

Analisis Dampak Anomali Iklim (ENSO dan IOD) pada lingkungan berdasarkan komputasi di Wilayah Sumatera Barat (Wilayah Khatulistiwa Indonesia)

Analysis of the Impact Climate Anomalies (ENSO and IOD) on environments based of computing in the Western Sumatra Region (Equatorial Region of Indonesia)

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Abstrak. ENSO (El Niño - Southern Oscillation) adalah bentuk anomali iklim di Samudra Pasifik yang ditandai dengan peningkatan suhu permukaan laut (SPL) di bagian Tengah dan Timur khatulistiwa. Fenomena ini memainkan peran penting dalam variasi iklim tahunan dan musiman di Indonesia, terutama di wilayah khatulistiwa Indonesia. Studi ini bertujuan untuk menganalisis dampak anomali iklim komputasi di wilayah khatulistiwa Indonesia. Metode yang digunakan dalam studi ini adalah metode regresi linier dengan membandingkan dua mesin statistik, yaitu bahasa pemrograman Python dan SPSS. Pengaruh ENSO dirasakan di beberapa daerah Indonesia yang ditandai dengan jumlah curah hujan yang lebih rendah selama tahun ENSO dibandingkan dengan sebelum dan sesudah ENSO. Peristiwa El Niño juga mempengaruhi masuknya musim kemarau dan durasinya sepanjang evolusi ENSO. Penurunan jumlah curah hujan berkorelasi negatif dengan peningkatan jumlah kebakaran hutan per tahun. Analisis curah hujan berbasis pembelajaran mesin menggunakan Google Colab dan Python memberikan hasil yang identik dengan analisis berbasis SPSS, sehingga hasil analisis berbasis pembelajaran mesin memiliki nilai yang akurat. Perubahan iklim akan menghasilkan perubahan pola iklim tahunan dan antartahunan seperti penundaan dalam awal musim hujan atau musim kemarau. Selain ENSO, juga terdapat gejala anomali iklim yang dihasilkan oleh interaksi antara laut dan atmosfer di Samudra Hindia di sekitar khatulistiwa, yang disebut IOD (Indian Ocean Dipole). Selain melihat dampak anomali iklim terhadap lingkungan, studi ini juga menguji perbandingan hubungan antara anomali perubahan iklim dan curah hujan menggunakan metode SPSS dan bahasa pemrograman Python dengan membandingkan akurasi *output* yang dihasilkan secara komputasi. Pengaruh IOD dan ENSO terhadap wilayah tipe hujan ekatorial tidak cukup signifikan. Hubungan antara IOD dan ENSO tidak cukup kuat untuk wilayah khatulistiwa dan tidak terjadi pergeseran pada puncak *onset* di wilayah ini.

Abstract. ENSO (El Niño -Southern Oscillation) is a form of climate deviation in the Pacific Ocean which is characterized by an increase in sea surface temperature (SST) in the Central and Eastern parts of the equator. This phenomenon plays an important role in annual and seasonal climate variations in Indonesia, especially in the equatorial region of Indonesia. This study aimed to analyze the impact of a computational climate anomaly in the equatorial region of Indonesia. The method used in this study was the linear regression method by comparing two statistical engines, namely the Python coding language and SPSS. The influence of ENSO is felt in several areas of Indonesia which are characterized by lower amounts of rainfall during the ENSO year compared to pre- and post-ENSO. El-Niño events also affect the entry of the dry season and its duration throughout the evolution of ENSO. Reducing the amount of annual rainfall is negatively correlated with increasing the number of forest fires per year. Machine learning-based rainfall analysis using google collab and python gives identical results to SPSS-based analysis, so the results of machine learning-based analysis have an accurate value. Climate change will result in changes in annual and interannual climate patterns such as a delay in the start of the rainy season or dry season. In addition, the rainy season period is also expected to be shorter. Apart from ENSO, there are also symptoms of climate deviations produced by the interaction of the sea and the atmosphere in the Indian Ocean around the equator, which is called the IOD (Indian Ocean Dipole). In addition to looking at the impact of climate anomaly on the environment, this study also examines the comparison of the relationship between climate change anomaly and rainfall using the SPSS method and the Python coding language by comparing the accuracy of the computationally generated output. The influence of IOD and ENSO on the rain-type region with the Equatorial rain-type region is not significant enough. The relationship between IOD and ENSO is not strong enough for the equatorial region and there is no shift in the peak onset in this region.

