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Rainfall distribution patterns in South Sulawesi during the El Niño and La Niña periods 1995-2020

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सार – दक्षिण सुलावेसी, अपनी विविधतापूर्ण भौगोलिक स्थिति और जलवायु के कारण, वर्षा में उतार-चढ़ाव का अनुभव करता है जिसका कृषि क्षेत्र और लोगों के जीवन पर महत्वपूर्ण प्रभाव पड़ सकता है। इस क्षेत्र में वर्षा के पैटर्न को प्रभावित करने वाला मुख्य कारक दक्षिणी नीनो दोलन (ENSO) जलवायु घटना है, विशेष रूप से ला नीना और अल नीनो। इस अध्ययन का उद्देश्य 1995-2020 की अवधि के दौरान दक्षिण सुलावेसी में वर्षा के वितरण पैटर्न का विश्लेषण करना है, जिसमें अल नीनो और ला नीना घटनाओं की उपस्थिति पर विशेष ध्यान दिया गया है। वितरण पैटर्न और वर्षा की अनियमितताओं का वर्णनात्मक विश्लेषण किया गया। विश्लेषण के परिणामों के आधार पर पश्चिमी, मध्य और पूर्वी क्षेत्रों के बीच उल्लेखनीय भिन्नता दिखाई देती है। दिसंबर-फरवरी में, पश्चिमी क्षेत्र में वर्षा अधिक होती है, जबकि पूर्वी और मध्य क्षेत्रों में कम होती है। जनवरी में वर्षा अपने चरम पर होती है। मार्च-मई में, पूर्वी क्षेत्र में वर्षा बढ़ जाती है जबकि पश्चिमी और मध्य क्षेत्रों में घट जाती है। जून-अगस्त में सभी क्षेत्रों में वर्षा में कमी आती है, जो शुष्क मौसम का संकेत है। अक्टूबर-नवंबर में वर्षा बढ़ने लगती है। सितंबर में ला नीना का प्रभाव अलग-अलग रूप में देखा जाता है। कमजोर ला नीना के दौरान, पश्चिमी क्षेत्र में आंशिक रूप से अधिक वर्षा होती है, जबकि पूर्वी और मध्य क्षेत्र स्थिर रहते हैं। मध्यम ला नीना के दौरान, पश्चिमी, मध्य और पूर्वी क्षेत्र स्थिर रहते हैं। जब ला नीना मजबूत होता है, तो इसका पूरे दक्षिण सुलावेसी क्षेत्र पर महत्वपूर्ण प्रभाव पड़ता है। जुलाई में, कमजोर अल नीनो का वर्षा पर प्रभाव सभी क्षेत्रों में मजबूत होता है, जबकि मध्यम और मजबूत अल नीनो के दौरान इसका कोई खास प्रभाव नहीं होता है।

ABSTRACT. South Sulawesi, with its diverse geography and climate, experiences fluctuations in rainfall that can have a significant impact on the agricultural sector and people's lives. The main factor affecting rainfall patterns in this region is the El Niño Southern Oscillation (ENSO) climate phenomenon, namely La Niña and El Niño. This study aims to analyze the distribution pattern of rainfall in South Sulawesi during the period 1995-2020 with a focus on the occurrence of El Niño and La Niña phenomena. The determination of distribution patterns and rainfall anomalies was analyzed descriptively. Based on the results of the analysis shows a striking variation between the western, central and eastern regions. In December-February, rainfall in the western region is high, while the eastern and central regions are low. Peak rainfall occurs in January. In March-May, the eastern region has increased rainfall while the western and central regions have decreased. In June-August there is a decrease in rainfall in all regions, indicating a dry season. In October-November rainfall begins to increase. The influence of La Niña is seen in September, with varying impacts. During weak La Niña, the western region partly experiences increased rainfall, while the western region is stable and the eastern and central regions are stable. During moderate La Niña, the western, central and eastern regions are stable. When La Niña is strong, it has a significant effect on the entire South Sulawesi region. In July, the effect of weak El Niño on rainfall is strong in all regions, while during moderate and strong El Niño, there is no significant impact.

