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Analysis of Rainfall Patterns in the Nusa Tenggara Region Using the Fast Fourier Transform (FFT) Method and its Relationship with El-Niño and IOD

Atika Agustina[1], Hamdi Akhsan[1*], Melly Ariska[1], Suhadi[2], Nely Andriani[1]

[1]*Physics Education Study Program, Faculty of Teacher Training and Education, Sriwijaya University, Indonesia*

[2]*Physics Education Study Program, Universitas Islam Negeri Raden Fatah Palembang, Indonesia*

Corresponding Authors E-mail: hamdiakhsan@fkip.unsri.ac.id

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Abstract

Changes in rainfall patterns have a significant impact on agriculture and water management in arid regions such as Nusa Tenggara. Water availability in this region is highly dependent on rainfall, which is influenced by global climate phenomena such as El-Niño and the Indian Ocean Dipole (IOD). This study aims to analyze the characteristics of rainfall patterns and analyze the relationship between rainfall and the El-Niño and IOD phenomena. Daily rainfall data from three BMKG observation stations in West Nusa Tenggara and East Nusa Tenggara during the period 1983-2022 were used in the analysis. The Fast Fourier Transform (FFT) method is used to identify periodic cycles, while the Pearson correlation test is used to determine the relationship of rainfall with El-Niño and IOD. The analysis shows that the Nusa Tenggara region is characterized by a monsoonal rainfall pattern with an annual cycle (12 months). Peak rainfall occurs in January and December, while the dry season lasts from July to September. The correlation of rainfall with El-Niño shows a weak negative relationship, while the influence of IOD is very small and varies between locations. The analysis shows that the rainfall pattern in the Nusa Tenggara region is monsoonal with an annual cycle (12 months) and semi-annual cycle (6 months). The peak of rainfall occurs from December to January, while the dry season lasts from July to September. The relationship between rainfall and El-Niño shows a weak negative correlation, so that when El-Niño increases, rainfall tends to decrease, and vice versa. The influence of IOD on rainfall is very small and varies between locations. Overall, while both El-Niño and IOD affect rainfall, their impact in the region is weak and more significant when both phenomena occur together.

Introduction

Changes in rainfall patterns, such as rainfall intensity, shifts in the rainy season, and extreme climate phenomena, have a significant impact on the agricultural sector and water management, especially in arid regions like Nusa Tenggara. The provinces of West Nusa Tenggara (NTB) and East Nusa Tenggara (NTT) are regions dominated by a dry climate, with an area of dry land reaching 5.2 million hectares [1, 2]. The dry land in NTT, with uneven and unpredictable rainfall distribution and intensity, often experiences crop failures due to limited water availability [3]. With annual rainfall below 2,000 mm, the agricultural sector in this region is highly dependent on rainfall and vulnerable to climate change [4]. Agriculture is the main source of livelihood for the people in NTB and NTT, with the majority of the population working in this sector [1]. Therefore, understanding rainfall patterns is very important so that planting times can be optimized and the risk of crop failure can be minimized.

In general, Indonesia has three rainfall patterns, namely monsoonal, equatorial, and local [5]. However, each region can show significant variations. For example, research by Setiawan [6] shows that Sumatra, Java, and Papua tend to have moderate to high rainfall, while Bali, Nusa Tenggara, and Maluku experience low rainfall. This variation is closely related to global phenomena, which affect the intensity and distribution of rainfall. The rainfall patterns in the Nusa Tenggara region are influenced by global phenomena such as El-Niño and La Niña, as well as monsoon patterns generated by the movement of monsoon winds [4, 5].

Global phenomena like the El-Niño-Southern Oscillation (ENSO) and the Indian Ocean Dipole (IOD) have a significant impact on rainfall patterns in Indonesia [9]. Both of these phenomena affect the dry season (June to November) and the rainy season (December to May) in various regions [10]. ENSO has its warm phase, namely El-Niño, which causes a decrease in rainfall and increases the risk of drought and forest fires [8, 9]. Meanwhile, the IOD also affects rainfall patterns; during the positive phase, rainfall decreases, whereas during the negative phase, rainfall increases [12]. In the Nusa Tenggara region, the combination of El-Niño and the positive phase of the IOD often results in extreme dry seasons, where Bramawanto's research [13], shows that the positive phase of the IOD can extend the dry season by 4-5 months.

With dry climate conditions, low rainfall, and vulnerability to global phenomena, changes in the intensity and distribution of rainfall directly impact water availability and agricultural productivity. Rice yields, which are highly dependent on rainfall patterns, are vulnerable to disruption as shown by Khairulbahri [14], where a decrease in yields occurs despite an increase in land area. Therefore, the Nusa Tenggara region was chosen due to its vulnerability to changes in rainfall patterns and its strategic role in supporting food security. A precise analysis of rainfall patterns is crucial for formulating adaptation strategies and water management to support the sustainability of the agricultural sector in this region.

Various methods have been used to analyze rainfall patterns, such as the research conducted by Faishal [15], which, using Geographic Information System (GIS)-based analysis methods, shows that the rainfall pattern in NTT Province follows a monsoonal pattern influenced by monsoon wind movements as well as the La Niña and El-Niño phenomena. Another study conducted by Sipayung [8], using a 10-year rainfall composite (1994-2017), found that the West Nusa Tenggara Region (Mataram and Bima) is significantly influenced by the monsoonal rainfall pattern. However, these methods tend to focus on spatial patterns and annual averages, thus having limitations in capturing seasonal repetition cycles in more detail. To address these limitations, this study uses the Fast Fourier Transform (FFT) method, which can detect recurring patterns in long-term data more quickly and accurately.

