The Impact of Positive IOD and La Niña on Rainfall, Groundwater Level, and Soil Moisture in Peatlands in South Sumatra

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Abstract. Indonesia is between the Indian Ocean and the Pacific Ocean, so all of the natural phenomena that occur in these two oceans have an impact on Indonesia. This research aims to analyze the impact of IOD+ in 2019 in the Indian Ocean and La Niña in 2020 in the Pacific Ocean on rainfall, groundwater levels, and soil moisture on peatlands in South Sumatra. The data used are the results of measurements at the Karang Anyar station in the period from January 2019 to December 2020. The data was then analyzed statistically. The result is that rainfall in the 2019 dry season was much lower than in the 2020 dry season. Groundwater levels and soil moisture in the 2019 dry season were also lower than in 2020. There was also a strong correlation between groundwater levels and soil moisture.

Keywords: climate anomaly, ENSO, dynamics, relationship, correlation

1 Introduction

In the Pacific Ocean, the natural phenomenon El Niño Southern Oscillation (ENSO) can occur, which consists of El Niño and La Niña. In the Indian Ocean, the natural phenomenon of the Indian Ocean Dipole (IOD) can also occur, which consists of positive IOD (IOD+) and negative IOD (IOD-) [1]–[3]. Natural phenomena that occur in the two oceans occur due to interactions between the sea and the atmosphere in the two oceans, which results in climate anomalies [4], [5]. Indonesia is located between these two oceans so these phenomena influence the climate in Indonesia which results in climate anomalies in Indonesia [6]–[8].

SICBAS 2023, November 03, Palembang, Indonesia

DOI 10.4108/eai.3-11-2023.2347941

El Niño and IOD+ can cause parts of Indonesia to experience severe drought, especially in the dry season. As a result, forests and peatlands in the area experienced severe fires. La Niña and IOD- can cause excess rain in parts of Indonesia, which can result in flooding in those areas [4], [9]. ENSO and IOD can be divided into three categories, namely: weak, moderate and strong [10], [11]. This strong category has a great impact on climate conditions in Indonesia, including in South Sumatra [1].

In 2019 there was a high level of IOD+ so that peatlands in South Sumatra experienced severe fires which burned forests and land including peatlands covering an area of 361,857 ha. In 2020 there was a mid-level La Niña which resulted in rain in South Sumatra being above normal. This research analyzes the impact of IOD+ in 2019 and La Nina in 2020 on the dynamics of 3 hydro-climatological parameters, namely: rainfall, groundwater level, and soil moisture on peatlands in South Sumatra. The data used comes from one of the SESAME stations in South Sumatra [12]–[14], namely Karang Agung Station.

Research on the impact of ENSO and IOD on a region has been carried out by many previous researchers [15]–[22]. However, special research on the impact of IOD+ in 2019 and La Niña in 2020 on the dynamics of rainfall, groundwater levels and soil moisture using data from the Karang Agung station has never been carried out before. It is hoped that the results of this research can be input for those interested in mitigating natural disasters due to climate change on peatlands, especially in South Sumatra.

2 Methodology

2.1 Data

This research data comes from in-situ measurements from one of SESAME's stations called Karang Agung Station.. The data from this station measurement is hourly data which is then processed into monthly data. The data is shown in Table 1:

Table 1. Monthly data on rainfall, groundwater level, and soil moisture

	Rainfall (mm/month)		Groundwater Level (m)		Soil Moisture (%)	
	2019	2020	2019	2020	2019	2020
January	169	167.6	0.07	-0.08	48.95	33.69
February	162.2	84.4	0.13	-0.01	55.09	41.4
March	209.8	161.8	0.05	-0.1	48.43	31.8
April	183.2	203.2	0.12	0.01	52.09	44.26
May	28	128	-0.1	-0.04	50.38	35.48
June	61	182.6	-0.11	-0.02	48.07	37.73
July	37.4	58	-0.3	0.06	40.87	34.45
August	22	29.8	-0.54	-0.31	31.89	28.95
September	10.6	133.6	-0.67	-0.23	23.63	29.3
October	25	80	-0.96	-0.17	20.46	31.16
November	95.8	99.6	-0.93	0	22.23	44.48
December	126.2	125.4	-0.31	-0.04	24.67	39.15

2.2 Data analysis

Hourly data from Karang Agung station measurements is processed into monthly data to make it easy to analyze. The analysis focuses on data at the peak of the dry season in Indonesia which usually occurs in the period July to October (JASO)[14], [20], [23], [24]. The data is then processed statistically to obtain graphs of the dynamics of rainfall, groundwater level and soil moisture. Then we also look for the relationship between rainfall and groundwater level and the correlation between groundwater level and soil moisture.