Key words – Rainfall, El Niño, La Niña, Oceanic nino index.

1. Introduction

South Sulawesi is a geographically and climatically diverse region. Rainfall in this area plays an important role in determining agricultural productivity, water availability and overall ecosystem balance. However, rainfall in this region is not always stable, and often experiences fluctuations that can affect the agricultural sector and people's lives. (Heryani *et al*., 2020; Qudriyah *et al*., 2022).

One factor that has a significant impact on rainfall in the South Sulawesi region is a natural phenomenon known as ENSO (*El Nino Southern Oscillation)*. ENSO is a natural phenomenon that occurs in the Equatorial region of the Pacific Ocean which causes Global climate anomalies (Alizadeh, 2022; Latif & Keenlyside, 2009; Trenberth, K. E., & Caron, 2000). ENSO will affect meteo-oseanographic conditions, namely rainfall conditions on land and sea, sea surface temperature, and sea level. Positive or rising sea level changes will cause seawater intrusion into surface water and sinking of a number of coastal areas so that it can damage coastal facilities such as port areas, settlements, and commercial areas (Barnston *et al*., 2012; Bastianin *et al*., 2016; Handoko *et al*., 2019).

The ENSO phenomenon is known as El Nino and La Nina. El Nino and La Nina are conditions that arise due to interactions between the atmosphere and the ocean under the influence of solar control. This interaction between the atmosphere and the ocean is indicated by an increase or decrease in sea surface temperature (SST) that exceeds its climatological temperature, causing anomalies (Ryadi *et al*., 2019).

In a study conducted by Sarvina who analyzed the impact of ENSO on rainfall characteristics in several regions in the Papua Islands namely Merauke, Jayapura, Manokwari, and Wamena. The results of her analysis show that the characteristics of rainfall in the area are influenced by ENSO with different influences between regions. In general, the rainy season comes earlier in La Nina years compared to normal years and the dry season comes earlier in El-Niño years. Annual rainfall in La-Nina years is higher than normal years and El-Nino years are lower than normal years. Sarvina continued that ENSO extreme phases, have significant impacts on all sectors including agriculture, marine, fisheries, health, forest fires, *etc*. (Sarvina, 2023)

El Nino occurs when sea surface temperatures in the eastern Pacific Ocean increase, but temperatures in the western Pacific Ocean and around Indonesia experience a decrease (deviation) so that rainfall decreases (Handoko *et al*., 2019). The impact of El Nino on the weather in Indonesia is to trigger drought or long drought which can cause problems in the agricultural sector experiencing crop failure (Rosmiati *et al*., 2023).

La Nina is the opposite phenomenon to El Nino. La Nina occurs when sea surface temperatures decrease or cool down. As a result, cloud formation in the Pacific Ocean is minimized, resulting in increased rainfall in the Indonesian region (Supari *et al*., 2018). When La Nina occurs, Indonesians need to increase their vigilance as this phenomenon can cause heavy rainfall, potentially resulting in floods, strong winds and landslides (Ditta *et al*., 2023; Hoyos *et al*., 2013).