Keywords: Climate Anomalies, ENSO, IOD, Computing, Equatorial Region

Introduction

Climate change is a change in several climate indicators caused directly or indirectly by human activities. One indicator of climate change is rainfall. Factors contributing to climate change include the greenhouse gas effect, land use change, and industrial waste. The impact of climate change is high and uneven rainfall in several areas (Iskandar, 2010; Ariska *et al.*, 2022). Changes in the climate system drive changes in the frequency, intensity, extent of coverage, duration and timing of extreme weather and climate events (IPCC, 2018; Ariska *et al.*, 2022). Region of Indonesia equatorial rain pattern is related to the movement of the north and south convergence zones which follow the apparent motion of the sun (Fitra *at al*, 2019; Misnawati and Perandawanti, 2019). The convergence zone is a place where two air masses from the two hemispheres meet. Convergence is an air mass that moves towards a point then moves upwards. The area where the convergence phenomenon occurs is referred to as the convergence zone (Sipayung *et al.*, 2007; Glisan *et al.*, 2016; Ariska, Akhsan and Muslim, 2022). The location of the convergence zone always changes every 14 days following the apparent annual motion of the sun from north to south and vice versa with coordinates 23.5° North Latitude – 23.5° South Latitude.

Rainfall is closely related to climate change. In determining climate change with extreme changes in Indonesia, indicators that can be used are high amounts of rainfall and long dry seasons (Melly *et al*, 2019). The dry season can last longer and the rainy season can be very short. A very long dry season can reduce land productivity in an area. The rainy season can last shorter with high intensity and has the potential for flood disasters (Ramage, 1968; Saji and Vinayachandran, 1999).

Rainfall variability in Indonesia is included in the high category. Rainfall in Indonesia is influenced by various weather and climate factors, both locally and globally (Aldrian and Dwi Susanto, 2003). Phenomena that have an influence on rainfall in Indonesia are the Madden Julian Oscillation (MJO), El Niño Southern Oscillation (ENSO) and the Dipole Mode Index (IOD) (Putra *et al*, 2020). Most of the rainfall in the Indonesian region is affected by ENSO in the moderate category (Ye and Li, 2017; Tavakol *et al*, 2020). ENSO has low influence in some parts of western and eastern Indonesia. As for the areas of Indonesia that have high influence, they can be found in eastern Indonesia. ENSO (El Niño Southern Oscillation) is a symptom of temperature fluctuations at sea level that occur in the eastern Pacific Ocean from normal conditions caused by differences in temperature and pressure. ENSO consists of two events, namely El Niño and La Niña (Kumar *et al*, 2019; Tavakol, Rahmani *et al*, 2020). El Niño is a form of climate deviation in the Pacific Ocean which is marked by an increase in Sea Surface Temperature (SST) in the south and east of the equator (Hermon, 2014; Melly *et al*, 2019).

El Niño and La Niña events can cause an increase or decrease in rainfall intensity.

IOD is a phenomenon of sea surface temperature anomaly between the western Indian Ocean and the eastern Indian Ocean. The temperature anomaly that occurs forms an oscillation that occurs periodically. Because of the temperature difference between the two sides, there will be a long drought on one side and very heavy rain on the other. IOD is one of the factors that determines climate conditions in Indonesia and countries in the Indian Ocean Region. Research related to the relationship between the Indian Ocean Dipole and rainfall that occurs in the province of West Sumatra. The results of this study state that the IOD phenomenon causes the West Sumatra Province to always be wetter and the rainfall is always higher than other Indonesian regions throughout the year (Brandes *et al*, 2002; Baeda *et al*, 2019; Ariska *et al*, 2022).