The FFT method has several advantages compared to other methods, such as ARIMA (Auto-Regressive Integrated Moving Average). FFT can process data directly without requiring complex transformations and excels in identifying recurring patterns and seasonal cycles in long-term data, while ARIMA, which is more suitable for short-term forecasting, requires stationary data and additional adjustments to function well [16]. Considering these advantages, the FFT method was chosen for this research. This research aims to determine the periodicity of rainfall cycles using spectral analysis, which allows for the identification of recurring patterns.

By using FFT, the rainfall recurrence patterns associated with global phenomena such as ENSO and IOD can be accurately identified, thereby providing valuable information for planting schedule planning and water management strategies in regions with high rainfall variability such as Nusa Tenggara. In previous research, Risa [17] used FFT to analyze rainfall patterns in North Sumatra during the period 1985–2019. The research results show that FFT can detect annual (12-month) and semi-annual (6-month) cycles, as well as identify additional periodic patterns within the 18–30 month range. These findings confirm that FFT is effective in identifying seasonal cycles and repetitions in rainfall data, which is highly relevant for regions with high variability such as Nusa Tenggara.

Although FFT has been used to analyze rainfall patterns in several regions of Indonesia, this research is novel with a focus on the Nusa Tenggara region. In addition, the novelty of this research also examines the relationship between rainfall and the El-Niño and IOD phenomena, which have not been widely discussed in this region. Thus, this research aims not only to identify the characteristics of rainfall patterns in Nusa Tenggara but also to examine their relationship with El-Niño and IOD.

Experimental Method

This research focuses on one of the regions in Indonesia, located between the longitude lines 117°E–125°E and latitude lines 7,5°S–11°S, as shown in Figure 1.

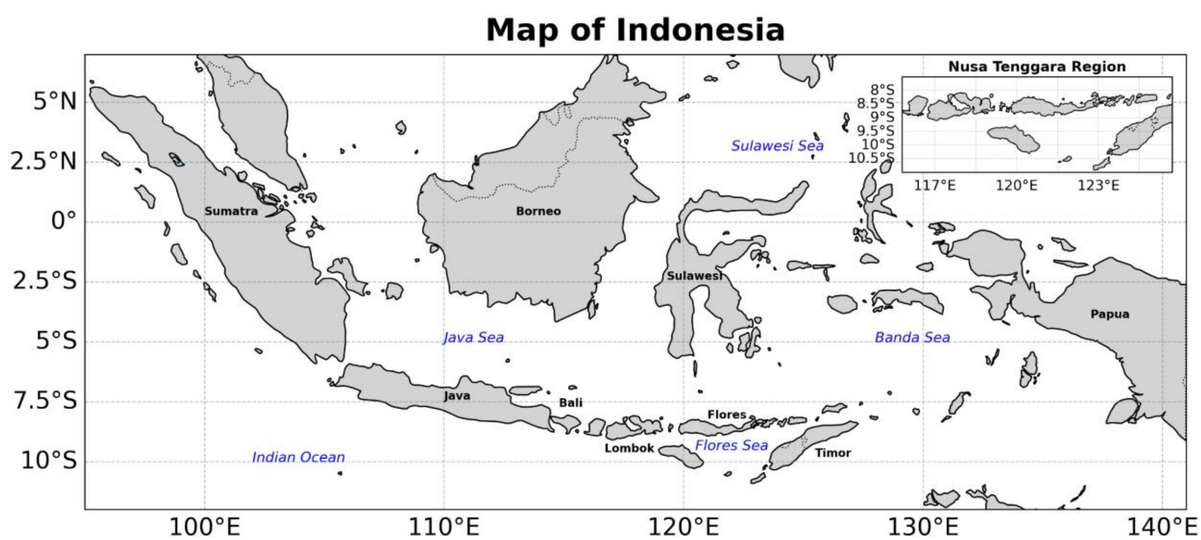


Figure 1. Observation Area

This study uses rainfall data from BMKG observation stations in the provinces of West Nusa Tenggara and East Nusa Tenggara during the period 1983–2022. Daily data was downloaded from the official BMKG website (https://dataonline.bmkg.go.id), while missing or empty data was supplemented using the Metomanz website (http://www.meteomanz.com). The data obtained from the Metomanz.com website includes data observed through SYNOP and BUFR messages, as well as forecast data from the GFS and ECMWF models. Time differences in this data may occur due to differences in the timing of data collection or transmission from weather stations, which can affect the accuracy and update timing of the available meteorological data. The correlation data of rainfall with El-Niño and IOD were obtained through the Niño 3.4 Index and DMI, which are available on the NOAA website (https://psl.noaa.gov/gcos_wgsp/Timeseries/Data/). This study collected rainfall data from 15 BMKG stations in the Nusa Tenggara region over a period of 39 years (1983–2022). However, to maintain the quality of the analysis, only 3 stations with complete and consistent data records without significant gaps were selected for further analysis. Incomplete or interrupted rainfall data risks producing biased results [16], and reduces the accuracy of pattern identification in FFT-based analysis. The selection of the three rainfall stations was based on geographical considerations, climate variations, and the topography of the Nusa Tenggara region. SM Eltari in the city of Kupang reflects coastal areas with lowlands and hills, SM Umbu Mehang Kunda in East Sumba Regency encompasses hills and gentle mountains, while SM Sultan Muhammad Salahuddin in the city of Bima represents highland areas with mountainous terrain. These topographic characteristics influence the rainfall patterns in each area. Previous research has shown that topographic characteristics, such as elevation and landform, can significantly affect the distribution of rainfall [18]. In addition, these stations have strategic locations to capture rainfall patterns related to global phenomena such as ENSO and IOD, which affect the rainy and dry seasons differently in various regions. The list of observation stations is presented in Table 1.