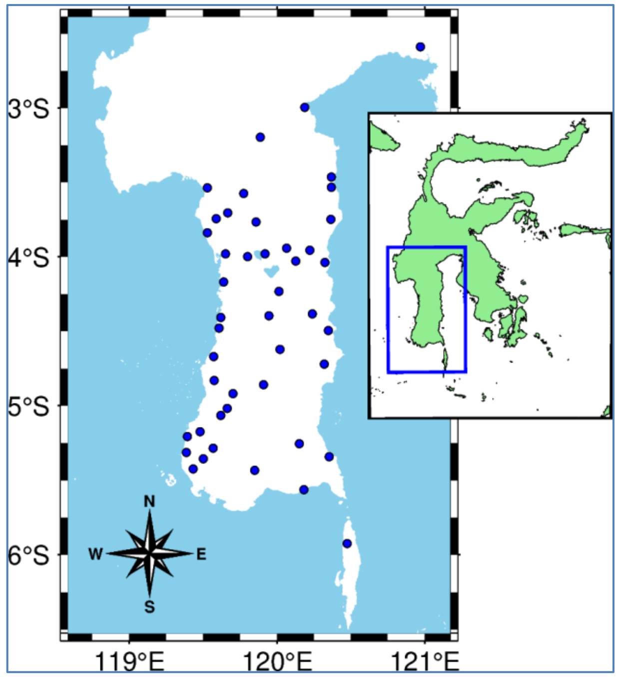


Fig. 1. Map of rain post distribution patterns and research locations

2. Data and methodology

The data used in this study are Nino 3.4 index data, and rainfall data from 1995-2020. Nino 3.4 index data was obtained from the website www.bom.gov.au, while rainfall data was obtained from the Meteorology, Climatology and Geophysics Agency, Maros Class 1 Climatology Station. The data is in the form of monthly rainfall data for 25 years from 1995-2020 in South Sulawesi.

Rainfall data is converted into the form of rainfall anomalies, by performing monthly calculations to understand the characteristics of rain in a region over a period of time. Rainfall anomaly is the difference between the observed value of rainfall in a particular month and the average value of rainfall during the same month. The calculation of rainfall data anomalies is done using the following formula:

$$Rainfall\ Anomalies = \frac{X - X_0}{X_0}\ X\ 100\ \%$$

where: X = Average rainfall during La Niña and El Niño events, X_0= Monthly average rainfall over the period 1995-2020 (Wicaksono, 2022).

