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EFFECT OF CLIMATE ANOMALY IN 2023 DRY SEASON ON RAINFALL, GROUNDWATER LEVEL, SOIL MOISTURE AND HOTSPOT ON PEATLANDS

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ABSTRACT: Climate anomalies observed in 2023 in Indonesia were caused by the simultaneous occurrence of two natural phenomena, including IOD+ (Positive Indian Ocean Dipole) and El Niño. Therefore, this research aimed to analyze the effect of the two phenomena on the parameters of rainfall, groundwater level, soil moisture, and hotspots during the dry season from July to October 2023. The data used for the first three types of parameters were obtained from the OKI-2 measuring station in Ogan Komering Ilir (OKI) Regency, and the hotspot data came from the MODIS satellite, which were both processed graphically and statistically. The results showed that there was very minimal rainfall in the 2023 dry season, even zero rainfall was recorded in October 2023. Additionally, the groundwater level decreased drastically, and the depth reached -1.23 m on October 10. The lowest soil moisture was only 11.21% on October 24, transforming peat soil to become very dry and flammable, while the highest hotspots (486) occurred in October. From July to October 2023, the average rate of decrease in groundwater level and soil moisture was 0.74 cm/day and 0.25%/day, respectively. A significant correlation was found between groundwater level (GWL) and soil moisture (SM), represented by the empirical equation SM = 27,654 GWL + 60,245.

Keywords: Climate change, Peatland, ENSO, IOD, Hydro-climatological parameters

1. INTRODUCTION

Indonesia is an Asian country with very large tropical peatlands spread across several islands. The three islands with the largest peatlands are Kalimantan, Sumatra, and Papua. Most of the peatlands in Sumatra are found in the provinces of Riau, Jambi, and South Sumatra. The depth varies from shallow (50-100 cm) to deep (more than 400 cm). This is also supported by the quite large carbon content, namely approximately 18 million tonnes. The province that has the most extensive peatland, namely Riau Province with an area of 3.8 hectares, actually used to have an even larger area. Inappropriate land use then causes peatlands to slowly degrade. It is feared that the hydrological function and production will no longer be the same as before. Based on data from 2011, the peat area in Kalimantan is in second place after the island of Sumatra. The largest peatlands can be found in Central Kalimantan Province with an area of 2,659,234 hectares. Just like in Sumatra, peatlands in Kalimantan are also vulnerable to degradation due to inappropriate use by humans [1-3]. In South Sumatra, large peatlands are found in the districts of Ogan Komering Ilir (OKI), Banyu Asin (BA,) and Musi Banyu Asin (MUBA), therefore, this research was conducted on peatlands in OKI Regency [4-6].

Peatlands are formed from various processes. According to science, it is thought that the formation of peat originated in the Holosin period, or 10,000 to 5,000 years BC, while peat in Indonesia is estimated to have existed in the period 6,800 to 4,200 BC. Even the peat in Central Kalimantan has been studied using radioisotope and carbon dating techniques and was stated to be 6,230 years old at a depth of 100 cm and at a depth of 5 meters 8,260 years old. From these scientific facts, peat formation requires a very long process. In other words, the speed of peat formation is 0.3 mm per year and generally occurs in shallow lakes that are gradually overgrown with wetland vegetation and aquatic plants. Tropical peatlands are generally highly flammable during severe drought, and peatlands in OKI Regency are extremely flammable when scorched. Therefore, various efforts have been carried out by the Indonesian government to prevent peatlands from experiencing severe drought. These include creating artificial rain during the dry season, making canals channel water from nearby rivers, and drilling wells around the peatlands to allow wetting [7-9].

The Indonesian government has collaborated with Japan to build a hydro-climatological parameter measurement station on peatlands. Measurements are conducted in situ and the results are processed first in the laboratory before being released for research [10-12] . The parameters measured include rainfall, groundwater level, and soil moisture, which are closely related to peatland fire events [13]. The measurements are generally carried out during the dry season in Indonesia. A measuring station is located in OKI-2 Village, OKI Regency, hence this research uses data from OKI-2 Station.