Table 1. Locations of BMKG observation stations used in the research

Station Number	Station Name	Province	Coordinates	
			Latitude	Longitude
97340	SM Umbu Mehang Kunda	East Nusa Tenggara	−9.66944	120.29972
97372	SM Eltari	East Nusa Tenggara	−10.16780	123.67039
97270	SM Sultan Muhammad Salahuddin	West Nusa Tenggara	−8.54279	118.69280

The complete data is then subjected to manual Quality Control (QC) analysis using Microsoft Excel to ensure the data meets the standards, namely without missing data and abnormal data such as the number 8888. Next, an analysis is conducted to determine the periodicity of rainfall cycles and the types of rainfall that occur. For this, a spectral analysis method is used that can identify periodic patterns in long-term data. One of the methods used is the Fast Fourier Transform (FFT), which converts data from the time domain to the frequency domain [19]. This method has been applied to study rainfall patterns based on the highest periodicity in several regions in Indonesia [20]. The formula for the Fast Fourier Transform equation taken from Tulak research [21] is as follows:

$$f(t) = a_0 + \sum_{p=1}^{\left(\frac{N}{2}\right)-1} \left[a_n cos\left(\frac{2\pi pt}{T}\right) + b_n sin\left(\frac{2\pi pt}{T}\right)\right] \quad (1)$$

$$a_0 = \bar{x}$$

$$a_n = \frac{2\left[\sum x_t \cos\left(\frac{2\pi pt}{T}\right)\right]}{T}$$

$$b_n = \frac{2\left[\sum x_t \sin\left(\frac{2\pi pt}{T}\right)\right]}{T}$$

with a_n being the coefficient a to n, b_p being the coefficient b to n, T being the amount of data, t being time, and p being periodic. Monthly rainfall data is used as a function (t) in the Fourier series equation, which is then transformed into a frequency function (ω), to obtain the Fast Fourier Transform equation as follows:

$$f(\omega) = \int_{-\infty}^{\infty} f(t)e^{-i\omega t}dt \quad (2)$$

Next, the value of spectral density strength (magnitude) on the periodogram is obtained from:

$$KKS\ (\omega) = \frac{T}{2}\left(a_n{}^2 + b_n{}^2\right) \quad (3)$$

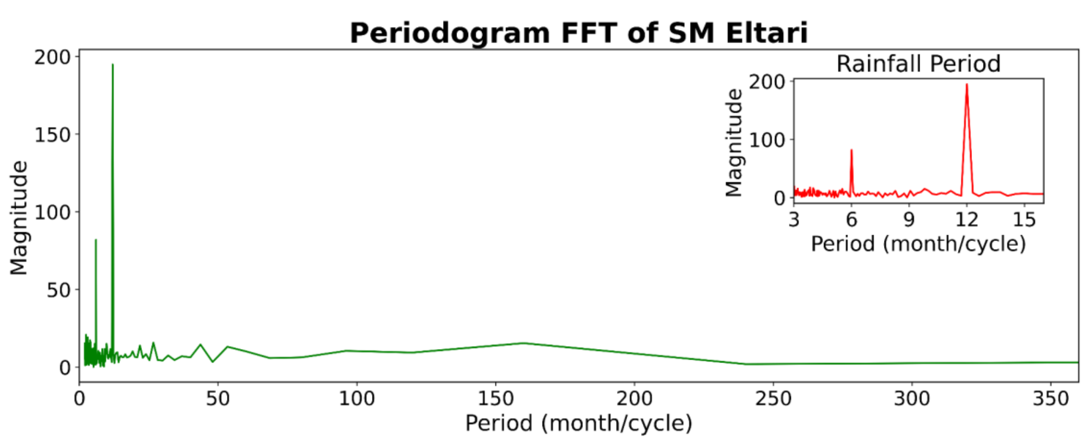
The periodogram will produce the period with the highest spectral density power (KKS) indicating the cycle of rainfall change [21]. From the results of the periodogram, the highest peak period will be taken from the graph of the Fast Fourier Transform method [20]. After that, a Pearson correlation analysis is conducted between rainfall and climate anomaly phenomena, namely El-Niño and IOD. The calculation of the correlation coefficient value uses the following equation [22].

$$r_{XY} = \frac{n\sum XY - (\sum X)(\sum Y)}{\sqrt{(n\sum X^2 - \sum X^2) - (n\sum Y^2 - \sum Y^2)}} \quad (4)$$

with r_{xy} being the correlation coefficient of X and Y, X is the independent variable, Y is the dependent variable, and n is the number of data points.