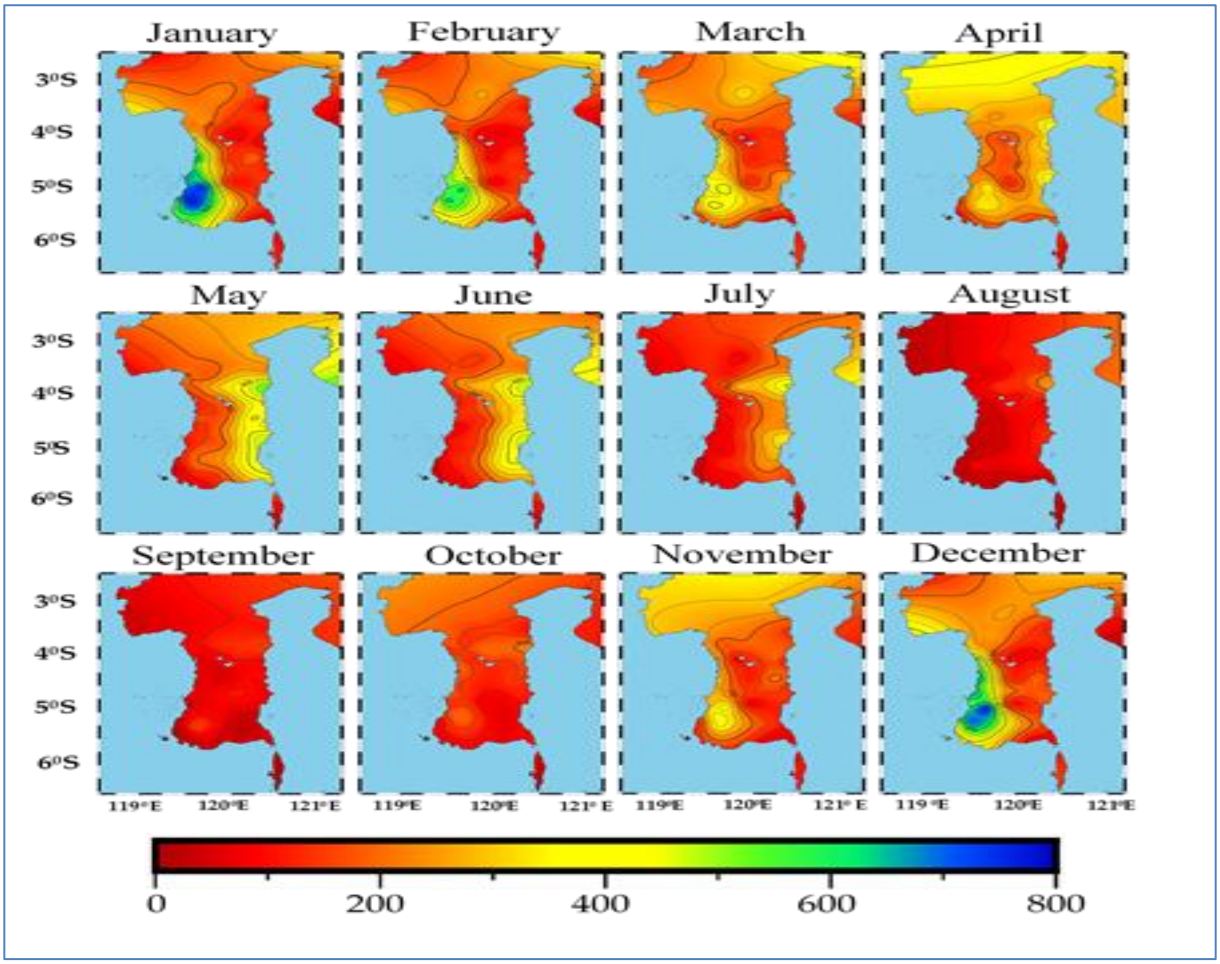


Fig. 2. Spatial pattern map of monthly rainfall of South Sulawesi in 1995-2020

3. Results and discussion

3.1. *Spatial Pattern of Monthly Rainfall in South Sulawesi*

Fig. 2, shows that the results of the analysis of the spatial distribution of monthly rainfall in the South Sulawesi region vary in each month. During December, January, February (DJF) in South Sulawesi, there are different rainfall patterns between the western, central and eastern regions. From December to February, the western region experiences high rainfall intensity, reaching its peak in January. In contrast, the eastern and central regions experience a decrease in rainfall. In February, there is a decrease in rainfall in the western region. During DJF, the northwest monsoon brings water vapor from the Sulawesi Sea to the western region, causing high rainfall in this region.

Entering March, April, May (MAM), from March to May, the rainfall trend in the eastern region shows an increase in March. In the western part of the region, there is a decrease in rainfall followed by the central part and parts of the eastern region. In April and May, the eastern region experienced a decrease in rainfall, while in the western region there was an insignificant increase, and in the central region there was a decrease in rainfall. Changes in sea surface temperature in MAM can stimulate rain cloud formation in the eastern region, while parts of the western region experience a decrease in rainfall due to lower temperatures.

Global climate variability such as El Niño and La Niña also play an important role. El Niño events can cause a decrease in rainfall across South Sulawesi, while La Niña has the opposite effect. Topographical factors, particularly the presence of mountains in the central region, influence the distribution of rainfall through orographic phenomena. Tropical cyclones in DJF also contribute to rainfall intensity in the western region.

June, July and August (JJA) saw a decrease in rainfall across the eastern, western and central regions. This pattern reflects the dry period generally experienced

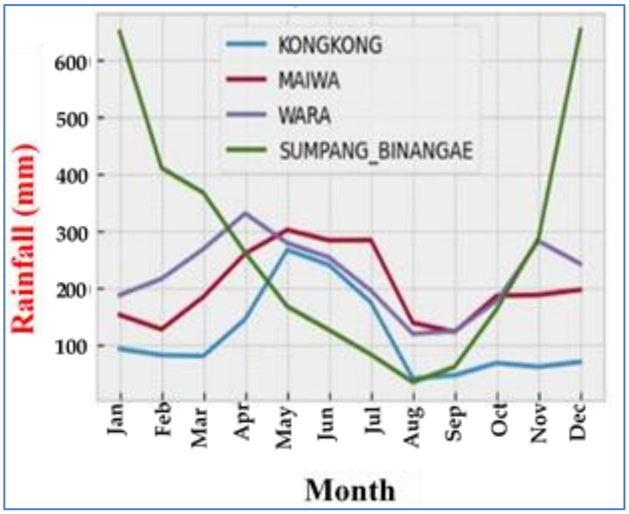
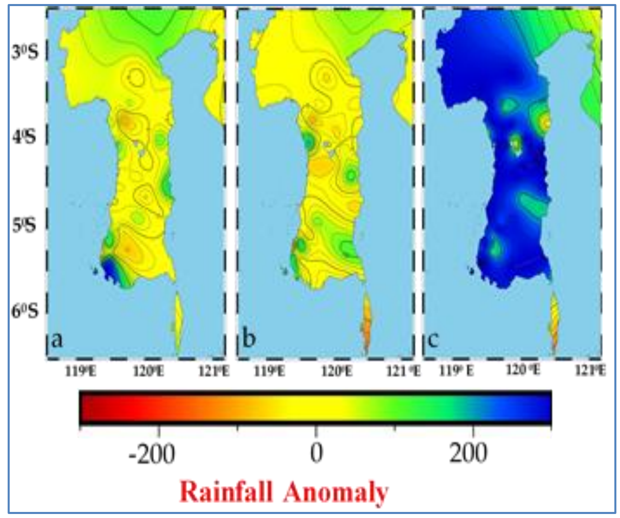