The natural phenomena IOD+ (Positive Indian Ocean Dipole) and El Niño occurred in 2023, leading to severe drought in the OKI peatlands [14]. Exploring the effect of these two simultaneous phenomena on rainfall, groundwater level, soil moisture, and hotspots in peatlands is insightful. Research on hydro-climatological parameters in peatlands affected by ENSO and IOD has been widely carried out [15-17]. However, the effect of IOD+ and El Niño in 2023 in OKI-2 station has not been examined. This research aims to analyze the impact of 2023 climate anomalies on the dynamics of rainfall, groundwater levels, soil moisture and hotspots on peatlands in OKI Regency. The results of this current research will be considered in making decisions regarding peatland management, specifically in OKI Regency.

2. RESEARCH SIGNIFICANCE

The simultaneous occurrence of IOD+ and El Niño in 2023 led to peatlands in OKI Regency experiencing massive fires. Three hydro-climatological parameters, including rainfall, groundwater level, and soil moisture, may be affected. Therefore, this research aimed to analyze the effect of IOD+ and El Niño on the three parameters as an effort to provide input to all parties in the context of mitigating fires on peatlands, specifically in OKI Regency.

Fig. 1 Hydro-climatological arameters measurement station

3. MATERIAL AND METHOD

The governments of Indonesia and Japan (JICA) have collaborated since 2017 to establish several stations measuring hydro-climatological parameters on the islands of Sumatra and Kalimantan. On the island of Sumatra, equipment installation is carried out in the provinces of South Sumatra, Riau, and Jambi. In South Sumatra province, the focus is on the Ogan Komering Ilir (OKI), Musi Banyu Asin (MUBA), and Banyu Asin (BA) Regencies [13]. In OKI Regency, there are OKI-1 stations and OKI-2 stations. Therefore, this research used measurement data from the OKI-2 station due to being more complete than the OKI-1 station data. The research location map is shown in Figure 2, with the maroon color representing peatland in OKI Regency. Meanwhile, the equipment system installed at the location is shown in Figure 1.

The station can measure hourly data for rainfall parameters, groundwater level, and soil moisture in situ. Subsequently, the data are processed in the laboratory for research purposes related to efforts to mitigate natural disasters on peatlands, particularly fire outbreaks. Peatlands in OKI Regency are highly flammable during the extreme dry season [18].

Indonesia is located between the Pacific and Indian Oceans, which are extremely large. All phenomena occurring in the two oceans, specifically those related to climate anomalies, greatly affect climate conditions. The natural phenomenon El Niño Southern Oscillation (ENSO) occurs in the Pacific Ocean, consisting of El Niño and La Niña. The Indian Ocean Dipole (IOD) occurs in the Indian Ocean and consists of IOD+ and IOD-. El Niño and IOD+ decrease rainfall in Indonesia, while La Niña and IOD- can increase rainfall. Stronger occurrence of ENSO and IOD leads to a more severe effect on climate conditions in this country. The ENSO and IOD categories are based on Ocean Nino Index (ONI) and Dipole Mode Index (DMI) values, respectively [19-21].

The simultaneous natural occurrence of IOD+ and El Niño in 2023 has the same effect, namely reducing the amount of rainfall in Indonesia. IOD+ has a significant effect on peatlands in OKI because the position of OKI Regency is closer to the Indian Ocean than the Pacific Ocean. The strength of El Niño and IOD+ that occurred during the dry season (J-A-S-O) 2023 is shown in Table 1.

Table 1. Category of IOD+ and El Niño in J-A-S-O 2023

Month	IOD+		El Niño	
2023	DMI °C	Category	ONI °C	Category
Jul	0.12	Normal	0.8	Weak
Aug	0.71	Weak	1.1	Weak
Sept	0.84	Weak	1.3	Moderate
Oct	1.44	Moderate	1.6	Strong