Result and Discussion

Rainfall data at SM Eltari, SM Umbu Mehang Kunda, and SM Sultan Muhammad Salahuddin were transformed using the FFT algorithm. The transformation results are visualized in a periodogram where the x-axis represents the period (months/cycles) and the y-axis represents the magnitude. The results of the FFT analysis at the three stations can be seen in Figure 2.



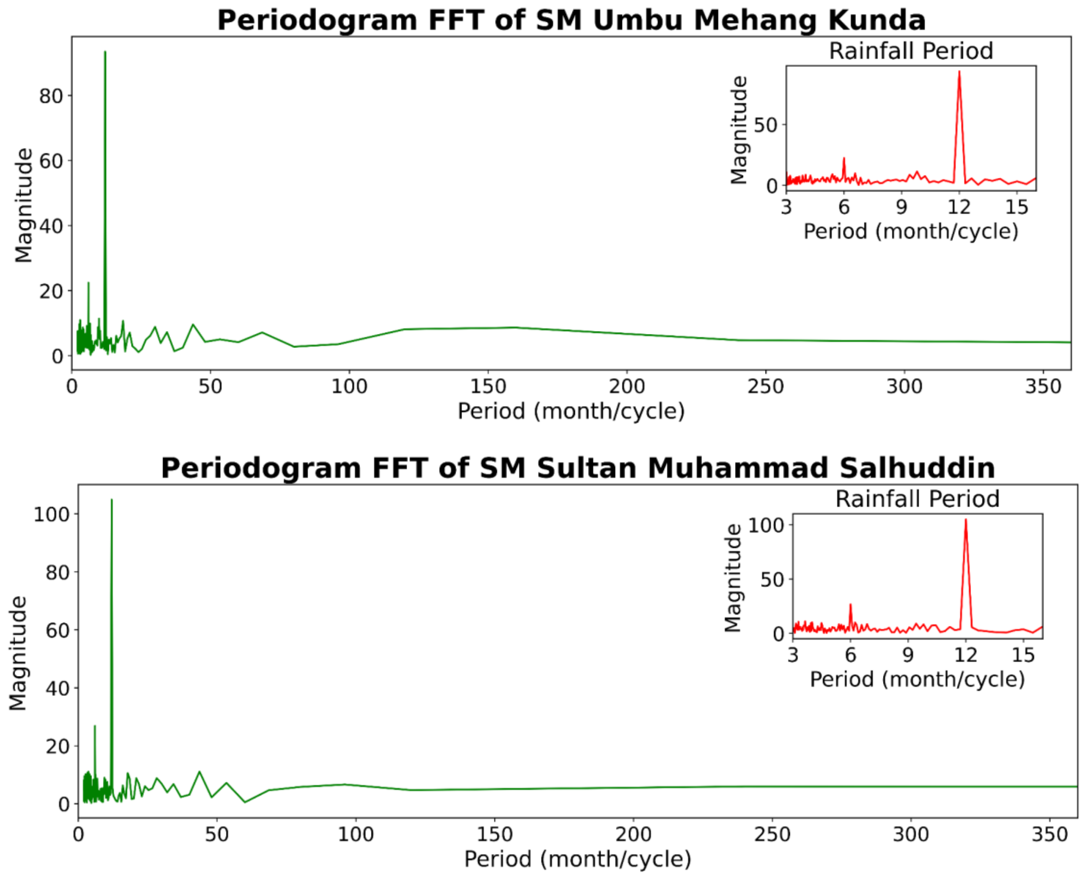


Figure 2. FFT Periodogram of Eltari Meteorological Station, Umbu Mehang Kunda, and Sultan Muhammad Salahuddin

Figure 2 shows the results of the rainfall periodogram analysis at the three dominant stations have an annual cycle (12 months). This indicates that the rainfall pattern in the Nusa Tenggara region is monsoonal with seasonal variations every year. The 12-month cycle represents the wet and dry seasons. However, the 6-month cycle is also evident but not as dominant, it represents fluctuations in the transition phase between the two main seasons. Local factors such as sea surface temperature play a role in influencing the semi-annual cycle. Prayogo and Natul [23] found that sea surface temperatures in the waters of Bali tend to be lower during the rainy season compared to the dry season, which can affect weather patterns in the surrounding areas. Additionally, the western monsoon and eastern monsoon contribute to the seasonal rainfall patterns in Nusa Tenggara, where rainfall increases during the western monsoon due to winds from the Pacific Ocean carrying abundant moisture, and decreases during the eastern monsoon due to dry winds from Australia [21]. This pattern is relevant to Lesik's findings [24], which state that rainfall on Flores Island is influenced by monsoonal winds and global climate events such as El-Niño and La Niña. The correlation between the FFT results and Lesik's findings reinforces the understanding that the annual and semi-annual cycles identified through FFT are part of the monsoon seasonal influence. This study is also relevant to Risa's findings [17], who used FFT to analyze rainfall in North Sumatra and found similar patterns of annual and semi-annual cycles. Similar findings in different regions affirm the reliability of FFT in detecting seasonal rainfall patterns, while also demonstrating that global phenomena such as ENSO and IOD consistently impact various regions of Indonesia with varying intensities.