This study examines the impact of ENSO and IOD on the environment, especially in areas with Equatorial rainfall patterns on the surrounding environment. It is undeniable that the content of global warming and climate change is a strategic content that is a major global topic that requires an immediate solution. Apart from looking at these impacts, this paper also compares the manual method and uses Python coding to see the relationship between the impact of ENSO and IOD on the environment. A comparison of these two methods is used to see the most appropriate and accurate method for analyzing extreme climate change in the Indonesian Region based on computation.

Methodology

Correlation analysis was carried out to find out whether there is a relationship between the research variables. There are two types of correlation tests, namely parametric and non-parametric correlation tests (Harrison, 1998; Strategy, 2011; Zhan *et al.*, 2017; Handoko *et al.*, 2019; Bhatti *et al.*, 2020). The use of the correlation test is based on the results of the normality test of the two variables. If the two variables are normally distributed then use the parametric correlation test. An example of a parametric correlation test is the Pearson correlation test.

Table 1 Guidelines for correlation analysis based on the value of the correlation coefficient

Coefficient intervals	Relationship level
0.00 – 0.199	Very Low
0.20 – 0.399	Low
0.40 – 0.599	Moderate
0.60 – 0.799	Strong
0.80 – 1.000	Very Strong

If the two variables are not normally distributed, a non-parametric correlation test is used. An example of a non-parametric correlation test is the Spearman correlation test. The correlation test was carried out with a

significance level of 5%. Basic decision making on correlation analysis can be seen in the Tabel 1.

Linear regression analysis was carried out to find out how much influence the El Niño Southern Oscillation (ENSO) variable represented by the Niño3.4 Index and the Indian Ocean Dipole (IOD) represented by DMI had on rainfall in the equatorial region in the 1991 – 2020 period and to see the trend of significance between both of them. Linear regression analysis is performed entirely on machine learning. The system in machine learning will divide the data into two parts, namely train data and test data. Linear regression analysis is carried out by studying the regression graph generated on the output data generated on machine learning. The linear regression equation is mathematically formulated as:

$$Y = a + bX \quad (1)$$

Y = Response Variable

a = constant

b = regression constant

X = Independent variable

Results and Discussion

ENSO and IOD affect variations in rainfall in Indonesia (Harrison, 1998; Strategy, 2011). Increases and decreases in the amount of rainfall will have an impact on the environment in the region. Rainfall that occurs in a prolonged period has the potential to cause flooding, while a decrease in the amount of rainfall for a long time can cause drought and has the potential to cause forest and land fires. To study this, the authors used sample data on the area of forest and land fires, as well as the number of floods in 2008 – 2020. Data on the area of forest and land fires was obtained from the website <https://sipongi.menlhk.go.id>, while data on the number of floods was obtained from website <https://gis.bnpb.go.id/>.

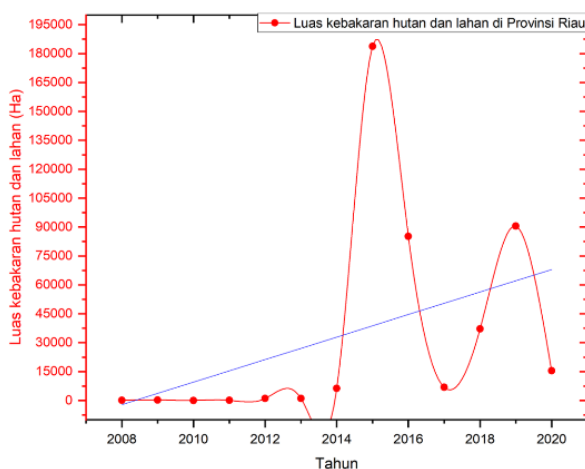


Figure 1 Graph of forest fire area in Riau Province

The author only uses forest and land fires data and the number of floods in the provinces of Riau and West Sumatra related to SM Japura and SM Minangkabau.