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

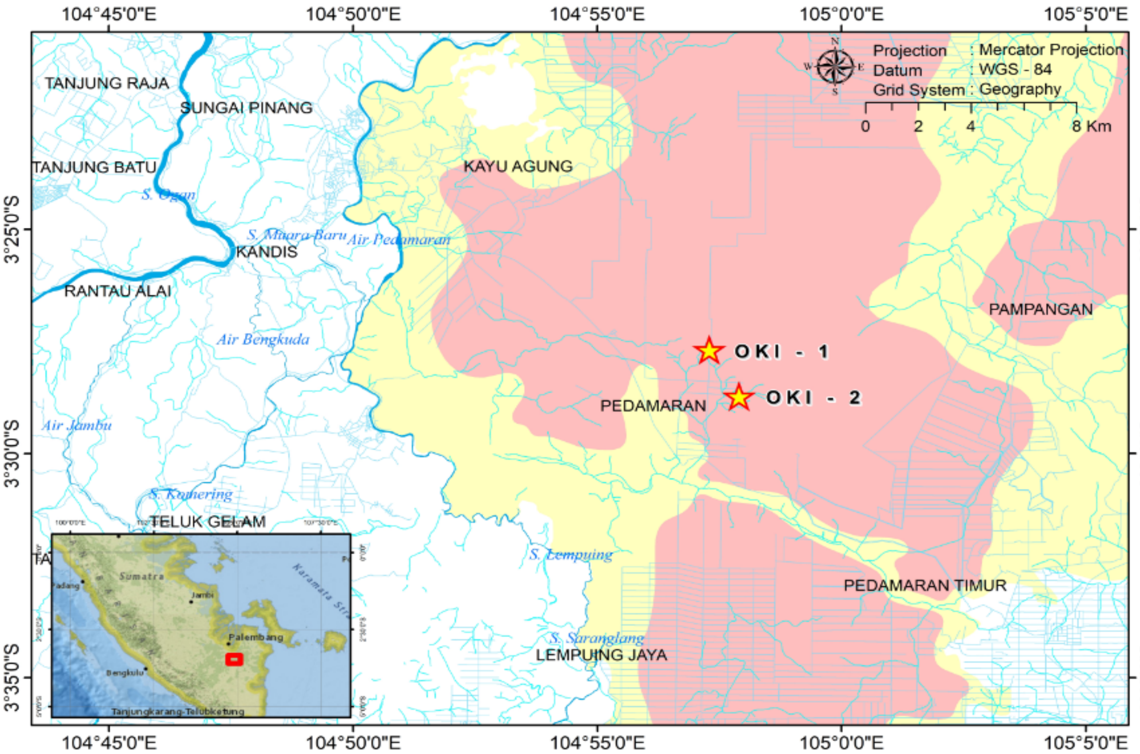

Fig. 2 Map of research location

The data measured by this station are rainfall, groundwater level, and soil moisture in the dry season (J-A-S-O), which are processed graphically to determine the time series dynamics of the three parameters. Specifically, the rate of decline for groundwater level and soil moisture was calculated using linear regression. Additionally, the relationship and correlation between these two parameters were determined. In the final section, the number of hotspots that appeared from July to August (J-A-S-O) 2023 were analyzed. Hotspot data were obtained from MODIS satellite measurements which could be downloaded on the website https://hotspot.brin.go.id/.

4. RESULT AND DISCUSSION

The results of data processing are presented in this section, as well as a discussion of the effect of IOD+ and El Niño in the 2023 dry season on rainfall, groundwater level, soil moisture, and hotspots. Additionally, the relationship and correlation between groundwater level and soil moisture are discussed.

4.1 Rainfall

The IOD+ and El Niño phenomena which appeared simultaneously in 2023 caused very minimal rainfall from July until October in OKI Regency. This can be observed in the rainfall time series graph in Figure 3. Rainfall tends to decrease in the J-A-S-O period from July to October 2023. In July, there was still a good amount of rainfall, but as the time increased the rainfall reduced until there was no rainfall in October 2023. According to Table 1, there was a medium level of IOD+ phenomenon and a strong El Niño in October 2023. These two phenomena led to the absence of rainfall [22-24].

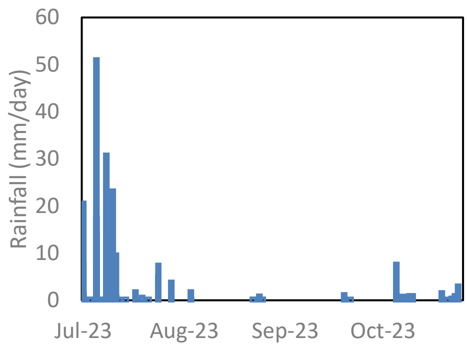

Fig. 3 Rainfall time series in July to October 2023

Figure 4 shows the monthly rainfall in 2019, 2020, and 2023 in the peatlands of OKI Regency. The effect of the climate anomalies during the dry season (J-A-S-O) was greater in 2023 compared to 2019 and 2020 because only the IOD+ phenomenon occurred in 2019, and there was a weak La Niña in 2020 [25-27]. During the J-A-S-O period in 2019 and 2023, the amount of rainfall did not reach zero compared to 2023.