Findings regarding annual cycles in Nusa Tenggara have significant practical implications for agricultural sector planning and water resource management. A deep understanding of seasonal patterns can help farmers adjust planting and harvesting times, thereby increasing agricultural productivity. Research shows that the Nusa Tenggara region, particularly in West Nusa Tenggara Province, has great potential in providing rice supply, which is very important considering Indonesia's dependence on agriculture for food security [25]. Thus, adjusting planting times based on seasonal cycles can help maximize agricultural yields. In addition, this information can also be used to design early warning systems to address the risks of drought or flooding, as well as to optimize irrigation based on rainfall patterns. Thus, the results of this analysis play an important role in supporting food security and climate change adaptation in the Nusa Tenggara region.

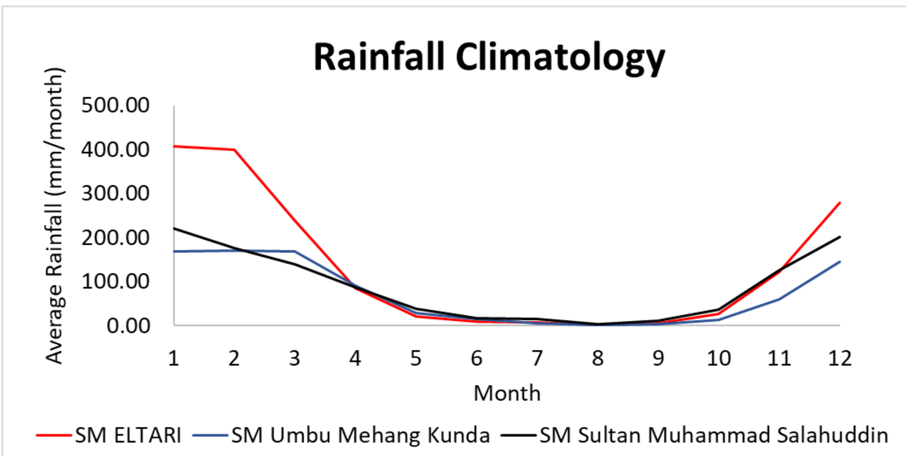


Figure 3. Rainfall Climatology

It can be seen from Figure 3 that the rainfall patterns of the three observation stations appear to be monsoonal. This graph shows two peaks in rainfall occurring around January (the first peak) and December (the second peak). Meanwhile, the lowest rainfall occurs in the middle of the year (around July to September), indicating a strong dry season during that period. The pattern illustrates the presence of two main rainy seasons separated by a dry season. The high rainfall period from January to April is caused by the wet monsoon winds bringing moisture from the Indian Ocean, while the low rainfall period from July to September reflects the dominance of the dry monsoon winds from the Australian mainland. This is in line with Oldeman's theory which states that the rainfall pattern in Nusa Tenggara has a monsoonal type.

The rainfall patterns displayed on the graph show consistency among the three meteorological stations, although there are differences in rainfall intensity. The variations in rainfall observed among the meteorological stations in Nusa Tenggara can be influenced by various geographical and topographical factors. SM Eltari, located in a coastal area with lowlands, shows higher rainfall compared to the other two stations. In this case, topography plays an important role in the distribution of rainfall. In coastal areas like SM Eltari, the influence of the sea can increase the humidity of the air entering the region. This process often results in higher rainfall, especially during the rainy season, when sea winds carry enough water vapor to produce precipitation [28]. Conversely, in hilly and mountainous areas such as those found in SM Umbu Mehang Kunda and SM Sultan Muhammad Salahuddin, rainfall can decrease due to orographic effects, where air rising over the mountains can cause evaporation and deposition of water vapor before reaching higher altitudes [26].

The rainfall pattern in this region is dominated by an annual cycle (12 months), with a secondary peak in the form of semi-annual oscillations (6 months), in accordance with the periodogram results from the previous FFT analysis. This is in line with the rainfall climatology graph in Figure 3, which shows rainfall fluctuations throughout the year with rainfall peaks occurring in January and December. This pattern confirms the existence of an annual cycle component, where rainfall increases once a year. Both findings suggest that the seasonal monsoon has a large impact on the Nusa Tenggara region, with high variations in rainfall occurring every 12 months.

Using the results of this research, the community in the Nusa Tenggara region has an optimal planting time from Januari and December, when rainfall peaks and soil conditions have sufficient moisture, allowing for harvesting from March to April, before rainfall drastically decreases at the beginning of the dry season. In other regions of Indonesia, such as the research conducted by Dwiratna [27] in Cimanggung District, West Java, which also has a monsoonal rainfall pattern, the optimal planting time there is from November to February. Although there are similarities in rainfall patterns, planting times can vary depending on the climatic conditions and the amount of rainfall in each region.

Climatological graphs emphasize that the annual cycles identified through FFT are not merely statistical patterns, but are real parts of regional climatological phenomena influenced by wet and dry monsoon winds. Thus, the combination of FFT analysis and climatological graphs provides a comprehensive understanding of rainfall patterns in Nusa Tenggara, indicating consistency between climatological patterns and the previously identified temporal cycles.

