ANALYSIS OF RAINFALL AND TEMPERATURE DYNAMICS IN PEATLANDS DURING 2018-2021 CLIMATE CHANGE

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ANALYSIS OF RAINFALL AND TEMPERATURE DYNAMICS IN PEATLANDS DURING 2018-2021 CLIMATE CHANGE

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ABSTRACT: In 2018-2021, several natural phenomena occurred that caused climate change in Indonesia. This climate change is estimated to have affected the dynamics of rainfall and temperature in Indonesia. This study aims to analyze the incidence of climate change, rainfall dynamics, and temperature dynamics, and find the correlation between rainfall versus temperature during the 2018-2021 dry season. The location of this research is on peatlands in Central Kalimantan and West Kalimantan where both locations have installed automatic measurement stations for rainfall and temperature. Peatlands were chosen because the dynamics of rainfall and temperature greatly affect the condition of peatlands that are prone to fires and floods. The results of this study indicate that very minimal rainfall occurs in the dry season in 2019, especially from July to September 2019. Rainfall in the 2019 dry season is much lower when compared to the dry season in 2018, 2020, and 2021. This happens because in 2019 two natural phenomena occurred simultaneously, namely: moderate IOD+ and weak El Niño. These two phenomena reinforce each other in reducing rainfall in Indonesia. The temperature during the dry season for 4 years did not show a significant difference, but in general, the temperature in Central Kalimantan was lower than the temperature in West Kalimantan. It was also found that there was a trend in the relationship between rainfall and temperature where the higher the rainfall, the lower the temperature. Based on the results of the statistical method of linear regression and t-test, it has been found that the correlation between rainfall and temperature is significant.

Keywords: Rainfall, Temperature, Climate change, Indian Ocean Dipole, El Niño Southern Oscillation.

1. INTRODUCTION

In the period 2018-2021, there have been several natural phenomena that have caused climate change in Indonesia. This climate change is mainly characterized by abnormal rainfall during the 2018-2021 period. In the 2018-2019 period the average rainfall is below normal and in the 2020-2021 period the average rainfall is above normal. This incident caused several natural disasters in Indonesia, such as massive fires on peatlands, drought on agricultural land, and flooding in residential areas. The most felt impact was the massive peatland fires that occurred in the Kalimantan Islands in 2019. The largest peatland fires in 2019 in Indonesia were in Central Kalimantan, which was 134,227 hectares, and West Kalimantan province covered 127,462 hectares [1-5].

Several hydro-climatological parameters whose dynamics are affected by climate change include rainfall and temperature [7-9]. The dynamics of rainfall and temperature are closely related to the occurrence of natural disasters on peatlands [7-11]. To mitigate natural disasters on peatlands, the government has installed tools to measure and monitor the dynamics of hydro-climatological parameters, including rainfall and temperature. This equipment system measures hydro-climatological parameters automatically, in situ, and in real time. This equipment system is called a SESAME Sensory data transmission Service Assisted by the Midori Engineering laboratory (SESAME) station. SESAME stations have been installed in several areas in Indonesia. The Kalimantan Islands have been installed in the Provinces of West Kalimantan and Central Kalimantan Provinces [1–3].

This study aims to analyze climate change events, rainfall dynamics, temperature dynamics, and the correlation between rainfall versus temperature during the period 2018-2021 on the peatlands of Kalimantan islands. The data used are Niño 3.4 index data, DMI index, daily average rainfall, and daily average temperature. The Niño 3.4 index data and DMI index data are downloaded from the NOAA website. The daily average rainfall data and the daily average temperature data were downloaded from the SESAME website for the two research locations, namely SESAME stations in West Kalimantan and Central Kalimantan [4–6]. The research period began in 2018 because the SESAME equipment system was only installed in 2018.

Several previous studies have been carried out related to the dynamics of hydro-climatological parameters on peatlands in Indonesia. The research was conducted in the range of 2019-2020 at a location in South Sumatra [7–11]. However, there has been no specific research on the analysis of rainfall dynamics and temperature dynamics on peatlands in West Kalimantan and Central Kalimantan in the 2018-2021 period. The results of this study are expected to be input for the government and interested parties regarding the impact of climate change on the dynamics of rainfall and temperature on peatlands in the Kalimantan Islands.