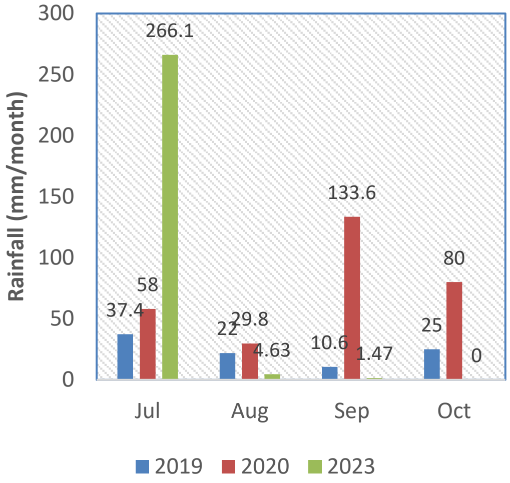

Fig. 4 Monthly rainfall in 2019, 2020, and 2023.

4.2 Groundwater Level

The effect of IOD+ and El Niño 2023 on groundwater level can be observed from the time series graph presented in Figure 5 which shows a continual level decline along with an increase in time. The lowest peak groundwater level value occurred on October 10, namely -1.23 m. This is extremely lower than the groundwater level threshold (-0.4 m) that should be maintained to prevent hotspots from appearing on peatlands in Indonesia. The groundwater level was below -0.4 m in August to October 2023, hence many hotspots appeared during the three months period. Data on the number of hotspots are shown in Tables 4 and 5.

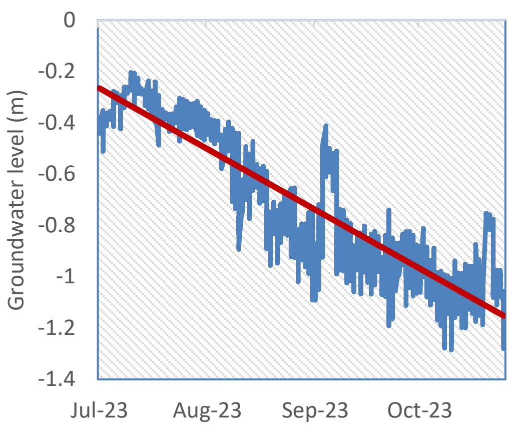

Fig. 5 Groundwater level time series in July to October 2023

The effect of climate anomalies on reducing groundwater level were stronger in 2023 than in 2019 and 2020. These can be observed in Figure 6 which shows the lowest value of groundwater level at -0.96 m during the 2019 dry season, compared to -0.31m in 2020 [20], and -1.23 m in 2023. Additionally, the recorded values proved that the simultaneous occurrence of IO+ and El Niño in 2023 had a stronger effect on hydro-climatological parameters, specifically groundwater level, compared to only IOD+ in 2019 and La Niña in 2020.

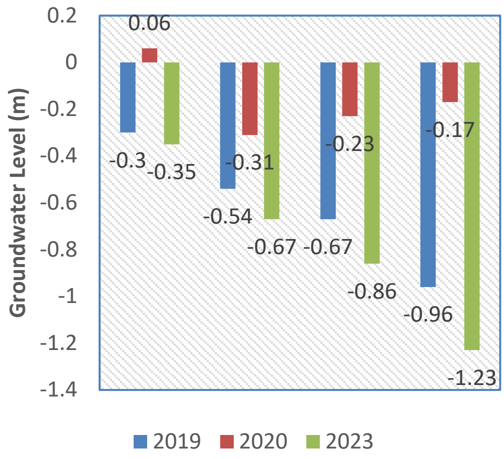

Fig. 6 The lowest groundwater level in 2019, 2020, and 2023

The red linear line in Figure 5 shows the trend of decreasing groundwater from the start of July 2023 to the end of October 2023. Based on this, the average speed of decreasing groundwater levels can be calculated. The x-axis represents July 1 to October 31 2023 or 122 days. The y-axis shows the decrease in groundwater level during this period, namely 1.17 - 0.27 = 0.9 m. Therefore, the average speed of decreasing groundwater level is 0.9 m / 122 days = 0.74 cm/day.