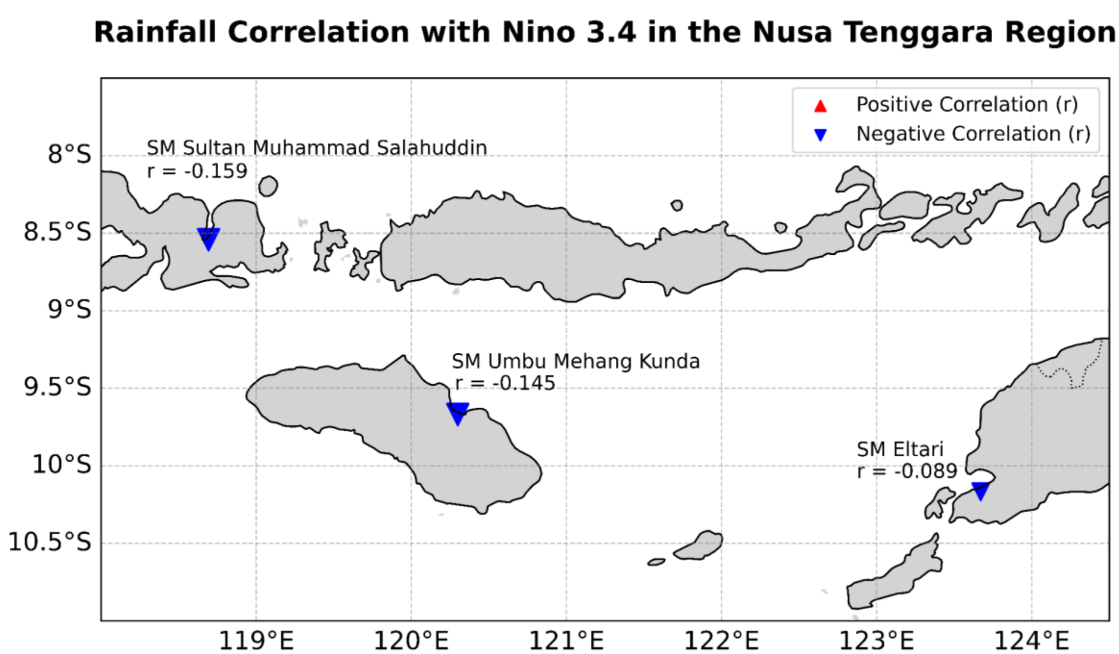


Figure 4. Correlation of Rainfall with Nino 3.4 Index in the Nusa Tenggara Region

Based on Figure 4, there is a negative correlation between rainfall and the El-Niño phenomenon in the Nusa Tenggara region. At the three observation stations, namely SM Eltari, SM Umbu Mehang Kunda, and SM Sultan Muhammad Salahuddin, a very low negative correlation is shown, as seen in Table 2.

Table 2. Correlation Results of Rainfall with El-Niño in the Nusa Tenggara Region

Number	Station Name	n (Many monthly rainfall data)	r (Correlation)
1.	SM Eltari	480	-0.089
2.	SM Umbu Mehang Kunda	480	-0.145
3.	SM Sultan Muhammad Salahuddin	480	-0.159

This negative value indicates an inverse relationship between the two parameters [28], which means that when El-Niño increases, rainfall tends to decrease, and vice versa, although the relationship is weak. These results do not fully support previous findings that state that El-Niño and the positive phase of the IOD can extend the dry season by 4-5 months. This weak correlation suggests that the influence of El-Niño on rainfall in Nusa Tenggara may not be as significant as previously estimated. These findings are in line with the research by Nurlatifah & Wulandari [29], which shows that rainfall in fourteen locations in NTB also tends to be inversely proportional to the Niño 3.4 index value, with a not very high correlation (-0.4) between the two variables.

In March 2016, during the El-Niño event with a Niño 3.4 index of 1.6, rainfall at the three stations remained high, with values of 231.5 mm at SM Eltari, 232.8 mm at SM Umbu Mehang Kunda, and 157.2 mm at SM Sultan Muhammad Salahuddin. This shows that, although El-Niño generally reduces rainfall, the effect did not directly cause a drastic decrease in this region. Local factors, such as the wet monsoon winds and atmospheric conditions at the time, play a role in maintaining a relatively high level of rainfall despite the occurrence of El-Niño. Additionally, in years with neutral conditions or without El-Niño, rainfall in March is generally higher and more stable. This indicates that, although El-Niño tends to reduce rainfall, its influence can vary depending on atmospheric conditions and other external factors. These findings are also related to the research by Suhadi [30], which shows that in the period 2000–2023, the intensity of ENSO decreased compared to the previous period (1970–2000), while IOD became more dominant in influencing rainfall patterns in Indonesia. This is relevant to the conditions in March 2016, where negative IOD activity likely reduced the impact of drought that usually occurs during El-Niño. Thus, although El-Niño plays a role in reducing rainfall, its impact in the Nusa Tenggara region is not always significant every year or at every observation location. Local factors and other climate phenomena, such as monsoon winds and IOD, also influence rainfall patterns and add complexity to understanding climate variability in this region. These findings indicate that a more in-depth analysis is needed to understand the interactions between ENSO and other climatic factors in order to design more effective adaptation strategies in the agriculture and water management sectors in Nusa Tenggara.

