ONI) data, namely Nino 3.4 Index and Southern Oscillation Index (SOI) and monthly rainfall data for the Maros Karst Area, Babul National Park. The data analysis technique is graphical analysis and simple linear regression equations using Microsoft Excel 2010 software and making maps using ArcGIS software.

2. Methods

2.1. Research Duration and Location

The research was conducted from April to July 2021. This research was conducted at the Earth Physics Laboratory, Department of Physics, Faculty of

Mathematics and Natural Sciences, Makassar State University and Maros Climatology Station, South Sulawesi. The research location is the Maros Karst Area. Geographically, this location is located between 4°42'49"-5°06'42" South Latitude and 119°34'17"-119°55'13" East Longitude. The Maros Karst area of Babul National Park is divided into seven sub-districts, namely the Bantimurung, Camba, Cenrana, Mallawa, Simbang, Tanralili and Tompobulu zones (KLHK, 2021).

2.2. Research Data

The data used in this study are a) quantitative data of ENSO including monthly data in the last ten years in the range of 2011-2020 of Oceanic Nino Index (ONI) data (i.e. the Nino 3.4 Index and the Southern Oscillation Index (SOI)) b) monthly rainfall data in the range of 2011-2020 from three rainfall stations in the Karst area of Maros TN Babul, namely Bantimurung CH Station (05º00'34.8'' South Latitude and 119º38'02.6'' East Longitude), CH Cenrana Station (05º01'23.6). '' South Latitude and 119º46'53.5'' East Longitude) and CH Tanralili Station (05º03'57.4'' South Latitude and 119º37'10.6'' East Longitude) c) historical data on flood events in Maros Regency in 2011-2020.

2.3. Research Procedures

2.3.1. Preparation Stage

The preparatory stage consists of collecting research literature related to the El Nino Southern Oscillation (ENSO), rainfall in the Maros Karst Area of Babul National Park and the effect of ENSO on rainfall in Indonesia.

2.3.2. Data Collection Stage

The monthly data on the Nino 3.4 Index in the range between 2011-2020 used in this study was obtained by downloading the Nino 3.4 Index data from the official NOAA website: Climate Prediction Center-ONI. For the SOI data was obtained by downloading from the official website of the BoM (Bureau of Meteorology). Monthly rainfall data in the range from 2011 to 2020 in the Karst Area of Maros TN Babul is represented by three rainfall stations, namely Bantimurung Station, Cenrana Station and Tanralili Station. This data was obtained from the Maros Climatology Station. Furthermore, historical data on flood events in Maros between 2011 and 2020 were obtained through online newspaper from the Kompas.com website.

2.3.3. Data Analysis Stage

Data analysis is divided into four stages. The first stage is calculation of the average value of rainfall from three rainfall stations that represent the rainfall in the Maros Karst Area of Babul National Park based on the following equation (Sugiyono, 2006):

$$P = \frac{P1+P2....+Pn}{n} \quad (1)$$

where P is the average rainfall area, P1 is the rainfall Station 1, Pn is the rainfall Station n, n is the number of rainfall stations.

The second stage is analyzing monthly and annually rainfall profiles in the Maros Karst area of Babul National Park for the 2011-2020 period.

The third stage is analyzing the effect of ENSO on rainfall in the Karst area of Maros, Babul National Park in the period of 2011-2020 by using a linear regression to determine the correlation coefficient (r_{xy}) and the coefficient of determination (r^2). Correlation coefficient (r_{xy}) is used to measure how strong a relationship is between variables X and Y two variables. The coefficient of determination is determined by squaring the correlation coefficient (r^2) and is used to determine the contribution or influence of variable X on variable Y (Sugiyono, 2006). Correlation analysis was carried out twice, namely between the Nino 3.4 index and the rainfall and between SOI and the rainfall.

