AL-MARSHAD: JURNAL ASTRONOMI ISLAM DAN ILMU-ILMU BERKAITAN
ISSN 2442-5729 (print) || ISSN 2598-2559 (online)
http://jurnal.umsu.ac.id/index.php/almarshad
DOI: https://doi.org/10.30596/jam.v11i1.25129 || Vol. 11, No. 1 Juni 2025

The Impact of La Nina 2022 on Monthly Rainfall Variabillity in Papua

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Abstract

ENSO (El Nino Southern Oscillation) is a phenomenon of sea surface temperature (SST) deviation in the Central and Eastern equatorial Pacific Ocean (Nino 3.4). ENSO phase consists of two deviations, namely El Nino and La Nina. La Nina has an impact on increasing rainfall in the Nino 3.4 region. Indonesia, which is part of the Nino 3.4 region, is affected by La Nina in the JJA period (June July August). With research conducted in Eastern Indonesia, Papua in the 2022 La Nina period has varying results. Through four observation points namely Sorong, Enarotali, Jayapura and Merauke. The most affected area of La Nina 2022 is Sorong while for the area affected by ENSO activity during the 11 years of observation (2013-2023) is Merauke with a significance value of 0.000306429; 0.000943892; 5.13748E-05. As for the time most affected by La Nina 2022 and ENSO activity 11 years of observation is in the same month of August with a significance value for the Sorong region of 0.011474481; Enarotali 0.006271735; Jayapura 0.431875715; and Merauke 5.13748E-05.

Keywords: ***La Nina, Rainfall, ENSO, Spatial Analysis, Statistical Analysis***

Article Info
Received: 15 Juni 2025
Revised: 21 Juni 2025
Accepted: 26 Juni 2025
Published: 30 Juni 2025

A. Introduction

Indonesia's geography affects the occurrence of climate variability. One of the main factors affecting climate variability is ENSO (El Nino Southern Oscillation) [1]. ENSO is a global climate phenomenon caused by deviations in sea surface temperature (SST) in the Pacific Ocean region, especially the eastern and central equatorial parts [2]. The main phase of ENSO is divided into two, namely El Nino and La Nina. El Nino is an anomalous picture of warming sea surface temperatures in the Pacific Ocean. While La Nina is an anomalous picture of the Pacific Ocean sea surface temperature cooling [3].

In the La Nina phase, a decrease in sea surface temperature (STT) will affect the increase in pressure which allows the divergence of air mass currents. So theoretically these conditions will cause an increase in rainfall in the Nino 3.4 region (central and eastern Pacific Ocean) compared to the norm [3].

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Indonesia, which is included in the Nino 3.4 region, can certainly also receive impacts from ENSO, especially those related to rainfall variability. There are several previous studies that discuss the impact of La Nina. In the 2015-2021 vulnerability, La Nina in Eastern Indonesia caused a significant increase in rainfall in each monthly period that was different each year [4]. In Lesmana's 2024 research, El Nino and La Nina for Papua allow for different impacts for each region [5]. In other studies, La Nina in the 2020-2022 research period for the Northern Papua region had the impact of a significant increase in rainfall [6].

From some of the research above, it provides an opportunity for further research on the influence of La Nina on rainfall in Papua with a focus on monthly rainfall JJA (June July August) and the distribution of areas affected by La Nina 2022, through spatial and statistical approaches. The purpose of this study is to identify the distribution of areas in Papua affected by La Nina 2022, analyze changes in JJA monthly rainfall in the La Nina 2022 phase, and see the significant relationship of La Nina's influence in Papua

B. Method

This research was conducted in Papua with coordinates 129 oBT 143 oBT and -9.5 oLS 1 oLU. Papua is a region of Eastern Indonesia that has a unique topography and is adjacent to a warm pool that is suitable for measuring the significant influence of La Nina 2022. To support the analysis process, the observation location is divided into 4 observation points namely Sorong (132 oBT and -1 oLS) representing Southwest Papua, Enarotali (138.5 oBT and -4.6 oLS) representing Central Papua, Sentani, Jayapura (140.5 oBT and -2.5 oLS) and Merauke (140.4 oBT and -8.5 oLS) representing Southern Papua. The time that is the focus of research is the 2022 La Nina phenomenon with a range of observations from 2013-2023.