Fig. 3. Temporal pattern of monthly average rainfall



Figs. 4(a-c). Percentage of La Niña anomalies: a) Weak, b) Moderate, c) Strong, in September 1995-2020

in the region. During the JJA season, there is a decrease in rainfall throughout South Sulawesi, influenced by changes in wind patterns and air circulation.

Entering September, October, November (SON), September saw a dry spell across the eastern, western and central regions. October and November saw an insignificant increase in rainfall, these changes did not create a noticeable impact in overall weather conditions.
Based on the graph in Fig. 3, it shows that the temporal pattern of rainfall at several observation stations in South Sulawesi illustrates interesting variations throughout the year, which are influenced by a number of complex factors. To represent the western, central and eastern parts of South Sulawesi, four stations were selected from a total of 45 stations. First, Kongkong Station located in Bulukumba Regency and Wara Station in Palopo City were chosen to represent eastern South Sulawesi. Meanwhile, Sumpa Binange Station located in Barru Regency represents the western region, while Maiwa Station in Endrekang represents the central region. With this selection, each station has a strategic role in covering and representing the conditions and needs of that part of the region.

Kongkong station shows peak rainfall in May, followed by a significant decline until August. In October, the station again experiences peak rainfall. Factors influencing this pattern involve seasonal changes and monsoon wind patterns, where May tends to be the peak of the rainy season, while August generally marks the beginning of the dry season. The increase in rainfall in October is attributed to changes in monsoon patterns or other regional climatic factors.

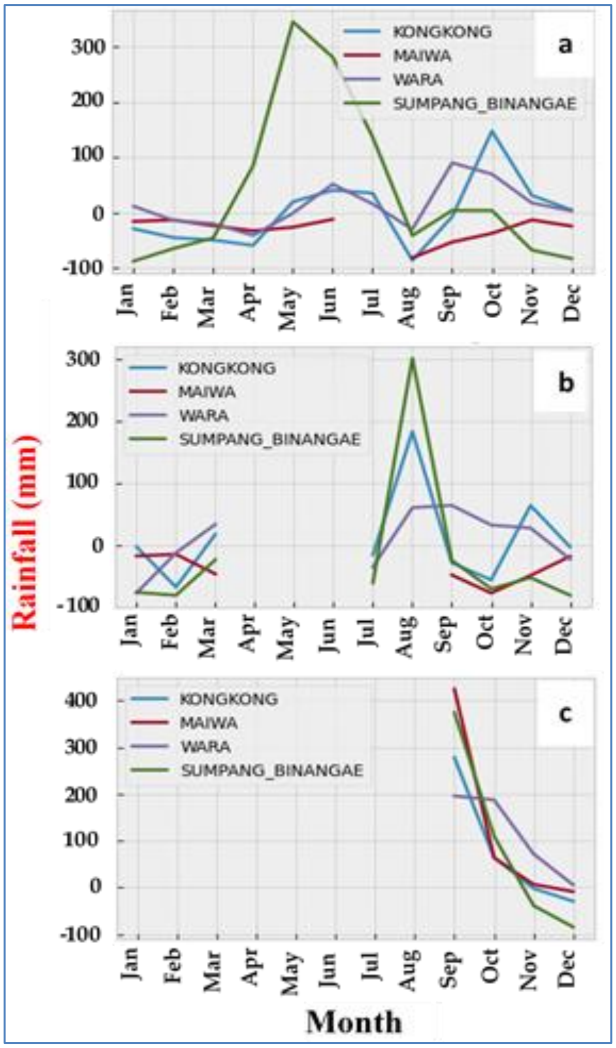
Maiwa Station, experienced peak rainfall in May, but experienced a significant decrease in September. Peak rainfall again occurs in December. This variability is influenced by seasonal changes and global climate influences, with September marking the transition between the wet and dry seasons, while December being the start of the next rainy period. Wara station shows a peak in rainfall in April, followed by a significant decrease in August. Rainfall peaks again in November. Factors such as changes in sea surface temperature, monsoon patterns, and global climate variability may influence this pattern, with April and November being periods more influenced by regional or global climate phenomena.