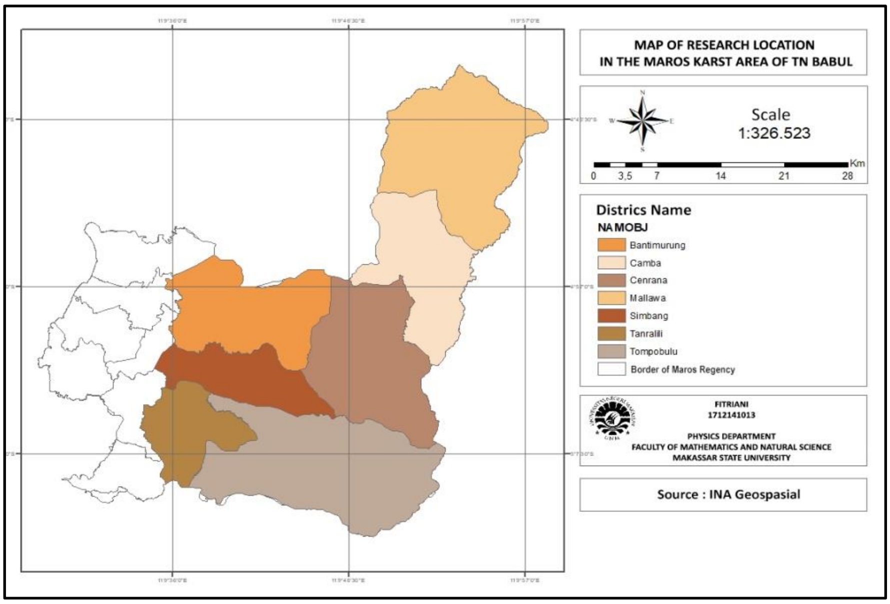

Figure 1 Research Location Map

The correlation coefficient equation (r_{xy}) is calculated using the following equation:

$$r_{xy} = \frac{n\sum X_iY_i - (\sum X_i)(\sum Y_i)}{\sqrt{\{n\sum X_i^2 - (\sum X_i)^2\}\{n\sum Y_i^2 - (\sum Y_i)^2\}}} \quad (2)$$

where X is the predictor (ENSO: Nino Index 3.4 and SOI), Y is the variable bound (response) (rainfall Karst Maros TN Babul Area) and n is the amount of data.

Sugiyono (2006) states that the strength index of the relationship between variables X and Y is as following in Table 1.

The fourth stage is analyzing the impact of ENSO on the flood disaster in the Karst area of Maros, National Park Bantimurung Bulusaraung for the period 2011-2020. The analysis was carried out from the intensity of rainfall in the area during the ENSO period 2011-2020. Flood disaster occurs when the intensity of rainfall in the ENSO phase, namely La Nina, is above 301 mm/month. Then, the data is matched with historical data on flood events and its effect on sub-districts in Maros Regency in the period of 2011-2020. From the above analysis, the effect of the ENSO on flood disasters can be determined. The results are then described in a map of the flood-affected sub-districts in the Karst Region of Maros National Park Bantimurung Bulusaraung using ArcGIS software.

3. Results and Discussion

3.1. Rainfall Profile in The Karst Maros National Park Bantimurung Bulusaraung Region in the Period of 2011-2020

Based on the results of processing rainfall data from three rainfall stations (i.e. Bantimurung Station, Cenrana Station and Tanralili Station), the annual rainfall profile of the Maros Karst Area of Babul National Park for ten years (2011-2020) can be determined (see Figure 2). Figure 2 shows that the highest rainfall occurred in 2013, 2017, and 2020 of 4,112.66, 3,619.00, 3,490.50 mm, respectively. While the lowest rainfall occurred in 2019, 2014, 2012 amounting to 1,941.00 mm, 2,465.34 mm, and 2,830.66 mm, respectively.

The average of monthly rainfall in the karst area of Maros, National Park Bantimurung Bulusaraung in the period of 2011-2020 is shown in Figure 3. Figure 3 shows the highest values of rainfall in the Karst Maros TN Babul Area occurs in November and December in the left side and in January and February on the right. This rainfall pattern is a monsoon pattern which has two months of the highest rainfall on the right and left.

The peak of rainfall in January and December is 690.30 mm and 531.48 mm, respectively. While the lowest rainfall occurred in August, i.e. 6.70 mm.

The rainfall in the Maros Karst Area of Babul National Park for the period 2011-2020 has a monsoon rainfall pattern which is characterized by an increase in rainfall at the end and beginning of the year, namely in December, January to February. This is in line with work done by Arsyad et al., (2016a).

Meanwhile, rainfall decreased in June, July, and August, which is the time of the dry season with very low rainfall intensity. On the other hand, in December, January and February when the rainy season occurs, the intensity of rainfall is very high. The other 6 (six) months are the transition season: a) March, April and May are the months of transition from the rainy season to the dry season b) September, October and November are the months of transition from the dry season to the rainy season.