Meanwhile, data for the Riau Archipelago province area relating to SM Hang Nadim is not available, so it cannot be analyzed further. Based on the analysis carried out, data on the number of forest and land fires from the two provinces was obtained as shown in Figure 1.

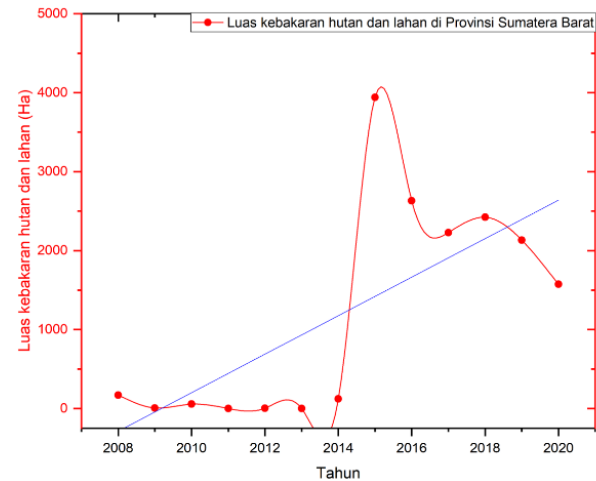


Figure 2 Graph of forest fire area in West Sumatra Province

Based on the results of data analysis, the two provinces experienced two peaks of forest fires. The main peak in both provinces occurred in 2015. Riau Province is the area with the highest fire area with an area of more than 180,000 hectares, and West Sumatra province with an area of 3,940 hectares. The second peak in Riau province occurred in 2019 with an area of 90,550 ha, while in the province of West Sumatra it occurred in 2018 with an area of 2,421 ha.

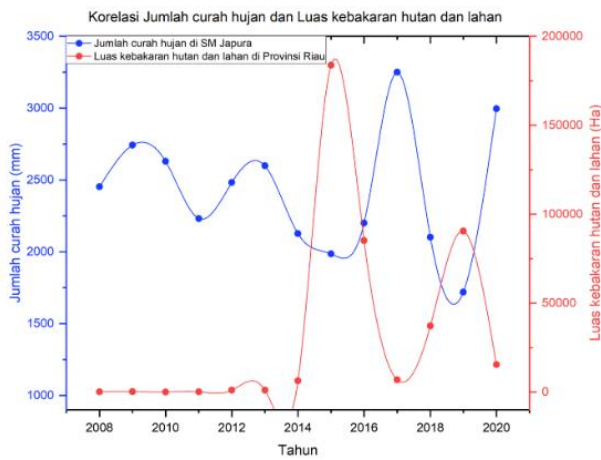
Table 2 Correlation analysis of the amount of rainfall and the area of forest fires

	Area of forest fires in Riau province	
	Significance level	Correlation coefficient
Total rainfall in SM Japura	0,015	-0,654
	Area of forest fires in West Sumatra province	
	Significance level	Correlation coefficient
Total rainfall in SM Minangkabau	0,464	-0,223

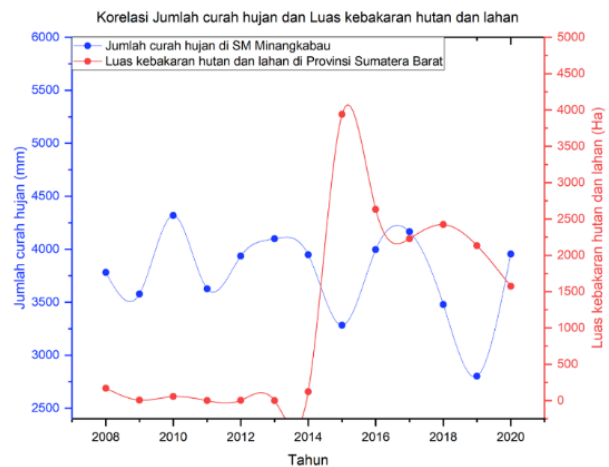
Based on the significance level guidelines in Table 2, it was found that the amount of rainfall in the Japura area has a relationship with the area of forest fires in the province of Riau, while the amount of rainfall in the Minangkabau area has no relationship with the area of forest fires in the province of West Sumatra. Meanwhile, based on the correlation coefficient guidelines in Table 1, the results show that the amount of rainfall in the Japura area has a strong relationship with the area of forest fires