Figure 1. Distribution of research location points, point A Sorong, B Enarotali, C Sentani Jayapura , D Merauke.

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Research data obtained from CHIRPS rainfall satellite data. CHIRPS data (Climate Hazardz Group InfraRed Precipitation with Station), a rainfall data product developed by the hazardz team at the University of California, USA. The working system of CHIRPS is the merging of global climatology data, satellite and in situ observation data into a land rainfall database [7].

The research data processing was carried out using 3 approach methods, namely spatial analysis, temporal analysis and statistical analysis (regression). Spatial analysis is done by processing CHIRPS data using the Grads application to produce output in the form of rainfall distribution map modeling. To add to the impression in modeling, legend settings are needed, making it easier to analyze the model.

Temporal analysis was carried out with the help of Microsoft Excel application. By comparing monthly rainfall in the La Nina 2022 phase with the average rainfall of 11 years of observation per month, data on the percentage of La Nina 2022's influence on rainfall in 10 years of observation will be obtained. The results of the percentage can be seen as the month in the JJA period that is most affected by La Nina 2022.

Statistical analysis is used as a supporting analysis of the results of spatial analysis and temporal analysis. The form of statistical analysis used is regression analysis. This analysis uses two variables, namely the independent and dependent variables. Where the independent variable is the Nino 3.4 index data and the dependent variable is rainfall data. With the regression analysis of the two variables, the results of the significant level of influence of La Nina 2022 on monthly rainfall variability will be obtained.

C. Results and Discussion

Ocean Nino Index (ONI) data shows that in 2022 the Nino 3.4 region was affected by the La Nina phase throughout the year, where the Sea Surface Temperature (SST) in the Nino 3.4 region was below -5 °C [8]. The decrease in sea surface temperature (STT) in tropical Pacific Ocean, central and eastern parts affects the direction of thade winds. In the state of decreasing SST, the trade winds will blow stronger to the west, so that warm water from the Pacific Ocean will accumulate in the west. The accumulation of warm water in the west causes higher evaporation of sea water in the region , and many clouds will form. This affects the occurrence of higher rainfall.

That way, the Indonesian region which is in the western part of the tropical Pacific Ocean will certainly experience increased rainfall during the La Nina phase. To see the influence of La Nina 2022, it will be easy to read when that phase occurs during the dry season. During the dry season of course the intensity of rainfall is quite small but with the impact of La Nina, of course the increase in rainfall will be seen more clearly. Thus, the research data used is the monthly rainfall data for JJA (June, July, August), which is usually the start of the dry season to the peak of the dry season.

Spatial Analysis

Rainfall in June 2022 in Papua began to appear and spread in the West. As for the eastern part, Jayapura is relatively unaffected by La Nina. In other words, the rainfall

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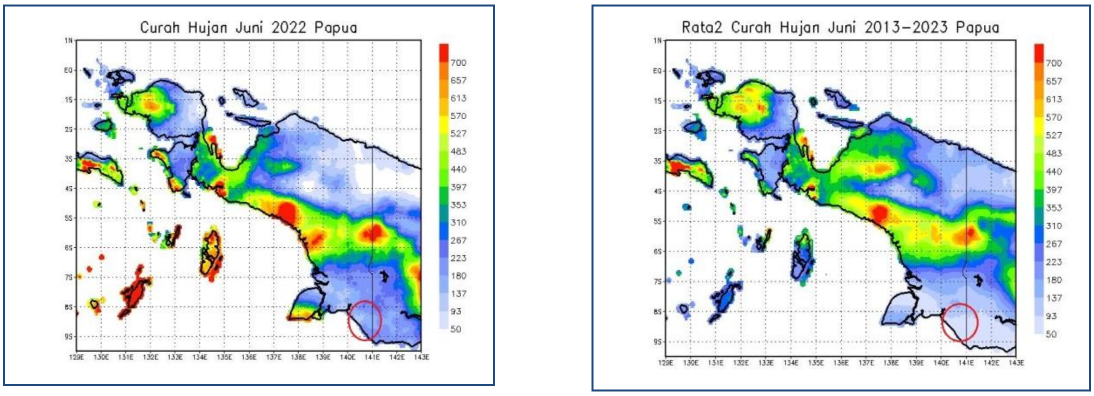
intensity in the Jayapura area is still below 50ml during the June La Nina 2022 period (Fig.2(a)).