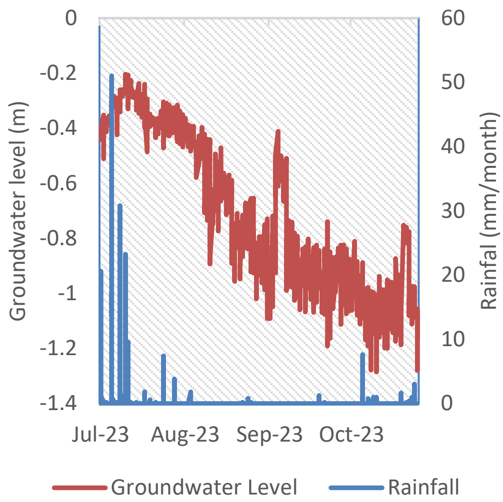

Fig. 7 Relationship graph of rainfall and groundwater

level from July to October 2023.

Groundwater level decline is caused by decreased rainfall. A graph of the relationship between these two parameters is shown in Figure 7. The graph shows that more rainfall leads to higher groundwater level. In early September 2023, the groundwater level appeared to have risen despite rainfall absence because of efforts by government officials including channeling water from nearby rivers into the peatlands. However, this did not last long because the lack of rainfall caused the water discharge from the rivers to decrease drastically.
The data for 2019 and 2020 are presented in Figures 8 and 9. These show that lower rainfall tends to initiate decrease in groundwater water.

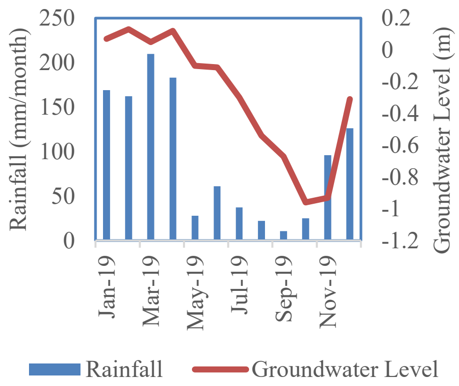

Fig. 8 Relationship graph of rainfall and groundwater level in 2019.

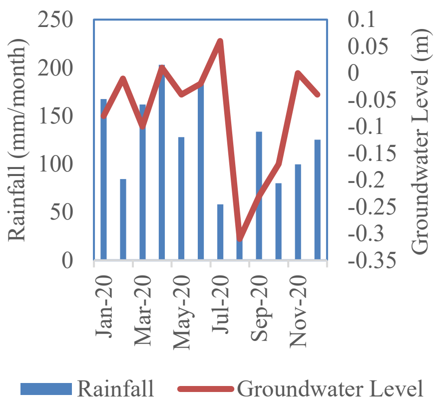

Fig. 9 Relationship graph of rainfall and groundwater level in 2020.

4.3 Soil Moisture

Figure 10 shows a time series graph of soil moisture decline in the 2023 dry season. Climate anomalies in the 2023 dry season had a similar effect on groundwater level by causing soil moisture values to fall quite sharply. The lowest soil moisture occurred on October 24, 2023, namely 11.21%. This small value led to the soil in peatlands becoming extremely dry and flammable. The majority of fire outbreaks originated from human activity, whether intentional or unintentional. An example of intentional activity is the deliberate burning of land to open new agricultural land and plantations. An unintentional case is the dumping of lit cigarette butts by anglers on peatlands [28-30].

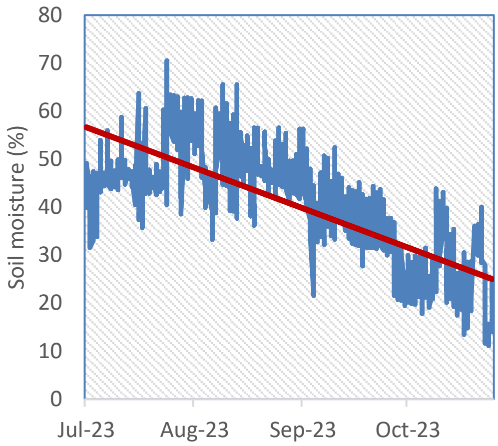

Fig. 10 Soil moisture time series in July to October 2023

The effect of the 2023 climate anomalies on soil moisture was stronger when compared with data from 2019 and 2020. Figure 11 shows the lowest soil moisture in 2019, 2020, and 2023 at 20.46%, 28.95%, and 20.23 %, respectively. These values signify that the lowest soil moisture in 2024 will still be lower than in 2019 and 2020.