in the province of Riau, while the amount of rainfall in the Minangkabau area has a low category relationship with the area of forest fires in the province of West Sumatra. Both

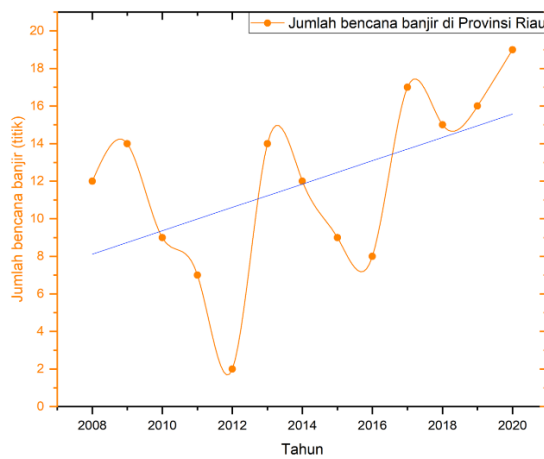
have a negative correlation relationship. This confirms that a decrease in the amount of rainfall causes an increase in the area of forest and land fires.



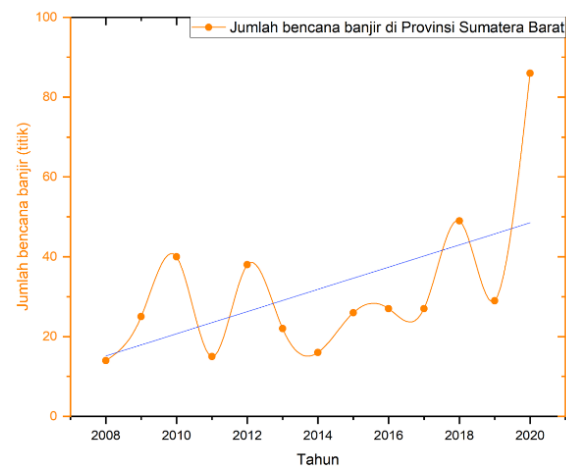
(a)



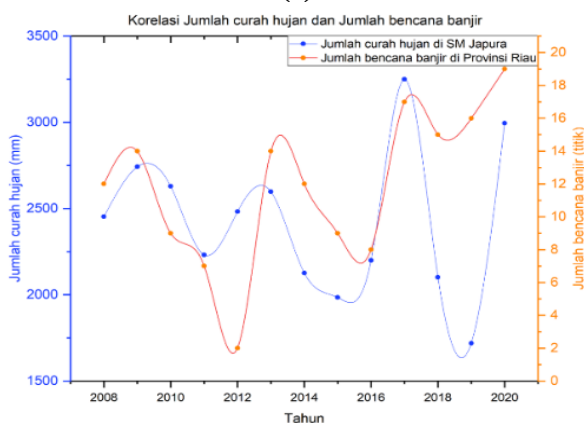
(b)



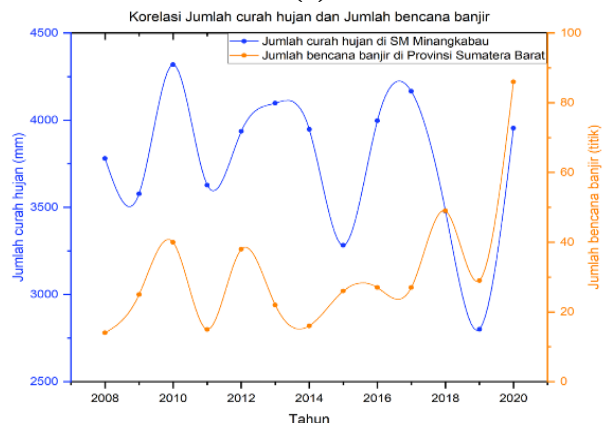
(c)