The characteristics of rainfall in the Maros Karst Region of Babul National Park are closely related to the Asian monsoon and the Australian monsoon. The highest peak rainfall occurs in the Asian Monsoon period (December, January, and February) and the lowest rainfall occurs in the Australian Monsoon period (June, July and August). This happens because the Asian monsoon blows consistently from the Asian continent to the Australian continent in October-April through the Pacific Ocean and the South China Sea, so that at that time the Indonesian region will experience the rainy season due to the mass of water vapor carried by the Asian monsoon. Conversely, the Australian monsoon winds blow from the Australian continent to the Asian continent in April-October through the desert in northern Australia and only through a narrow sea, causing Indonesia to experience a dry season.

Table 1. Index of strength relationship between variables X and Y (Sugiyono, 2006)

Value r_{xy}	Interpretation	Value r_{xy}	Interpretation
0.00-0.19	Very low	(-0.00)-(-0.19)	Very low
0.20-0.39	Low	(-0.20)-(-0.39)	Low
0.40-0.59	Moderate	(0.40)-(-0.59)	Moderate
0.60-0.79	Strong	(-0.60)-(-0.79)	Strong
0.80-1.00	Very strong	(-0.80)-(-1.00)	Very strong

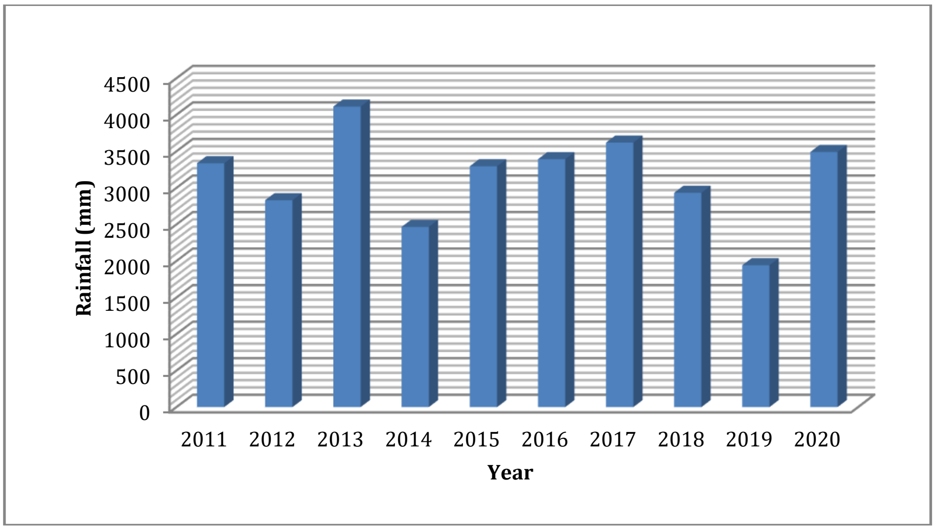

Figure 2 Annual Rainfall Graph for the Period 2011-2020 Karst Maros TN Babul Area

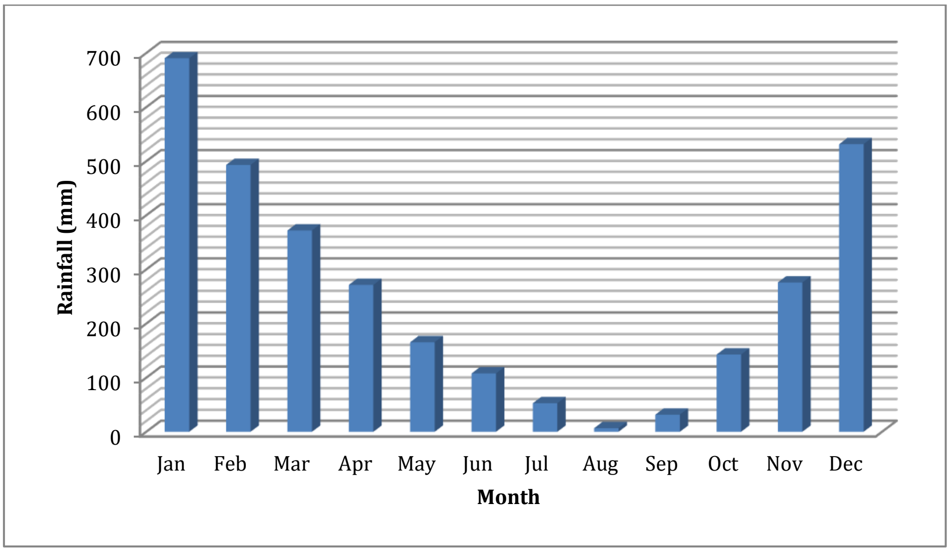

Figure 3 Average of monthly rainfall in the karst area of Maros, National Park Bantimurung Bulusaraung in the period of 2011-2020.