2. RESEARCH SIGNIFICANCE

Climate change that occurred in the period 2018-2021 has affected the dynamics of hydro-climatological parameters, especially rainfall [12–14]. During this period the rainfall was abnormal, sometimes very minimal and sometimes excessive. As a result, fires occurred on peatlands, drought in agricultural land, flooding in residential areas, and so on [10,15–17]. It is very interesting to study the dynamics of rainfall and temperature as well as the correlation between these two parameters during the 2018-2021 climate change period. This research is also important because the results can be used as input for the government in Kalimantan in efforts to mitigate natural disasters on peatlands related to climate change.

3. MATERIAL AND METHOD

The climate change that occurred in 2018-2022 was the result of the El Niño Southern Oscillation (ENSO) and Indian Ocean Dipole (IOD) natural phenomena. We can find out the events based on the Nino 3.4 Index and the Dipole Mode Index (DMI) on the NOAA website. This climate change causes dynamic changes in hydro-climatological parameters such as rainfall, temperature, soil moisture, and groundwater level.

The natural phenomenon of ENSO occurs due to the interaction of the sea with the atmosphere in the Pacific Ocean. This interaction can cause 2 natural phenomena, namely El Niño and La Niña which cause climate change in Indonesia. El Niño causes very little rainfall and La Niña can cause above-normal rainfall. These two phenomena occur because of an anomaly in surface water temperature in the Pacific Ocean. Therefore, the distinction between these two types of phenomena is based on the temperature anomaly that occurs on the surface of the Pacific Ocean, which is called the Niño 3.4 index. If the Niño 3.4 index is positive then it is classified as an El Niño event and if the Niño 3.4 index is negative then it is classified as La Niña [18].

El Niño and La Niña can be categorized into 4 categories based on the Niño 3.4 index as shown in Table 1. The natural phenomenon of the Indian Ocean Dipole (IOD) occurs due to the interaction of the ocean and the atmosphere in the Indian Ocean. This interaction can cause 2 natural phenomena, namely IOD+ and IOD- which can also cause climate change in Indonesia. IOD+ causes minimal rainfall and IOD- can cause above-normal rainfall. These two phenomena also occur because of the difference in temperature at the two poles, namely in the western and southeastern Indian Ocean. Therefore, the distinction between these two types of phenomena is based on the difference in temperature at the two poles, which is called the Dipole Mode Index (DMI). If the DMI is positive, it is classified as an IOD+ event and if the DMI is negative, it is classified as IOD-. IOD+ and IOD- if we make an analogy with Table 1, we get 4 categories of IOD as shown in Table 2 [24–26].

Table 1. El Niño Southern Oscillation category

Niño 3.4 Index (°C)	ENSO Category
0.5 to 0.9	Weak El Niño
1.0 to 1.5	Moderate El Niño
1.5 to 2.0	Strong El Niño
≥ 2.0	Very Strong El Niño
-0.5 to -0.9	Weak La Niña
-1.0 to -1.5	Moderate La Niña
-1.5 to -2.0	Strong La Niña
≤ -2.0	Very strong La Niña

Source: *https://psl.noaa.gov/gcos_wgsp/Timeseries/Data/*

Table 2. Indian Ocean Dipole category

Dipole Mode Index (°C)	IOD Category
0.5 to 0.9	Weak IOD+
1.0 to 1.5	Moderate IOD+
1.5 to 2.0	Strong IOD+
≥ 2.0	Very Strong IOD+
-0.5 to -0.9	Weak IOD-
-1.0 to -1.5	Moderate IOD-
-1.5 to -2.0	Strong IOD-
≤ -2.0	Very strong IOD-

Source: *https://psl.noaa.gov/gcos_wgsp/Timeseries/Data/*

The research data consists of 4 types of data, namely Niño 3.4 index, DMI, rainfall, and temperature. Niño 3.4 data and DMI data were downloaded from the website: https://psl.noaa.gov/gcoswgsp/Timeseries/Data/. Rainfall and temperature data were downloaded from the website: https://web.sesame-system.com. The research location is at the SESAME station on peatlands in West Kalimantan with coordinates (-0.210, 109.394) and in Central Kalimantan with coordinates (-2.321, 114.056).