3 Result and discussion

3.1 Dynamics of rainfall

The dynamics of rainfall in 2019 and 2020 are displayed in the form of a time series graph as shown in Figure 1. The analysis in Figure 1 focuses on the months July to October (JASO) 2019 and 2020. In Figure 1 it can be seen that in 2019 the peak of the dry season occurred in September where the rainfall was only 10.6 mm. The peak of the dry season in 2020 occurred in August when rainfall amounted to 29.8 mm. In the JASO 2019 period there was 95 mm of rainfall and in JASO 2020 the amount of rainfall was 301.4 mm. If we compare the data, the amount of rainfall in the JASO 2020 period is much higher than in 2019. Based on two years of data, can it be concluded that the natural phenomena IOD+ 2019 and La Niña 2020 have indeed affected precipitation on peatlands in the study area.

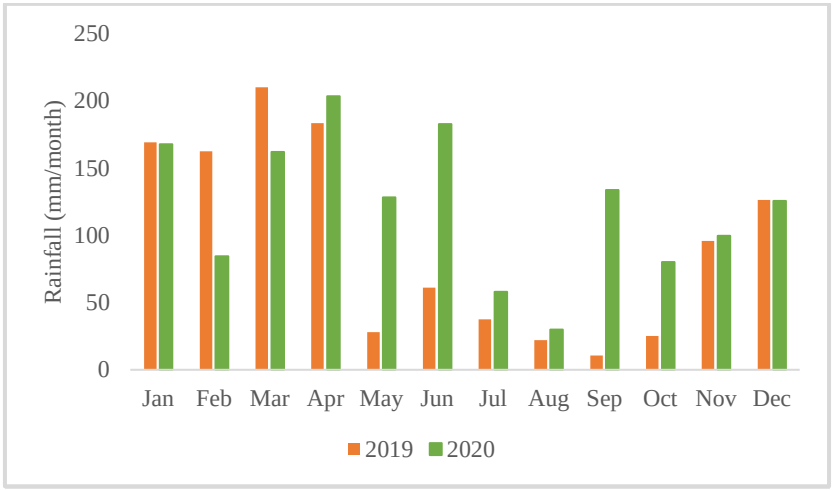


Fig 1. Time series graph of the dynamics of rainfall in 2019 and 2020

3.2 Dynamics of groundwater level

A time series graph regarding the dynamics of groundwater levels is shown in Figure 2. In this figure it can be seen that in the 2019 JASO period groundwater levels experienced a sharp decline and the peak occurred in October when it reached -0.96 m. In the 2020 JASO period groundwater levels also fell but not as sharply as in 2019. This shows that the IOD+ that

occurred in 2019 had a big influence on the depth of groundwater levels which far exceeded the critical condition of -0.4 m. If groundwater levels exceed critical conditions, peatlands can easily catch fire. In 2020, the lowest groundwater level was -0.31 m, which is still above the critical point.

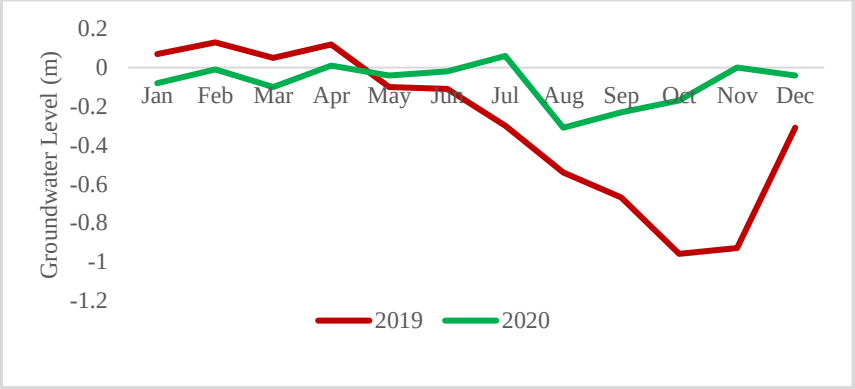


Fig 2. Time series graph of the dynamics of groundwater level in 2019 and 2020

3.3 Dynamics of soil moisture

Figure 3 displays a time series graph regarding the dynamics of soil moisture on the surface of peatlands in 2019 and 2020. In this figure it appears that in the 2019 JASO period soil moisture experienced a quite sharp decline. The lowest soil movement in 2019 occurred in October, namely 20.46%. This condition causes the surface of the peatland to become very dry. The decline in soil moisture in 2022 will not be as sharp as in 2019.