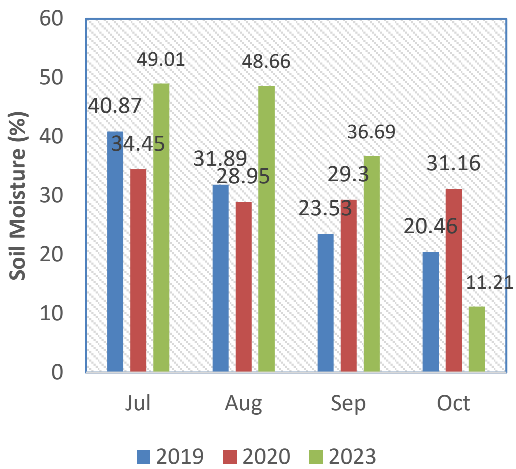

Fig. 11 The lowest soil moisture in 2019, 2020, and 2023

The trend of decreasing soil moisture is shown by the red linear line in Figure 10. Based on this, the speed of decrease in soil moisture in the 2023 dry season can be calculated. The x-axis represents the data collection period (122 days), while the y-axis states the decrease in soil moisture, namely 56.5% - 25.4% = 31.1%. Therefore, the average rate of decrease in soil moisture is 31.1% / 122 days = 0.25% per day.

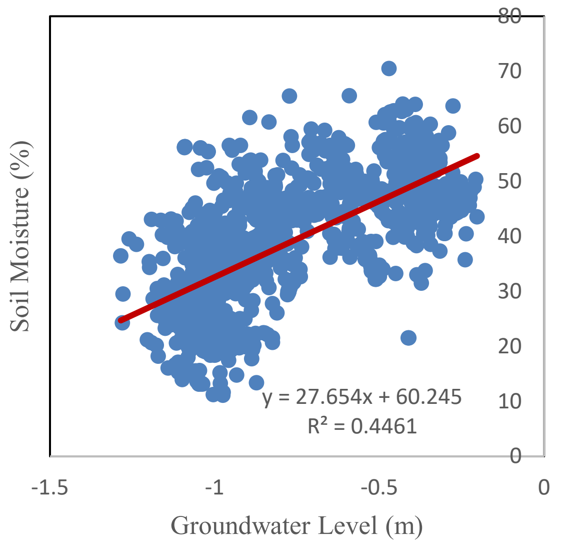

Fig. 12 Correlation graph between soil moisture and groundwater level from July to October 2023.

The results showed that the effect of climate anomalies in the 2023 dry season on groundwater level (GWL) and soil moisture (SM) were similar, hence both parameters might have a significant correlation. The correlation graph between these two parameters is presented in Figure 12 which is the result of statistical calculations producing a coefficient of determination (R2) at 0.4461 or a correlation coefficient (r) of 0.67. The t-test results of the correlation showed that t-count was > t-table, implying a significant correlation [31]. The empirical equation stating the correlation between these two parameters is SM = 27.654 GWL + 60.245, which can be used to predict soil moisture values based on known groundwater level values.

4.4 Hotspot

Table 2 shows the monthly values of rainfall, groundwater level, soil moisture, and hotspot parameters. The highest number of hotspots totalling 486 occurred in October. Moreover, the hotspots appeared during zero rainfall, as well as the lowest groundwater and soil moisture level. This implies that less rainfall leads to lower groundwater level and soil moisture, initiating more hotspots.

Table 2. Monthly values of rainfall, groundwater level, soil moisture, and hotspot

Month	Rainfall (mm/m)	GWL (m)	SM (%)	Hotspot
July	266.41	-0.35	49.01	3
August	4.63	-0.67	48.66	10
September	1.47	-0.86	36.69	227
October	0.00	-1.28	11.21	486

Table 3 shows the number of hotspots in the dry season in 2020 and 2023 in OKI Regency obtained from the website https://hotspot.brin.go.id/. The 2019 data for OKI Regency are not yet available. However, the number of hotspots in 2023 was much greater than in 2020. In 2023, there were IOD+ and El Niño, which caused rainfall to decrease drastically, even reaching zero in October. In 2020, La Niña occurred on a weak scale and tended to produce rainfall above the normal range, hence rainfall was available even in the dry season. This situation prevented the soil on peatlands from drying completely, leading to the formation of many hotspots during the 2020 dry season.