The Niño 3.4 index data and DMI index data are processed and analyzed to obtain the types of natural phenomena that occur in the 2018-2020 period. Rainfall and temperature data were processed and analyzed statistically to determine the dynamics pattern and correlation between these two parameters in the 2018-2022 period.

4. RESULTS AND DISCUSSIONS

4.1. Types of Natural Phenomena in 2018-2022

To find out the types of natural phenomena related to the ENSO and IOD phenomena that occurred in the 2018-2021 period, an analysis was carried out on the Niño 3.4 index data and DMI data. Both types of data are made in the form of time series graphs [18, 21, 27-28].

The time series graph of the Niño 3.4 index data is shown in Fig. 1. The graph is analyzed to find the maximum and minimum values per year. The maximum value (positive) relates to the El Niño phenomenon and the minimum value (negative) relates to the La Niña phenomenon that may occur in the 2018-2021 period.

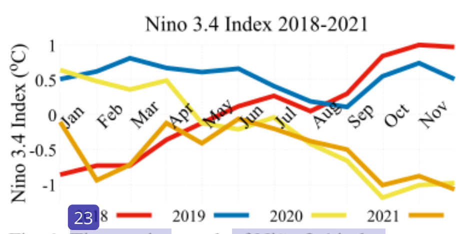

Fig. 1. Time series graph of Niño 3.4 index

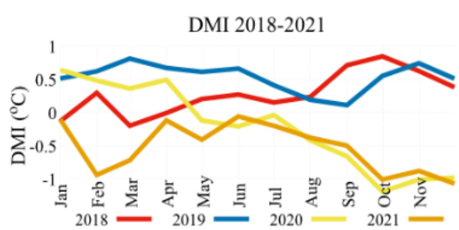

Fig. 2. Time series graph of DMI

DMI data is displayed in graphical form as shown in Fig. 2. The graph is also analyzed to find the maximum and minimum values per year. The maximum value is related to the IOD+ phenomenon and the minimum value is related to the IOD- phenomenon.

Based on the results of the analysis of Fig. 1 and 2, and based on Tables 1 and 2, the types of natural phenomena that occurred from 2018-2021 are shown in Table 3.

Table 3. Types of natural phenomena

Year	Natural phenomena
2018	Weak IOD+ and Moderate El Niño
2019	Moderate IOD+ and Weak El Niño
2020	Moderate La Niña
2021	Moderate La Niña

4.2. Dynamics of Rainfall in 2008-2021

Analysis of the dynamics of rainfall in the 2018-2021 period is focused on the dry season in Indonesia, which generally occurs in July, August, September, and October (JASO). Monthly rainfall data are shown in Table 4 and Table 5. Table 4 displays data from West Kalimantan stations and Table 5 displays data from Central Kalimantan stations.

Table 4. Rainfall data of West Kalimantan

Month	Rainfall (mm/month)			
	2018	2019	2020	2021
Jul	28.0	42.0	636	239
Aug	102.5	91.6	103	362
Sep	156.5	89.0	210	355
Oct	337.5	491	335	149

Table 5. Rainfall data of Central Kalimantan

Month	Rainfall (mm/month)			
	2018	2019	2020	2021
Jul	92.5	13	263	84
Aug	80	84	237	210.5
Sep	52.5	14	157	73.5
Oct	201.5	187	517	50

Monthly rainfall below normal (<100 mm/month) in the dry season period 2018-2021 mostly occurred in 2019 as shown in Table 4 and Table 5. In 2019 in West Kalimantan and Central Kalimantan, each occurred for 3 months in a row, from July to September. This happened because in 2019 there were two natural phenomena at once, namely Moderate IOD+ and Weak El Niño. These two phenomena reinforce each other in reducing rainfall in the territory of Indonesia. In 2018 below-normal rainfall occurred for 1 month in West Kalimantan and 3 months in Central Kalimantan. This also happened because in 2018 there were 2 natural phenomena at once, namely Weak IOD+ and Moderate El Niño. These two phenomena also reinforce each other in reducing the amount of rainfall. Based on this data, the effect of natural phenomena in 2019 on the reduction in rainfall appears to be stronger than in 2018 [30–31].