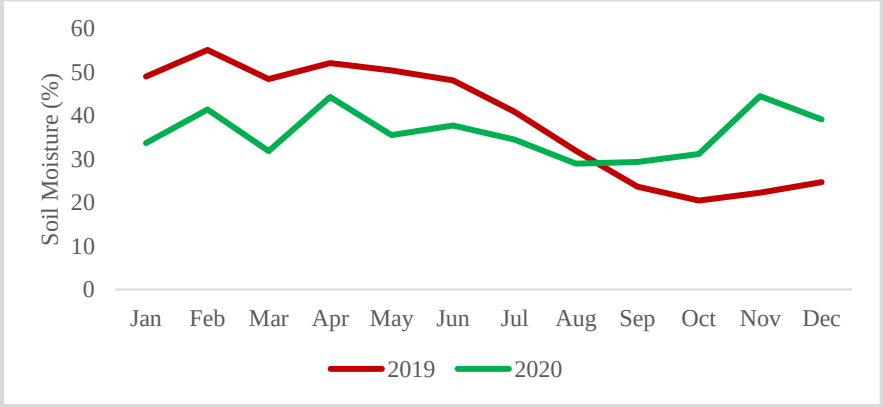
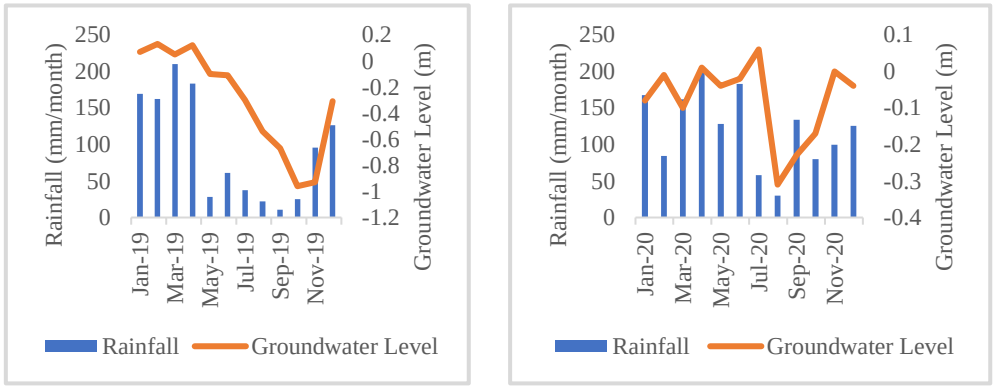


Fig 3. Time series graph of the dynamics of soil moisture in 2019 and 2020

3.4 Relationship between rainfall and groundwater level

A graphic of the relationship between rainfall and groundwater level is shown in Figure 4. In this figure it appears that there is a tendency that the higher the rainfall, the higher the groundwater level and vice versa. This shows that groundwater levels in peatlands are strongly influenced by rainfall. In the 2019 JASO period, it was clear that minimal rainfall caused groundwater levels to fall sharply.

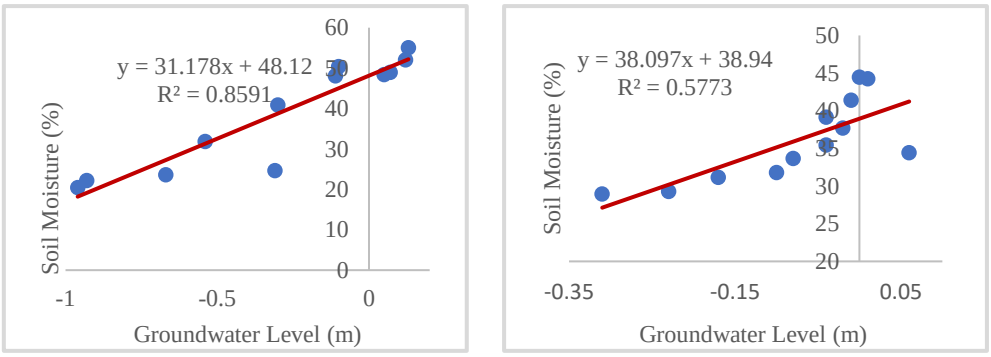


(a) (b)

Fig 4. Graph of relationship between rainfall and groundwater level in 2019 (a) and 2020 (b)

3.5 Correlation between groundwater level and soil moisture

The correlation graph between groundwater level and soil moisture is shown in Figure 5. The linear regression equation between groundwater level and soil moisture in 2019 is Y = 31,178 X + 48.12 and for 2020 it is Y = 38,097 + 38.94. The correlation coefficient between these two variables in 2019 was r = 0.93 and for 2020 it was r = 0.76. Based on the correlation coefficient (r) value in 2019 and 2020, it can be concluded that the correlation between groundwater level and soil moisture is quite strong. Especially in 2019, the correlation coefficient was very strong because the r value was almost close to 1 [25]. If you compare the correlation coefficient values in these two years, the correlation coefficient when the IOD+ phenomenon occurred was higher than when La Nina occurred. It can also be concluded that the correlation is stronger if the rainfall is minimal.



(a) (b)

Fig 5. Correlation between groundwater level and soil moisture in 2019 (a) and 2020 (b)

4 Conclusion

When the IOD+ phenomenon occurred in 2019, especially in the July to October (JASO) period, the values of rainfall, groundwater level and soil moisture parameters fell sharply. Meanwhile, in the JASO 2020 period, the values of these three parameters did not decrease sharply. It was also found that rainfall greatly influences groundwater levels. Then it was also found that in 2019 the correlation between groundwater level and soil moisture was very strong. Meanwhile the correlation in 2020 is not as strong as in 2019. The results of this research can be used as input for natural disaster mitigation needs, especially on peatlands in South Sumatra.

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