In contrast, the Australian monsoon winds blow from Australia to Asia in April-October through the deserts in the northern part of Australia and only through the narrow ocean, so that at that time Indonesia will experience the season.

3.2. The effect of ENSO on Rainfall in Karst Maros National Park Bantimurung Bulusaraung in the period of 2011-2020

The effect of ENSO on rainfall in the Maros Karst area of Babul National Park can be obtained using simple linear regression. Linear regression method was used to determine the correlation coefficient and the coefficient of determination. The correlation coefficient indicates the strength of the relationship between ENSO and rainfall in the Karst Maros area of National Park Bantimurung Bulusaraung. While the coefficient of determination shows how strong the contribution of ENSO's influence to rainfall. The strength of the relationship between ENSO, namely ONI parameters and rainfall in the Maros Karst Area of Babul National Park can be seen in Table 2.

Table 2 shows that the highest correlation coefficient value between ONI and rainfall in the Maros Karst Area of Babul National Park was in 2012 at 0.910 while the lowest was in 2020 at 0.093. It is also found that there are only 4 years, namely 2013, 2014, 2015 and 2020 from 10 years (2011-2020), the ONI correlation value with rainfall has a low correlation. This means that during that year ENSO had a low effect on rainfall in the Maros Karst Area of Babul National Park, but overall ENSO had a moderate to strong effect for the other 6 years. From the results of the ONI correlation with the rainfall in the Maros Karst Region of Babul National Park for the period 2011-2020, the average value of the correlation coefficient for 10 years is 0.521, which means that the strength of the relationship between ENSO and rainfall is in the medium category. The coefficient of determination obtained is 0.331, indicating that the contribution of the influence of ENSO on rainfall in the Maros Karst Area of Babul National Park for the 2011-2020 period is 33.1%.

Table 2. Correlation of ONI with Rainfall in Karst Maros National Park Bantimurung Bulusaraung Area

No.	Year	r_{xy}	R^2	Strength Index
1.	2011	0.810	0.657	Very Strong
2.	2012	0.910	0.828	Very Strong
3.	2013	0.313	0.098	Low
4.	2014	0.293	0.086	Low
5.	2015	0.365	0.133	Low
6.	2016	0.708	0.501	Strong
7.	2017	0.637	0.406	Strong
8.	2018	0.462	0.213	Moderate
9.	2019	0.614	0.377	Strong
10.	2020	0.093	0.009	Very Low
Average		0.521	0.331	Moderate

Table 3. Correlation of SOI with Rainfall Karst Maros TN Babul Area

No.	Year	r_{xy}	R^2	Strength Index
1.	2011	0.700	0.490	Strong
2.	2012	0.361	0.131	Low
3.	2013	0.389	0.152	Low
4.	2014	0.562	0.316	Moderate
5.	2015	0.637	0.405	Strong
6.	2016	0.781	0.611	Strong
7.	2017	0.059	0.003	Very Low
8.	2018	0.522	0.272	Moderate
9.	2019	0.377	0.142	Low
10.	2020	0.263	0.069	Low
Average		0.465	0.259	Moderate

From Table 3 it can be seen that the highest correlation coefficient value between SOI and rainfall in the Maros Karst Area of Babul National Park was in 2016 at 0.781. While the lowest one was in 2017 at 0.059. From 2011-2020 there were 5 years (2012, 2013, 2017, 2019, 2020) of ENSO with low influence and 5 years (2011, 2014, 2015, 2016, 2018) with moderate to strong influence. This means that ENSO has an influence on the rainfall in the Maros Karst Area of Babul National Park but is not at a high frequency. From the results of the correlation between SOI and rainfall in the Maros Karst Region for the period 2011-2020, the average value of the correlation coefficient for 10 years is 0.465, which means that the strength of the relationship between ENSO and rainfall is in the medium category. The coefficient of determination of 0.259 indicates that the contribution of ENSO influence to the rainfall in the Maros Karst Area of Babul National Park for the 2011-2020 periods is 25.9%.