In the dry season of 2020, monthly rainfall appears to be above normal. This happened because in 2020 there was a moderate La Niña natural phenomenon that caused some parts of Indonesia to have excess rainfall. In 2021, in West Kalimantan, rainfall is above-normal, while in Central Kalimantan, rainfall is 3 months below normal. Actually, in 2021 there will also be a moderate La Niña phenomenon, but the impact of excess rainfall in Indonesia is not too big, especially in Central Kalimantan.

4.3. Dynamics of Temperature in 2018-2022

The monthly average temperature data in the 2018-2021 dry season for the West Kalimantan location is shown in Table 6, and for the Central Kalimantan location, it is shown in Table 7. Table 8 shows the 4-month average temperature during the dry season for the two study sites.

Table 6. Temperature data of West Kalimantan

Month	Temperature (^{0}C)			
	2018	2019	2020	2021
Jul	31.02	29.96	29.15	29.97
Aug	31.10	29.80	29.81	29.04
Sep	29.85	29.14	29.17	29.14
Oct	29.26	28.87	29.40	29.67

The data shown in Table 8 shows that the highest temperature occurred in 2018 which was 30.31 0C in West Kalimantan. The lowest temperature of 29.38 0C occurred in 2019 in Central Kalimantan. The data shown in Table 8 also shows that it is still difficult to conclude the relationship between natural phenomena and the temperature that occurs because the temperature difference that occurs is very thin and does not form a certain relationship pattern.

Table 7. Temperature data of Central Kalimantan

Month	Temperature (^{0}C)			
	2020	2021	2020	2021
Jul	27.68	27.18	27.23	27.54
Aug	27.61	27.05	27.68	27.31
Sep	28.03	27.59	27.55	27.18
Oct	28.47	28.23	28.55	28.05

From Table 8 in general it appears that the temperature in West Kalimantan is higher than in Central Kalimantan. This happens because the position of the West Kalimantan station is closer to the coast when compared to the position of the Central Kalimantan station so the temperature is relatively higher.

Table 8. The average temperature of West Kalimantan and Central Kalimantan.

Year	Temperature (^{0}C)	
	West Kalimantan	Central Kalimantan
2018	30.31	27.94
2019	29.44	27.51
2020	29.38	27.75
2021	29.45	27.52

4.4. Correlation between Rainfall and Temperature

Before performing statistical calculations to determine the significance of the correlation between rainfall and temperature, we will first see how the trend of the relationship between the two parameters. For this reason, a time series graph of the two parameters is made as shown in Fig. 3. In Fig. 3 it can be seen that there is a trend in the relationship between rainfall and temperature where the lower the rainfall, the higher the temperature, especially from March 2018 to October 2018. This can be seen in the red and black dashed lines in Fig. 3. In months other than those months the trend of the relationship is irregular or difficult to conclude. Pada Fig. 4 also shows a relationship trend, the lower the rainfall, the higher the rainfall, especially from January 2021 to August 2021. From September 2019 to December 2019 the pattern of the relationship was irregular so it was difficult to conclude.

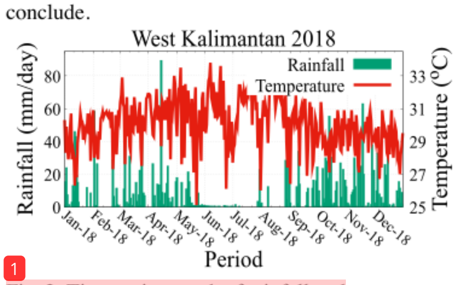

Fig. 3. Time series graph of rainfall and temperature in West Kalimantan in 2018.