Sumpang Binange Station experiences peak rainfall in January, followed by a decrease in August, and a peak again in December. These factors can be attributed to seasonal changes, tropical cyclone patterns and global climate variability that can affect rainfall in the region. Overall, the temporal patterns of rainfall at each station reflect the complexity of interactions between local and global climate factors.

3.2. *Percentage of Monthly Rainfall Anomalies due to La Nina Phenomenon for the Period 1995-2020*

Figs. 4(a-c) shows the occurrence of the La Nina phenomenon (Weak, Moderate and Strong) on monthly rainfall anomalies in South Sulawesi with a representative month of September.

Based on Fig. 4, in September in South Sulawesi, the La Niña phenomenon plays a key role in regulating the



Figs. 5(a-c). Graph of La Nina Anomalies: a) Weak, b) Moderate, c) Strong in September periode 1995-2020

pattern of monthly rainfall anomalies, and its influence varies depending on the strength of the La Niña. Under weak La Niña conditions, the western region, particularly the Patalasang station, recorded rainfall ranging from 200-300. Other western regions recorded rainfall in the range of 0-100. Meanwhile, the eastern and central regions generally had a rainfall range of 0-100. Batang Mata station in the eastern region was an exception with a range of -100-200, indicating a negative anomaly in rainfall.

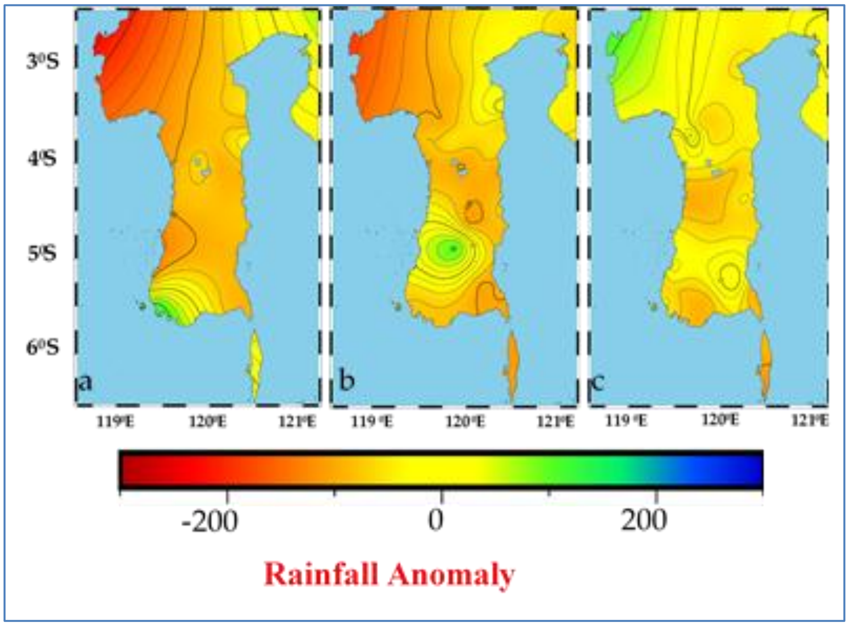
As La Niña reached a moderate level, its impact became more pronounced. The western and central regions remained within the 0-100 rainfall range, however, the east coast showed an increase in rainfall at most stations within the 0-100 range. Batang Mata station still recorded a negative anomaly in rainfall with a range of 0-(-100).