The influence of ENSO on rainfall in the Karst Maros TN Babul Area for the period 2011-2020 is included in the moderate category with an ONI correlation coefficient value of 0.521 and SOI of0.465. This happens because the ENSO phenomenon does not entirely affect the Karst Maros area's rainfall. Dewi & Marzuki (2020) point out that ENSO's position affects rainfall in some parts of Indonesia even though the impact is not uniform. This means that areas have strong, moderate, and low ENSO influence.

The phenomenon of moderately influential ENSO in the Karst area of Maros TN Babul can occur because the rainfall in the Maros Karst Area is largely influenced by local factors in the form of topography of the Karst Region. In mountainous areas, convective processes are lower than in areas with low topography. The sub-districts of Bantimurung, Simbang and Tanralili are areas of the Maros Karst Region which have a low topography so that rainfall tends to be higher during the rainy season than Tompobulu, Cenrana, Camba and Mallawa which are located in mountainous areas. The sub-districts of Bantimurung, Simbang and Tanralili will be more prone to flooding during the rainy season because they have a low topography and higher rainfall. In addition to local factors in the form of the topography of the Karst Region, the variability of rainfall in the Maros Karst Region is strongly influenced by regional factors, namely the Asia-Australia monsoon which causes the rainy season and dry season in this area so that the rainfall pattern in the Maros Karst Region of Babul National Park is a monsoon type according to the obtained on the rainfall profile.

3.3. Impact of ENSO on Flood Disasters in Karst Maros TN Babul Region for the Period 2011-2020

The impact of ENSO on rainfall can be seen through the intensity of rainfall in the Maros Karst Area of Babul National Park in 2011-2020 when the ENSO incident was the La Nina phase. The occurrence of rain can cause flooding when the rainfall intensity is > 301 mm/month which is a category of high to very high rainfall. It can be concluded that the category of rainfall in the Karst area of Maros TN Babul during the La Nina event ranged from the categories of low rain, medium rain, high rain to very high. In 2011-2020, La Nina was identified as occurring 4 (four) times with a total time of 35 months. Of the 35 months, there are 18 months that have high to very high rainfall which tends to occur at the end of the year, namely from November to March with the highest rainfall occurring in December 2020 of 1,044.5 mm which in intensity can have an impact on disasters. flood. To analyze that ENSO really had an impact on the flood disaster in the Karst Area of Maros TN Babul, the results obtained were confirmed with historical data on the flood disaster in Maros Regency based on the district in 2011-2020 obtained from the Kompas website, as shown in Table 4.

Table 4 shows that the ENSO phenomenon has an impact on the occurrence of flood disasters in the Karst Maros TN Babul Area, namely in Bantimurung District, with the frequency of events almost every year, namely in 2011, 2012, 2015, 2016, 2019, 2020 when the ENSO phenomenon (i.e. La Nina) took place. The other areas in the Karst Maros TN Babul area affected by flooding due to ENSO are Tompobulu, Camba, and Simbang districts. The flood disaster occurred in January, March, April, October, and December, with the frequency of many flood events coinciding with La Nina which occurred in January and December. Figure 4 shows a map of the sub district exposed to the flood of karst Maros TN Babul area for the period 2011-2020 to identify the areas affected by flooding in the Karst Maros TN Babul Area due to the ENSO phenomenon.

From Figure 4, it can be seen that there are 4 (four) of 7 (seven) sub-districts in the Karst Maros TN Babul Area that are susceptible to flood disasters. This disaster occurs when rainfall is higher than usual due to the rainy season, along with the occurrence of the La Nina phenomenon. A flood disaster is an event or circumstance in which an area of land is submerged due to increased water volume (BNPB, 2021).

Table 4 and Figure 4 show that the sub-districts affected by flooding during the ENSO phenomenon, namely the La Nina phase in the Maros Karst Area of Babul National Park for the 2011-2020 periods are Bantimurung, Tompobulu, Camba and Simbang Districts. This sub-district is a sub-district that has a low topography so that during the rainy season and coincides with the occurrence of La Nina, higher rainfall causes this area to have a higher frequency of flooding, especially in the Bantimurung sub-district which floods almost every year. These results are in line with the work done by Badwi et al., (2020). They stated that the area in Maros Karst of Babul National Park that are prone to flooding are Bantimurung, Simbang and Tanralili Districts. The ENSO phenomenon which has an impact on the flood disaster in the Maros Karst Area of Babul National Park occurs in January and December.