(d)



(e)



(f)

Figure 3 Correlations between the amount of rainfall and the area of forest and land fires in Riau Province (a) and West Sumatra Province (b). The numbers of flood events in Riau Province (c) and West Sumatra Province (d). Correlations of the amount of rainfall and flood disasters in Riau Province (e) and West Sumatra Province (f)

The results of an analysis of the number of flood disasters found an increasing trend in the provinces of Riau and West Sumatra. The two provinces had the highest number of flood disasters in 2020.

Based on the guidelines for the significance level in Table 3, the results show that the amount of rainfall in the Japura area has no relationship with the number of flood events in the province of Riau and the amount of rainfall in the

Minangkabau area has no relationship with the number of flood events in the province of West Sumatra. Meanwhile, based on the Correlation coefficient guidelines in Table 3, it was found that the amount of rainfall in Japura and Minangkabau BC had a very low category relationship to the number of flood events in Riau and West Sumatra provinces. Both seem to have a negative correlation. Based on the correlation analysis that has been carried out, an increase in the amount of rainfall is not always the cause of an increase in the number of floods in the provinces of Riau and West Sumatra.

To find out the causes of the increase in the number of floods, it is necessary to carry out further research by considering other factors, such as the condition of the waterways or drainage which plays a role in the flow of rainwater. In addition, the height factor also needs to be considered. Linear regression analysis was carried out using machine learning in the form of a regression algorithm with the Python programming language and run on Google Colab.

The results of the analysis obtained in the form of graphs and linear regression equations are shown in Figure 4a,b. Correlation analysis based on the criteria guidelines contained in Table 4 obtained the value of the correlation coefficient with the following criteria.

Table 3 Correlation analysis of the amount of rainfall and the number of floods in Riau Province and West Sumatra Province

	Number of floods in Riau province	
	Significance level	Correlation coefficient
Total rainfall in SM Japura	0.740	-0.102
	The number of floods in the province of West Sumatra	
	Significance level	Correlation coefficient
Total rainfall in SM Minangkabau	0.872	-0.050

The results of linear regression analysis using SPSS obtained regression equations and regression graphs. The results of the regression analysis for all variables produce a negative predictive trend. This confirms that an increase in the value of the Niño3.4 and DMI indices will lead to a decrease in the amount of rainfall. Conversely, a decrease in the Niño3.4 and DMI indices will cause an increase in the amount of rainfall. The linear regression graph between ENSO and the amount of rainfall can be seen in Figure 4c. Meanwhile, the linear regression graph between IOD and the amount of rainfall can be seen in Figure 4d.