Under strong La Niña conditions, the effect becomes more significant. The western, central and some eastern regions recorded high rainfall in the 200-300 range. Almost all of these regions experience intense rainfall. However, the east coast has only one station, Batang Mata, which shows a negative anomaly in rainfall with a range of 0-(-100).

Factors influencing these differences involve sea surface and atmospheric temperature dynamics, which can modulate rainfall patterns. While weak and moderate La Niña events tend to have a more even impact, strong La Niña events can produce more extreme rainfall patterns. The topography and geography of the region can also play a role in the distribution of rainfall observed in September in South Sulawesi.

Figs. 5(a-c) shows the anomalies during La Nina (weak, moderate, strong) for the observation area of 4 stations namely Kongkong, Maiwa, Wara, and Sumpa Binange stations. At Sumpa Binange station, there was a significant increase in rainfall, indicating that in that month the influence of weak La Nina was very strong. However, in the period from August to January, this station experienced a decrease in rainfall, indicating that there was no weak La Nina event. Meanwhile, Wara station experienced a dry season from January to April, indicating that there was no weak La Nina. In June, low rainfall reflected the beginning of a change in weather patterns. A decrease in rainfall in August and in September there was low rainfall indicating that there was a weak La Nina influence. Maiwa station continued to experience dry conditions with no significant signs of change, while Kongkong station experienced a dry spell in January, followed by low rainfall in June. In August, there was a decrease in rainfall, which then increased again, reaching its peak in October. This pattern may reflect a change in weather conditions from a weak La Niña to neutral or weak El Niño conditions.

For moderate La Nina conditions in August, all three weather observation stations, namely Sumpa Binange, Wara, and Kongkong, recorded the highest rainfall peaks. In particular, the Sumpa Binange station recorded the highest rainfall among the three, followed by Kongkong and Wara. This significant increase in rainfall in August can be interpreted as a moderate La Niña phenomenon, affecting all three stations. However, in October, all three stations experienced a decrease in rainfall. Sumpa Binange, Wara, and Kongkong stations recorded dry weather conditions until March, although there was a variable increase without any significant indication of rain. This reflects no influence of the moderate la nina on weather patterns in the region. Meanwhile, Maiwa station remained in dry season conditions, indicating that the



Figs. 6(a-c).. Percentage of El-Nino Anomalies: a) Weak, b) Moderate, c) Strong, in July 1995-2020

impact of the moderate La Niña was not uniformly felt across the region.

Under strong La Niña conditions, all four weather observation stations, namely Sumpa Binange, Wara, Kongkong, and Maiwa, showed a very strong influence in September. In December all four stations recorded a decrease in rainfall.

3.3. *Percentage of Monthly Rainfall Anomalies due to El Nino Phenomenon for the Period 1995-2020*

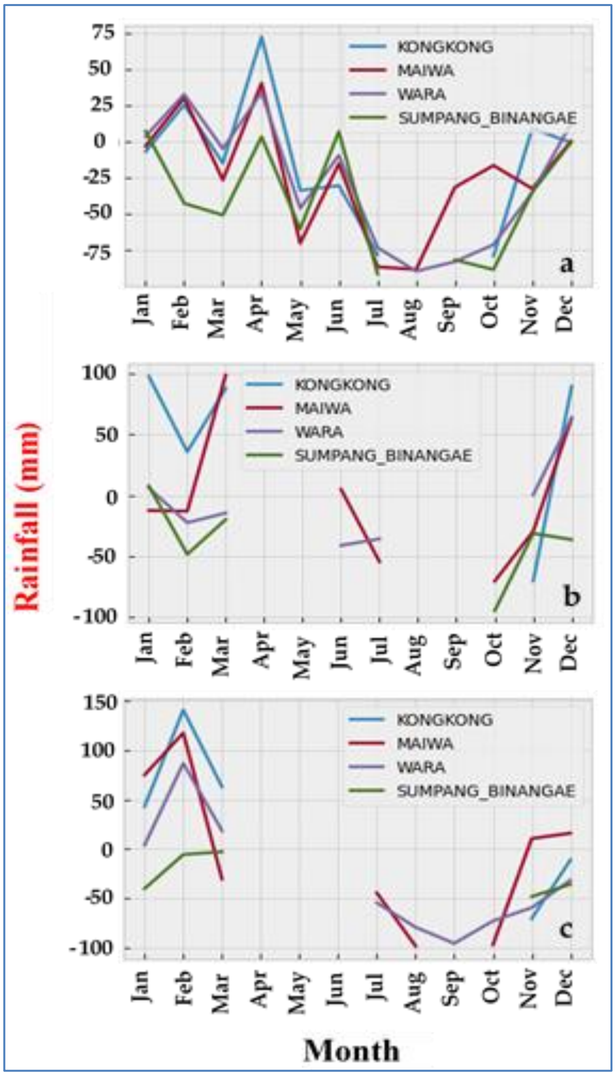
Figs. 6(a-c) shows the occurrence of the El Nino phenomenon (weak, moderate and strong) on monthly rainfall anomalies in South Sulawesi with a representative month of July.