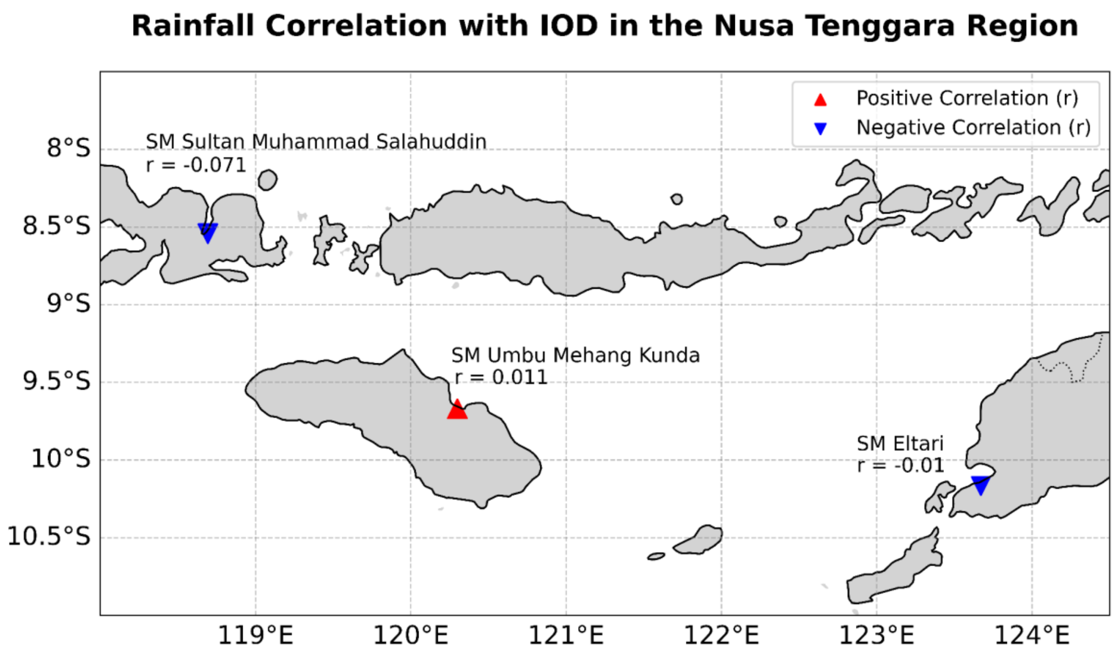


Figure 5. Correlation of Rainfall with IOD Index in the Nusa Tenggara region

Based on Figure 5, the relationship between rainfall and IOD in Nusa Tenggara varies at several locations. At the SM Eltari and SM Sultan Muhammad Salahuddin stations, a very low negative correlation was found, indicating that when the IOD increases (towards positive), rainfall slightly decreases. Conversely, at the SM Umbu Mehang Kunda station, a very low positive correlation was found, indicating a very small increase in rainfall when the IOD increases (towards negative), but the effect is almost negligible.

Table 3. Results of the Correlation between Rainfall and IOD in the Nusa Tenggara Region

Number	Station Name	*n* (Many monthly rainfall data)	r (Correlation)
1.	SM Eltari	480	-0.01
2.	SM Umbu Mehang Kunda	480	0.001
3.	SM Sultan Muhammad Salahuddin	480	-0.071

Although Bramawanto [13] identified a relationship between positive IOD and prolonged dry seasons, the results of this study show that the influence of IOD on rainfall fluctuations in Nusa Tenggara is very small, which means the impact of the positive IOD phase on the dry season in Nusa Tenggara is even smaller. These results also indicate that although IOD affects rainfall patterns in several regions of Indonesia, its impact in Nusa Tenggara is very limited. The weak correlation between IOD and rainfall at the three stations indicates that IOD fluctuations, whether positive or negative, do not significantly affect rainfall in this region. These findings are also relevant to research results that state that when El-Niño and positive IOD occur simultaneously, as in 2015, rainfall experiences a sharp decline. This indicates that the effects of the IOD in this region are more pronounced when it coincides with other global phenomena, such as El-Niño, rather than when the IOD stands alone.

Compared to El-Niño, which also shows a weak negative correlation with rainfall in Nusa Tenggara, these results reinforce the understanding that rainfall fluctuations in this region are more influenced by monsoon patterns and semi-annual and annual climate cycles, as identified through FFT, while IOD only has a small and not significant enough impact to trigger major changes in rainfall, unless it coincides with El-Niño. Thus, although ENSO and IOD play roles in influencing rainfall in Indonesia, their impact in Nusa Tenggara is not always significant and can vary from year to year. These findings indicate that, in addition to global phenomena, local factors such as monsoon winds and atmospheric conditions also need to be considered to comprehensively understand rainfall patterns in this region. Understanding the interaction between global phenomena and seasonal patterns is crucial for designing effective adaptation strategies and water resource management, especially to support food security in Nusa Tenggara.

Conclusion

Based on the research findings, it can be concluded that the rainfall pattern in Nusa Tenggara follows a monsoonal pattern with an annual (12-month) and semi-annual cycle (6-month). The peak of rainfall occurs in December and January, while the dry season lasts from July to September. The relationship between rainfall and El-Niño has a weak negative correlation, so when El-Niño increases, rainfall in this region tends to decrease and vice versa. Meanwhile, the relationship between rainfall and the Indian Ocean Dipole (IOD) has a very small influence on rainfall patterns in Nusa Tenggara. Although El-Niño and IOD affect rainfall, their impact is weak in the region and is more pronounced when they occur simultaneously.

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References

[1] M. Hikmat, D. P. Hati, M. M. Pratamaningsih, and Sukarman, "Study on High Productivity Dryland in Nusa Tenggara for Agriculture Development (Kajian Lahan Kering Berproduktivitas Tinggi di Nusa Tenggara untuk Pengembangan Pertanian)," *J. Sumberd. Lahan*, vol. 16, no. 2, p. 119, 2023.