Table 4. Maros Regency Flood History 2011-2020 (Kompas, 2021)

Month of Flood Events	Affected Districts	ENSO Phase
January 2011	Bantimurung and Tompobulu	La Nina
March 2012	Bantimurung	La Nina
January 2013	Camba and Simbang	ENSO Netral
January 2014	Maros	ENSO Netral
January 2015	Bontoa, Turikale, Maros Baru, Bantimurung	El Nino
December 2015	Bantimurung	El Nino
January 2016	Lau and Bantimurung	El Nino
October 2016	Maros	La Nina
December 2017	Lau District	La Nina
April 2018	Semangki Village	La Nina
January 2019	12 Districts, including Bantimurung and Simbang	El Nino
December 2020	Bantimurung	La Nina

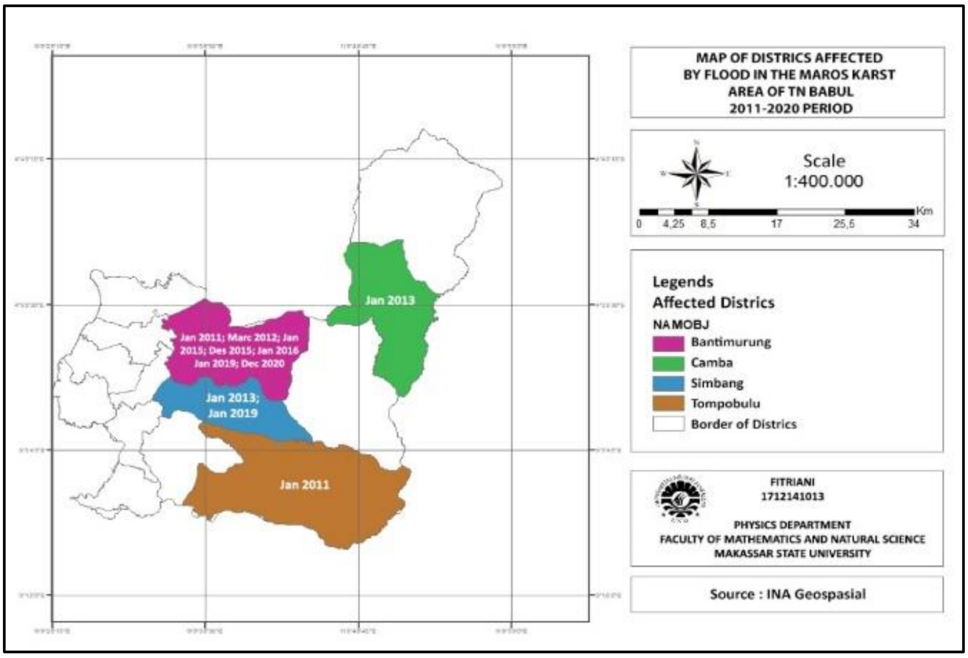

Figure 4 Map of Districts Affected by Flooding of Karst Maros TN Babul Area Period 2011-2020

The flood disaster that occurred in the Maros Karst Area of Babul National Park in the period 2011-2020 as a result of the ENSO phenomenon was not only influenced by the La Nina phase, but also influenced by the Neutral ENSO and El Nino phases. High rainfall that has an impact on flood disasters can not only be caused by La Nina but also due to local factors in the Karst Region. In mountainous areas such as Tompobulu, Cenrana, Camba and Mallawa sub-districts, the convective process will be lower than areas with low topography such as Bantimurung, Simbang and Tanralili Districts. This is in accordance with the results of research presented by Simbolon (2020) that the widespread flooding in several parts of Indonesia, one of which is due to the influence of the periodic La Nina climate, in addition to the topography of the region.

4. Conclusion

Rainfall profile in the Maros Karst area of Babul National Park for the period 2011-2020 has a monsoon rainfall pattern with the highest rainfall in December, January and February. The lowest rainfall occurs in June, July and August. The effect of the ENSO phenomenon on rainfall in the Maros Karst Area of Babul National Park for the 2011-2020 period is in the medium category with the ONI correlation coefficient value of 0.521 and SOI of 0.465. The flood disaster in the Maros Karst Area of Babul National Park for the period 2011-2020 due to ENSO occurred in the Bantimurung, Tompobulu, Camba and Simbang sub-districts. The floods mostly occur in January and December with the intensity of rainfall in the category of high to very high rainfall.

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