Based on Fig. 6, the El Niño phenomenon has a significant influence on monthly rainfall anomalies in South Sulawesi, especially in July. When El Niño is weak, the Patalasang station in the western region experiences rainfall variations between 0-100, some even reaching the 0-(-100) range. The eastern and central regions also experience rainfall anomalies in the 0-(-100) range. In the western region, particularly in Tanralili and Batubassi, which are moderately affected by El Niño, there are rainfall variations between 0-100. However, the eastern and central regions continue to experience rainfall anomalies in the 0-(-100) range. Under strong El Niño conditions, the western, central and eastern regions all experience rainfall variations in the 0-(-100) range. Thus, El Niño intensity has a significant effect on monthly rainfall patterns in South Sulawesi, with the western, central and eastern regions experiencing different variations depending on the strength of El Niño.

Based on Figs. 7(a-c), the anomaly graph under weak El Niño conditions, weather observations from all four stations, namely Sumpa Binange, Wara, Kongkong and Maiwa, show varying conditions in response to the weak El Niño phenomenon. Peak drought was recorded in July-August at all four stations, indicating the influence of weak El Niño affecting the region.

However, when El Niño conditions were present, the peak drought varied between stations. Maiwa and Sumpa Binange stations recorded peak drought in October, while Kongkong experienced drought in November indicating that Maiwa, Sumpa Binange, Kongkong stations exhibited moderate El Niño influence. Wara station, in June, showed normal conditions with no significant drought during the period.

When El Niño conditions were strong, drought peaks again varied between stations. Maiwa and Wara experienced drought peaks in August and September, Kongkong in November, so maiwa, wara and kongkong stations experienced the influence of strong El Niño. while Sumpa Binange remained in normal conditions in August and October.



Figs. 7(a-c). Graph of El-Nino anomalies: a) Weak, b) Moderate, c) Strong in July 1995-2020

4. Conclusions

Analysis of the spatial distribution of monthly rainfall in South Sulawesi illustrates significant variations in patterns each month in the western, central and eastern regions. During the December, January, February (DJF) season, the western region reaches a peak in rainfall intensity, especially in January, while the eastern and central regions experience a decrease in rainfall. March, April, May (MAM) shows an increase in rainfall in the eastern region, while parts of the western region experience a decrease. In June, July, August (JJA), there is a decrease in rainfall across the region, reflecting the dry season generally experienced in that season. October and November saw an increase in rainfall. In July, the impact of El Niño was significant, with the Patalasang station on the west coast experiencing variations in rainfall, creating a different dynamic. Global climate variability factors such as El Niño and La Niña exert an influence on rainfall patterns, with El Niño tending to cause a decrease in rainfall and La Niña having the opposite effect. In addition, topography, sea surface temperature and tropical cyclones also play an important role in rainfall distribution. Specific analysis in September showed that La Niña had a significant impact, with varying intensity depending on its strength, affecting particularly the west, central and parts of the east coast.

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sDisclaimer: The contents and views presented in this research article/paper are the views of the authors and do not necessarily reflect the views of the organizations they belong to.

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