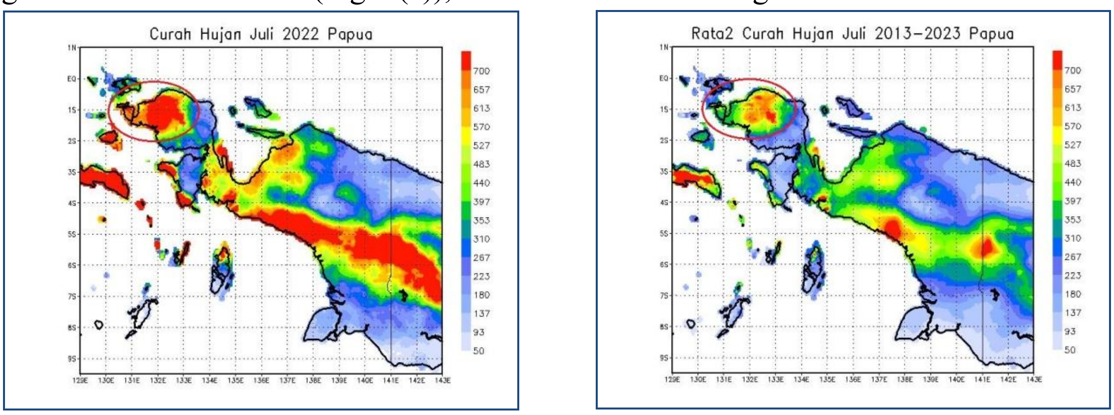
(a) (b)

Figure 2. (a) Rainfall distribution of June 2022. (b) Distribution of Rainfall Average research time 2013-2023 June, made with Grads.

Comparison that can be seen from (Fig.2) the regional distribution for the Merauke observation point (circled area) the intensity of the increase in rainfall in the La Nina phase 2022 in June increased significantly compared to the average of the last 11 years. Where at that point, the average rainfall of the last 11 years is quite low, in the range of 50-93 milliliters. Whereas in La Nina 2022, rainfall in Merauke is in the range of 180-223 milliliters. The Merauke area is marked with a red circle line on Fig. 2.

In contrast to other observation points, the distribution of rainfall intensity can be said to be high, marked by green and red images. However, in terms of influence, La Nina does not have a major impact on increasing rainfall.

As for July rainfall intensity, La Nina 2022 appears to have begun to have an impact on increasing rainfall intensity for Papua at large. For the Sorong observation point, the increase in 2022 rainfall intensity compared to the 11-year average observation time is clearly visible. By 2022, the Sorong and surrounding areas will have rainfall in the range above 700 milliliters (Fig. 3(a)), marked with the Sorong observation zone in red.



(a) (b)

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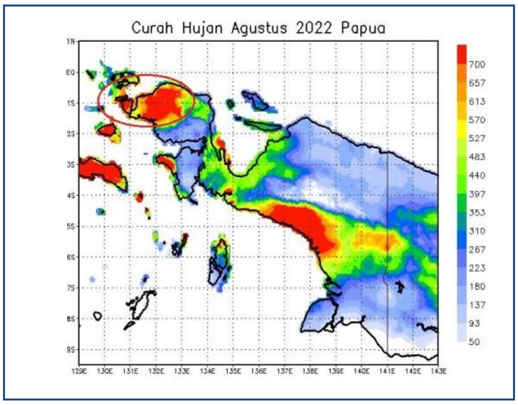
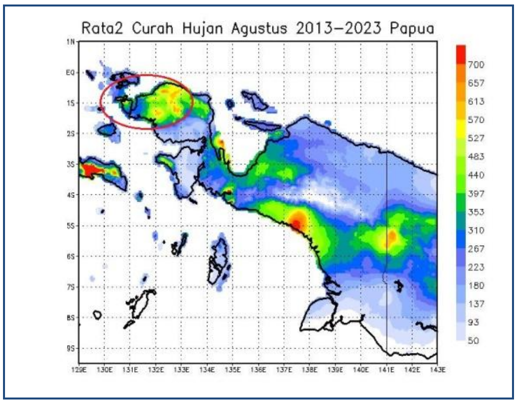
Figure 3. (a) Rainfall Distribution in July 2022. (b) Average rainfall distribution over the study period (2013-2023) in July, made with Grads.