Statistical tests to determine the significance of the correlation between rainfall and temperature were carried out through regression tests and t-tests. A regression test was carried out to get the correlation coefficient (r). Based on this r value, a t-test can be performed to obtain the t-count value. If the t-count is greater than the t-table, then the correlation between the two parameters is significant, and vice versa [18, 31-32].
The amount of data (n) in 2018 for both West Kalimantan and Central Kalimantan is n = 364. Based on the results of the regression calculations, the value of r = 0.4 for West Kalimantan, and r = 0.19 for Central Kalimantan. The graph of the

correlation between these two parameters is shown in Fig. 5 and Fig. 6.

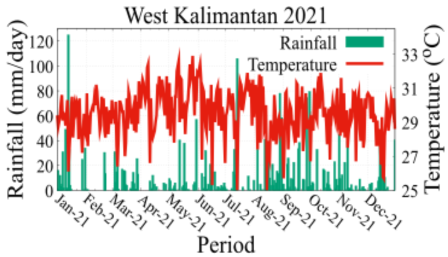

Fig. 4. Time series graph of rainfall and temperature in West Kalimantan in 2021.

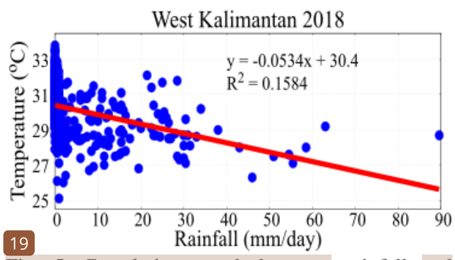

Fig. 5. Correlation graph between rainfall and temperature in West Kalimantan in 2018.

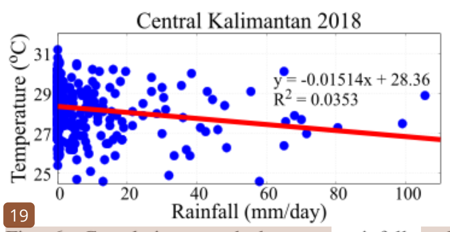

Fig. 6. Correlation graph between rainfall and temperature in Central Kalimantan in 2018.

After the r value is obtained, the t-count value can be calculated using the t-test. The result is t-count for West Kalimantan is t-count = 8.23 and for Central Kalimantan t-count = 3.69. Based on the t-test table, it was found that the t-table value = 1.97. Because the t-value for the two research sites is greater than the t-table, the correlation between these two parameters at both locations is significant.

Table 9. Results of statistical calculations for West Kalimantan.

Year	n	r	t count	t table	Signification
		West Kalimantan			
2018	364	0.40	8.23	1.97	Significant
2019	364	0.35	7.11	1.97	Significant
2020	365	0.37	7.59	1.97	Significant
2021	364	0.41	8.55	1.97	Significant

The same calculation process has been carried out on the data for the period 2019-2021 to obtain a significant correlation between rainfall and temperature. The complete statistical calculation results are shown in Table 9 and Table 10.

Table 10. Results of statistical calculations for Central Kalimantan.

Year	n	r	t count	t table	Signification
		Central Kalimantan			
2018	364	0.19	3.69	1.97	Significant
2019	364	0.15	2.89	1.97	Significant
2020	365	0.14	2.76	1.97	Significant
2021	364	0.22	4.17	1.97	Significant

5. CONCLUSIONS

On peatlands in West Kalimantan and Central Kalimantan, in the dry seasons of 2018 and 2019 in certain months, the amount of rainfall is below normal. This happened because in 2018 and 2019 the IOD+ and El Niño phenomena occurred. The number of months that experienced below-normal rainfall in 2019 was more than compared to 2018 because the IOD+ that occurred in 2019 had a very strong influence on the reduction in rainfall. In 2020 and 2021, in general, rainfall was above normal. The number of months in 2020 that experienced above-normal rainfall is more than in 2021. This shows that La Niña that occurred in 2020 has a stronger influence on increasing rainfall compared to La Niña in 2021. It is still difficult to conclude the relationship between natural phenomena and the temperature that occurs because the temperature difference that occurs is very thin and does not form a certain relationship pattern. However, based on statistical tests, a significant correlation was found between rainfall and temperature, where the lower the rainfall, the higher the temperature. We recommend conducting further research on the dynamics of hydro-climatological parameters such as groundwater level and soil moisture in the 2018-2021 period.

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