Table 3. Number of hotspots in 2020 and 2023 dry season

Month	Hotspot	
	2020	2023
July	6	3
August	16	10
September	5	227
October	7	486

5. CONCLUSION

In conclusion, the results showed that the climate anomalies in 2023 affected rainfall, groundwater level, soil moisture, and hotspot parameters. Furthermore, there was minimal rainfall in the 2023 dry season, as well as extremely low groundwater level and soil moisture. In October 2023, zero rainfall was observed, groundwater level reached -1.23, and soil moisture was only 11.21%. These situations caused peatlands to become extremely dry and flammable, generating 486 hotspots. This research identified a significant correlation between soil moisture and groundwater level with the correlation equation SM = 27,654 GWL + 60,245, which could be used to calculate soil moisture for the location in OKI Regency based on known values. The effect of climate anomalies in 2023 on climatological parameters was stronger compared to 2019 and 2020.

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7. REFERENCES

[1] Wulandari C., Novriyanti N., and Iswandaru D., Integrating ecological, social and policy aspects to develop peatland restoration strategies in orang kayo hitam forest park, jambi, Indonesia, Biodiversitas, vol. 22, no. 10, 2021, pp. 4158–4168.

[2] Rossita A., Boer R., Hein L., Nurrochmat D.R., and Riqqi A., Peatland fire regime across Riau peat hydrological unit, Indonesia, For. Soc., vol. 7, no. 1, 2023, pp. 76–94.

[3] Park H., Takeuchi W., and Ichii K., Satellite-based estimation of carbon dioxide budget in tropical peatland ecosystems, Remote Sens., vol. 12, no. 2, 2020, pp. 1–21.

[4] Robins L., van Kerkhoff L., Rochmayanto Y., Sakuntaladewi N., and Agrawal S., Knowledge systems approaches for enhancing project impacts in complex settings: community fire management and peatland restoration in Indonesia, Reg. Environ. Chang., vol. 22, no. 3, 2022, pp. 1-14.

[5] Lu X., Zang X., Li F., Drainage canal impacts on smoke aerosol emissions for Indonesian peatland and non-peatland fires, Environ. Res. Lett., vol. 16, no. 9, 2021, pp. 1-12

[6] Susetyo K.E., Kusin K., Nina Y., Jagau Y., Kawasaki M., and Naito D., 2019 Peatland and Forest Fires in Central Kalimantan, Indonesia, Newsl. Trop. Peatl. Soc. Proj. Inst. Humanit. Nat., vol. 08, 2020, pp. 1–4.

[7] Suryadi Y., Soekarno I., and Humam I.A., "Effectiveness analysis of canal blocking in sub-peatland hydrological unit 5 and 6 kahayan sebangau, central kalimantan, indonesia, J. Eng. Technol. Sci., vol. 53, no. 2, 2021, pp. 1-13.

[8] Ward C., Stringer L.C., Agus F.,Smallholder perceptions of land restoration activities: rewetting tropical peatland oil palm areas in Sumatra, Indonesia, Reg. Environ. Chang., vol. 21, no. 1, 2021, pp. 1-17.

[9] Humam I.A., Chalid A., Prasetyo B., The Modelling of Groundwater Table Management for Canal Blocking Scenarios In Sub Peatland Hydrological Unit, Int. J. Sci. Technol. Manag., vol. 1, no. 4, 2020, pp. 289–297.

[10] Lasminto U., Kartika A.A.G., and Ansori M.B., Reliability of Tropical Rainfall Measuring Missionfor Rainfall Estimation in Brantas Sub-Watersheds, Int. J. of Geomate, vol. 26, no. 116, 2024, pp. 27-36.

[11] Irfan M., Mardiansyah W., Surbakti H., Ariani M., Sulaiman A., and Iskandar I., Spatio-Temporal Variability of Observed Ground Water Level at Peat Hydrology Unit in South Sumatera, J. Comput. Theor. Nanosci., vol. 17, no. 2, 2020, pp. 1414–1421.

[12] Irfan M., Kurniawati N., Ariani M., Sulaiman A., and Iskandar I., Study of groundwater level and its correlation to soil moisture on peatlands in South Sumatra, J. Phys. Conf. Ser., vol. 1568, no. 1, 2020, pp. 1-6.

[13] Irfan M. and Iskandar I., The Impact of Positive Iod and La Niña on the Dynamics of Hydro-Climatological Parameters on Peatland, Int. J. Geomate, vol. 23, no. 97, 2022, pp. 115–122.