The average intensity of rainfall for the 11 years of the study is still in the range of 570 milliliters (Fig. 3(b)), which is marked with an orange color. Of course, it gives a picture of the Sorong region and around La Nina 2022 increasing the July rainfall increase to more than 700 milliliters (Fig. 3(a)). Beside the Fig. 3, point of regional observation Sorong had marked with red circle.

Similar to July, in August La Nina 2022 also had the most impact on increasing the intensity of rainfall in the Sorong and surrounding observation areas (Fig. 4(a)). The increase in rainfall is marked in red indicating an intensity of more than 700 milliliters in August 2022. The average rainfall for the 11 years of observation is arguably higher than the other observation points, at 440-613 milliliters (Fig. 4(b)). As for other observation points, the comparison of rainfall in August 2022 and August on average 11 years of observation time looks quite stable, not showing a large increase in rainfall



(a)



(b)

Figure 4. (a) Rainfall Distribution in August 2022. (b) Average rainfall distribution over the study period (2013-2023) in August, made with Grads.

In general, the area affected by La Nina 2022 and the average rainfall of 11 years of observation is not greater than the rainfall intensity in July. In August, the distribution of La Nina affected areas is dominant in the Southwest to South Papua, can be seen in the circled area.

The distribution of areas affected by La Nina 2022 can be seen through the percentage increase in rainfall when La Nina 2022 occurs. The percentage is obtained from comparing the amount of rainfall affected by La Nina 2022 with the average rainfall of 11 years of observation (2013-2023).

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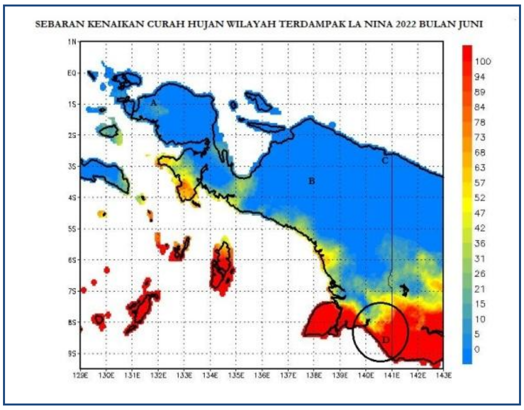

Figure 5. Percentage distribution of the impact of La Nina 2022 in June in Papua, made with Grads .

Of the four observation points (Fig. 5), La Nina 2022 is seen to have an impact only on the Merauke observation point (D) in June, marked by the red color distribution. Meanwhile, Sorong (A), Enarotali (B) and Jayapura (C) did not show any increase in rainfall, as seen from the blue distribution percentage. Where the blue color means an increase in rainfall of 0-5 percent only.

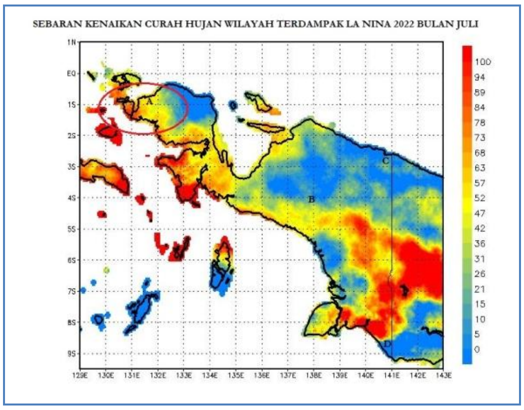

Figure 6. Percentage distribution of the impact of La Nina 2022 in July in Papua, made with Grads.