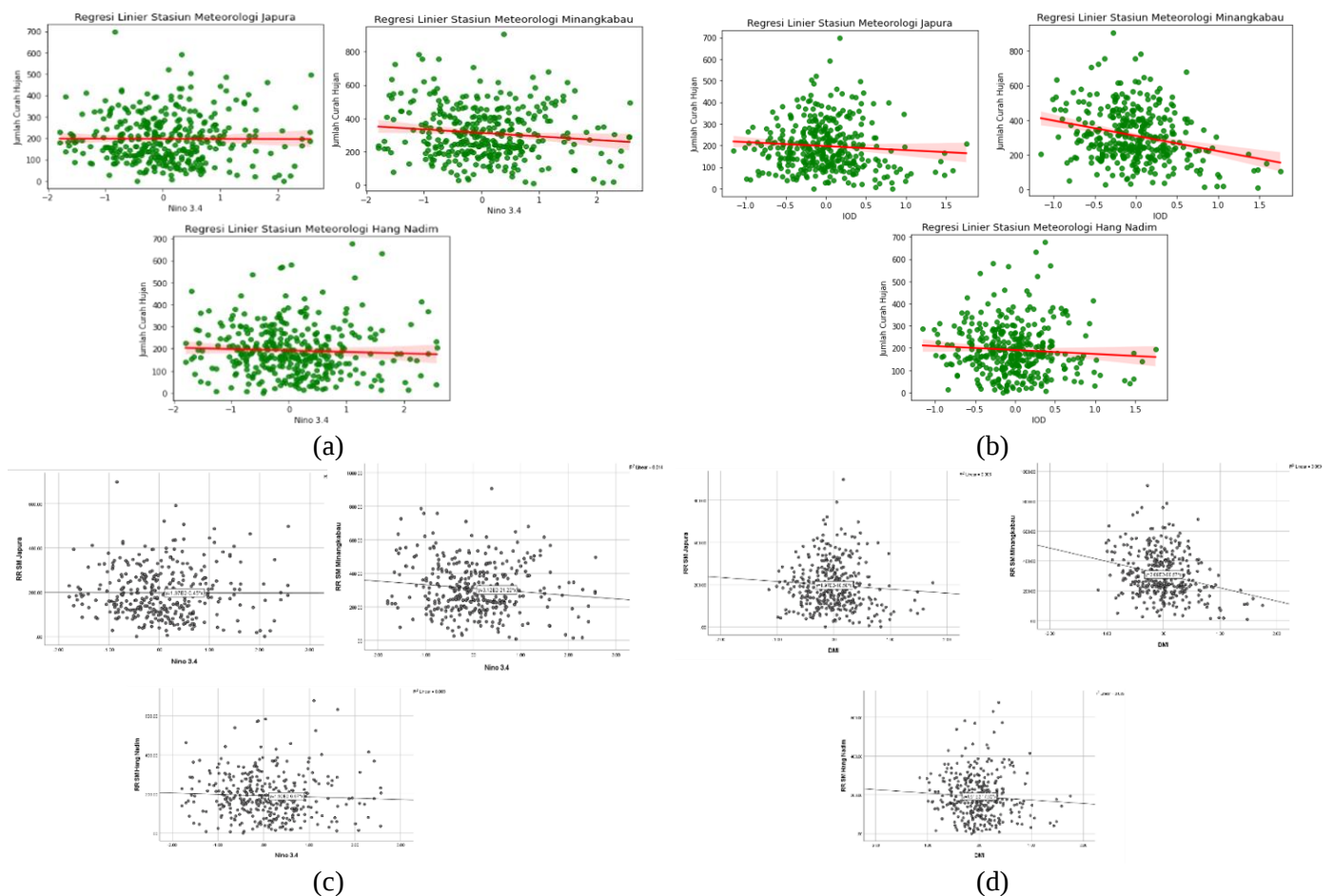


Figure 4 Linear regressions analysis of the Niño 3.4 index (a) and DMI index (b) on rainfall. Results of linear regressions of ENSO (c) and IOD (d) rainfall of SM Japura using SPSS

Table 4 Criteria for the results of correlation analysis using SPSS

	SM Japura	SM Minangkabau	SM Hang Nadim
Niño3.4	Very low	Very low	Very low
DMI	Very low	Low	Very low

Based on the normality test, correlation analysis, and linear regression analysis using SPSS, identical results were obtained with the results of the analysis carried out using python and google collab so that they showed the same research results. The difference is only seen in the value of the correlation coefficient and the regression equation, namely in the second decimal place after the comma. This is because python displays all decimal places, while SPSS is set to only display two decimal places, so SPSS will round up or round down. However, this did not have a significant effect on the results of the study.

Conclusion

Reducing the amount of annual rainfall is negatively correlated with increasing the number of forest fires per year. A decrease in the amount of rainfall can cause the number of forest fires to increase significantly. Machine learning-based rainfall analysis using google colab and python gives identical results to SPSS-based analysis, so the results of machine learning-based analysis have an accurate value.

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