[14] Irfan M., Safrina S., Sulaiman A., The Impact of Positive IOD and La Niña on Rainfall, Groundwater Level, and Soil Moisture in Peatlands in South Sumatra, 2024, pp. 1-8.

[15] Ariska M., Suhadi, Supari, Irfan M., and Iskandar I., Spatio-Temporal Variations of Indonesian Rainfall and Their Links to Indo-Pacific Modes, Atmosphere (Basel)., vol. 15, no. 9, 2024, pp. 1-18.

[16] Kurniadi A., Weller E., Min S.K., Seong M., Independent ENSO and IOD impacts on rainfall extremes over Indonesia, Int. J. Climatol., vol. 41, no. 6, 2021, pp. 3640–3656.

[17] Sambah A.B., Noor'izzah A., Intyas C.A., Widhiyanuriyawan D., Affandy D.P., and Wijaya A., Analysis of the effect of ENSO and IOD on the productivity of yellowfin tuna (Thunnus albacares) in the South Indian Ocean, East Java, Indonesia, Biodiversitas, vol. 24, no. 5, 2023, pp. 2689–2700.

[18] Irfan M., Kriyanti E., Saleh K., Hadi., "Dynamics of Peatland Fires in South Sumatra in 2019: Role of Groundwater Levels, Land, vol. 13, no. 3, 2024, pp. 1-15.

[19] Polonsky A., and Torbinsky A., The iod–enso interaction: The role of the Indian Ocean current's system, Atmosphere (Basel)., vol. 12, no. 12, 2021, pp. 1-13.

[20] Cao T., Zheng F., and Fang X., Key Processes on Triggering the Moderate 2020/21 La Niña Event as Depicted by the Clustering Approach, Front. Earth Sci., vol. 10, no. February, 2022, pp. 1–12.

[21] Li A., Zhang Y., Hong M., Shi J., and Wang J., Relative importance of ENSO and IOD on interannual variability of Indonesian Throughflow transport, Front. Mar. Sci., vol. 10, no. May, 2023, pp. 1–16.

[22] Zafar A., and Uchimura T., Relationship Between Air Pressure and Volumetric Water Content at Steady State in Rainfall-Induced Landslide Based on Modified Column Tests,

Int. J. of Geomate, vol. 26, no. 117, 2024, pp. 52–59.
[23] Reddy P.J., Perkins-Kirkpatrick S.E., and Sharplesm J.J., Interactive influence of ENSO and IOD on contiguous heatwaves in Australia, Environ. Res. Lett., vol. 17, no. 1, 2022, pp. 1-15.
[24] Ratna S.B., Cherchi A., Osborn T.J., Joshi M., and Uppara U., The Extreme Positive Indian Ocean Dipole of 2019 and Associated Indian Summer Monsoon Rainfall Response, Geophys. Res. Lett., vol. 48, no. 2, 2021, pp. 1–11.
[25] Hasudungan P., Irham I., and Utami A.W., The impact of el nino southern oscillation and covid-19 on the rice price dynamics in Indonesia: The vector error correction model approach, IOP Conf. Ser. Earth Environ. Sci., vol. 883, no. 1, 2021, pp. 1-11.
[26] Lim E.P., Why Australia was not wet during spring 2020 despite La Niña, Sci. Rep., vol. 11, no. 1, 2021., pp. 1–15.
[27] Tañagras J., Macuhal R., and Herrera E., Impact Evaluation of Land Use–Land Cover Change on The Hydrology of Salipit River Basin Cavite, Philippines, Int. J. of Geomate, vol. 25, no. 10, 2023, pp. 140-147.
[28] Putra R., Sutriyono E., Kadir S., and Iskandar I., Understanding of fire distribution in the South Sumatra peat area during the last two decades, Int. J. Geomate, vol. 16, no. 54, 2019, pp. 2186–2990.
[29] Hein L., The health impacts of Indonesian peatland fires, Environ. Heal. A Glob. Access Sci. Source, vol. 21, no. 1, 2022, pp. 1–17.
[30] Nurhayati A.D., Saharjo B.H., Sundawati L., Syartinilia S., and Cochrane M.A., Forest and peatland fire dynamics in South Sumatra Province, For. Soc., vol. 5, no. 2, 2021, pp. 591–603.
[31] Gerald B., A Brief Review of Independent, Dependent and One Sample t-test, Int. J. Appl. Math. Theor. Phys., vol. 4, no. 2, 2018, pp. 1-11