Sorong (A) is the observation point most affected by La Nina 2022 (Fig. 6) in July. In July, Sorong had a percentage increase above 57 percent. As for points B and D, the percentage increase in rainfall is in the surrounding area. In contrast to point C, Jayapura and surrounding areas have not experienced an increase in rainfall in July 2022. Areas that have a high percentage increase in rainfall are marked in Figure 6 with circles.

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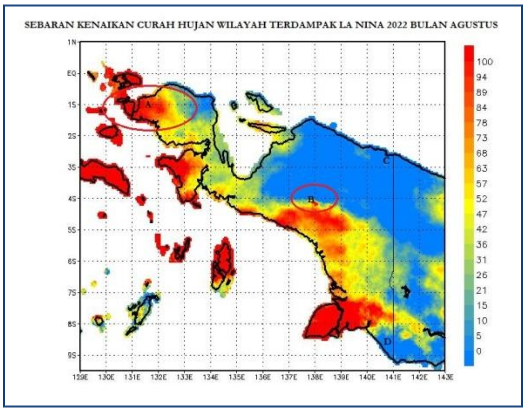

Figure 7. Percentage distribution of the impact of La Nina 2022 in August in Papua, made with Grads

Based on the regional distribution in Figure 7, there are two observation points that experienced an increase in rainfall in August 2022 due to the impact of La Nina, namely A and B (Sorong and Enarotali). Both points experienced an increase in rainfall from the range of 56-100 percent. As for point C (Jayapura), until August it is still not affected by La Nina which causes an increase in rainfall. Similar to Jayapura, Merauke also did not experience an increase in rainfall in August 2022

Temporal Analysis

Spatial Analysis has shown which observation points are affected by La Nina 2022. With Temporal Analysis, it will be known which months are most affected by La Nina 2022 activity, complete with calculations of the exact data. Based on Graph 1. A shows the Sorong Observation point, B the Enarotali observation point, C the Jayapura observation point and D the Merauke observation point. The highest percentage of the impact of La Nina 2022 on rainfall in June is at 148%, namely in the Merauke area (D). And the lowest percentage in June is at the Jayapura observation point, with a percentage of -62%. The minus value in the percentage means that if the rainfall in June during the La Nina 2022 phase is still below the average rainfall for 11 years of observation. Graph 1. Percentage of the influence of La Nina 2022 on Rainfall in Papua.

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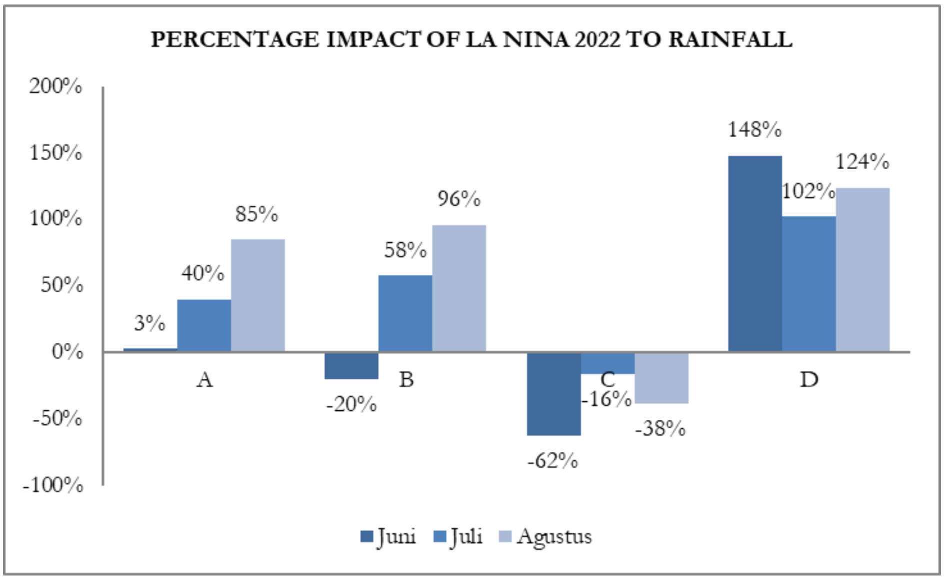

Figure 8. Graph Impact of La Nina to Rainfall, made with Excel

In July, the percentage increase in rainfall was found at 3 observation points, namely in Sorong (A) with an increase of 40%, Enarotali (B) 58% and the highest was at the Merauke observation point (D) 102%. Meanwhile, for the Jayapura point (C), the rainfall intensity was still below the average rainfall in July for 11 years of observation. August 2022 was the highest percentage increase in rainfall in the JJA period (Table 1). With 3 observation points experiencing an increase in rainfall above 80%. The highest percentage was still in the Merauke area with a value of 124% and the lowest at the Jayapura point, -38%.

Table 1. Percentage of the Influence of La Nina 2022 in Papua.

	A	B	C	D	Average
June	3%	-20%	-62%	148%	17%
July	40%	58%	-16%	102%	71%
August	85%	96%	-38%	124%	105%

Statistical Analysis

The calculation of statistical data is done by finding the *r* value and *p-value*. In this study, the *r* and *p-value* values were obtained from two variable data, namely CHIRPS rainfall data and Nino Index 3.4 data.

Table 2. Nino Index Value 3.4 Years 2013-2023.

	June	July	August
2013	- 0.4	- 0.4	- 0.3
2014	0.2	0	0.1
2015	**1,2**	**1,5**	**1,9**
2016	- 0.1	- 0.4	**- 0.5**
2017	0.3	0.1	- 0.1

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2018	0	0.1	0.2
2019	**0.5**	0.3	0.1
2020	- 0.3	- 0.4	**- 0.6**
2021	- 0.4	- 0.4	**- 0.5**
2022	**- 0.9**	**- 0.8**	**- 0.9**
2023	**0.8**	**1,1**	**1,3**

The red color on the index value means the occurrence of the El Nino phase for the area around Nino 3.4, the black color illustrates the condition of the Nino 3.4 area in a neutral state, while the blue value indicates the occurrence of La Nina activity [8]. With that, in 2022 the JJA period, Indonesia experienced the La Nina phase(on the table 2, can be highlight green). Data processing Table 2 with CHIRPS rainfall will obtain results in the form of *r* and *p-value*s. These results can be used to identify the correlation and significance of rainfall for 11 years of observation time with Nino 3.4 data.

Table 3. Interpretation Value *r*

Interval nilai *r*	Interpretasi *r*
$0 \leq r < 0.2$	Very Weak
$0.2 \leq r < 0.4$	Weak
$0.4 \leq r < 0.6$	Intermediate
$0.6 \leq r < 0.8$	Strong
$0.8 \leq r \leq 1$	Very Strong

Tabel 4. Interpretation *p-value*

Interpretasi *p-value*	Interpretasi *p-value*
$p < 0.05$	Significant
$p \geq 0.05$	Not Significant

By referring to the interpretation value *r* and *p-value*, the results of the statistical analysis can be obtained on the significance of JJA rainfall on the Nino Index. Table 5. Results of ANOVA Statistical.

Table 5. Analysis Result with Anova Statistical

SORONG				
	R square	*p-value*	Interpretation *R*	Interpretation *p*
June	0.025902	0.696017936	Very Weak	Not Significant
July	0.598948	0.005798455	Intermediate	Significant
August	0.548447	0.011474481	Intermediate	Significant
ENAROTALI				
	R square	*p-value*	Interpretation *R*	Interpretation *p*
June	0.000219	0.875457192	Very Weak	Not Significant
July	0.001098	0.053634546	Very Weak	Not Significant
August	0.601730	0.006271735	Strong	Significant

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JAYAPURA				
	R square	*p-value*	Interpretation *R*	Interpretation *p*
June	0.023561	0.762265131	Very Weak	Not Significant
July	0.004503	0.919231518	Very Weak	Not Significant
August	0.096187	0.431875715	Very Weak	Not Significant
MERAUKE				
	R square	*p-value*	Interpretation *R*	Interpretation *p*
June	0.480822	0.000306429	Intermediate	Significant
July	0.029948	0.000943892	Very Weak	Significant
August	0.325367	5,13748E-05	Weak	Significant

This statistical analysis provides an overview of the significance of the relationship between the Nino 3.4 index and monthly rainfall data for 11 years of observation (2013-2023). The area with the highest significance during the JJA period is at the Merauke observation point, with significance values of 0.00306439; 0.000943892; and 0.000051374 indicating that the value is at an interval of less than 0.05. So the Merauke area shows a high level of significance. It is different again for the Jayapura observation point, during the 11 years of observation, ENSO did not have a significant impact on the area. Where the *p-value* for the Jayapura area during the JJA period is at 0.762265131; 0.91923158; and 0.431875715. Of course, these values are at an interval of more than 0.005, so the Jayapura area is very unaffected by ENSO.

In contrast to the two observation points of Enarotali and Sorong, the JJA period was not affected as a whole. The Sorong area and its surroundings were affected in July and August with *p-value*s of 0.005798455 and 0.011474481. Meanwhile, for the Enarotali area, August was the only month affected by ENSO activity, as evidenced by a *p-value* of 0.006271735.

The relationship between *r* and *p-value* is when the *r* value is at a minimum of 0.2 or low representation, then the *p-value* is in the interval less than 0.05 which at that interval begins to have a significant impact. With this statistical analysis, it can be seen that ENSO including La Nina has a variational impact on rainfall in the Papua region. The observation point that was most affected during the 11 years of observation was in the South Papua region, Merauke. While the most impacted month in the JJA period was in August. The results of the statistical analysis proved that overall for the 11 years of observation time it was related to ENSO activity on rainfall, while the spatial and temporal analysis focused on the influence of La Nina 2022. So that the results of the months affected in the JJA period were generally still the same, namely in August, but for the most affected area based on the spatial analysis of La Nina 2022, Sorong was the observation point with the highest impact. However, in statistical analysis, the 11 years of observation time were in the Merauke area.

The study also showed variations in the influence of La Nina 2022 on JJA rainfall. Not all areas in Papua were significantly affected by La Nina 2022 in the JJA period.

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Several other factors cause variations in the distribution of the influence of La Nina 2022 on increasing rainfall in each region [9]. Factors that influence this variation include regional morphology and local seasons [3], [6]. Papua itself has various types of seasonal zones (ZOM), the Southwest Papua Region, especially Sorong, has high rainfall because this region has a monsoon season 1, which in this season, throughout the year will experience rain and there is one peak of rain. So that the intensity of rainfall in the region is high [9], besides that, what makes it possible in the La Nina 2022 phase in Sorong to experience a high increase in rainfall intensity is the presence of a warm pool around the waters of Sorong. Meanwhile, the Jayapura, Enarotali and Merauke regions are regions with local season zone (ZOM) 1. Local season 1 has a different rainfall pattern from the seasons in general [9]. So that in the JJA La Nina 2022 period, there is a strong influence of local season 1 on Jayapura which causes low rainfall variability.

D. Conclusion

La Nina 2022 has a varied impact on rainfall in Papua. In terms of spatial analysis, the influence of La Nina 2022 in Southwest Papua, with the Sorong observation point, is higher than the other four observation points. This is indicated by the spatial distribution of the percentage of rainfall in 2022 in Papua for the Sorong area and its surroundings in red. Meanwhile, through temporal analysis, the intensity of rainfall during the La Nina 2022 phase experienced a significant average increase in August with a value of 105%. This value is obtained by comparing the average increase in rainfall at four observation points. When compared with the statistical analysis that calculates the significance value of the influence of ENSO activity for 11 years of observation (2013-2023), the area affected by the increase in rainfall is in the Merauke area with a *p-value* of 0.000306429; 0.000943892; 5.13748E-05. The difference is caused by several factors that affect the variation of rainfall patterns in 2022, the JJA period is stronger by its local season. Meanwhile, the time most affected by ENSO activity in 11 years of observation and La Nina 2022, is at the same time, namely in August with *p-value*s in sequence from Sorong, Enarotali, Jayapura, and Merauke: 0.011474481; 0.006271735; 0.431875715; 5.13748E-05. For the Jayapura area, it does not show significance.

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