[2] A. Mulyani and M. H. Suwanda, "Pengelolaan Lahan Kering Beriklim Kering untuk Pengembangan Jagung di Nusa Tenggara," *J. Sumberd. Lahan*, vol. 13, no. 1, p. 41, 2020.

[3] R. Matheus, M. Basri, M. S. Rompon, and N. Neonufa, "Strategi Pengelolaan Pertanian Lahan Kering Dalam Meningkatkan Ketahanan Pangan Di Nusa Tenggrara Timur," *Partner*, vol. 22, no. 2, p. 529, 2017.

[4] A. Suriadi, A. Mulyani, L. Hadiawati, and Suratman, "Biophysical characteristics of dry-climate upland and agriculture development challenges in West Nusa Tenggara and East Nusa Tenggara Provinces," *IOP Conf. Ser. Earth Environ. Sci.*, vol. 648, no. 1, 2021.

[5] P. P. Simanjuntak and A. D. Nopiyanti, "Pengaruh Komponen Angin Zonal dan Meridional terhadap Curah Hujan Bulanan di Mempawah, Kalimantan Barat serta Pengaruh ENSO terhadap Variasinya," *J. Kumparan Fis.*, vol. 5, no. 3, pp. 187–192, 2023.

[6] D. Setiawan, "Analisis Curah Hujan di Indonesia untuk Memetakan Daerah Potensi Banjir dan Tanah Longsor dengan Metode Cluster Fuzzy C-Means dan Singular Value Decompotition (SVD)," *Eng. Math. Comput. Sci. J.*, vol. 3, no. 3, pp. 115–120, 2021.

[7] M. I. Faishal, "Analisis Pola Curah Hujan Wilayah dan Indeks Kekeringan Berbasis Geographic Information System (GIS) di Provinsi Nusa Tenggara Timur (NTT)," Universitas Gadjah Mada, 2017.

[8] S. B. Sipayung *et al.*, "Proyeksi Neraca Air di Wilayah Nusa Tenggara Barat (NTB) Berdasarkan Luaran Model Conformal Cubic Atmospheric Model (CCAM)," *J. Sains Dirgant.*, vol. 16, no. 2, pp. 79–90, 2019.

[9] H. Akhsan, M. Irfan, Supari, and I. Iskandar, "Dynamics of Extreme Rainfall and Its Impact on Forest and Land Fires in the Eastern Coast of Sumatra," *Sci. Technol. Indones.*, vol. 8, no. 3, pp. 403–413, 2023.

[10] M. N. Nur'utami and R. Hidayat, "Influences of IOD and ENSO to Indonesian Rainfall Variability: Role of Atmosphere-ocean Interaction in the Indo-pacific Sector," *Procedia Environ. Sci.*, vol. 33, pp. 196–203, 2016.

[11] A. Scaife, E. Guilyardi, M. Cain, and A. Gilbert, "What is the El-Niño–Southern Oscillation?," *Weather*, vol. 74, no. 7, 2019.

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

[13] R. Bramawanto, F. Y. Prabawa, and I. R. Suhelmi, "The Effect of ENSO and IOD Climate Variability on Salt Production in Nusa Tenggara Islands," *J. Segara*, vol. 18, no. 2, pp. 85–94, 2022.

[14] M. Khairulbahri, "Analyzing the impacts of climate change on rice supply in West Nusa Tenggara, Indonesia," *Heliyon*, vol. 7, no. 12, p. e08515, 2021.

[15] M. I. Faishal, B. D. A. Nugoho, and P. Sudira, "Analisis Pola Curah Hujan Wilayah Dan Indeks Kekeringan Berbasis Geographic Information System (GIS) Di Provinsi Nusa Tenggara Timur (NTT)," 2017, [Online]. Available: http://etd.repository.ugm.ac.id/penelitian/detail/115817

[16] D. Susilokarti, S. S. Arif, S. Susanto, and L. Sutiarso, "Studi Komparasi Prediksi Curah Hujan Metode Fast Fourier Transformation (Fft), Autoregressive Integrated Moving Average (Arima) Dan Artificial Neural Network (Ann)," *J. Agritech*, vol. 35, no. 02, p. 241, 2015.

[17] R. Albeta, I. Iskandar, H. Akhsan, and Suhadi, "Analisis Pola Curah Hujan di Wilayah Sumatera Bagian Utara Menggunakan Fast Fourier Transform (FFT)," *J. Ilmu Fis. dan Pembelajarannya*, vol. 8, no. 1, pp. 9–13, 2024.

[18] D. Kurniawati, "Penaksiran Indeks Erosivitas Hujan dengan Metode Lenvain di Kecamatan Dau Kabupaten Malang," *Geodika J. Kaji. Ilmu dan Pendidik. Geogr.*, vol. 7, no. 1, pp. 33–42, 2023.

[19] Rahmatika and J. Wiratmo, "The Effect of Rainfall Anomalies Due to Enso on tea Productivity in West Java Indonesia (Case Study: Bandung Regency)," *IOP Conf. Ser. Earth Environ. Sci.*, vol. 1245, no. 1, 2023.

[20] A. Bimaprawira and H. A. Rejeki, "Keterkaitan Periodisitas Curah Hujan di Daerah Pesisir dan Pegunungan Provinsi Jawa Timur dengan Variabilitas Cuaca Skala Global dan Regional," *J. Sains Teknol. Modif. Cuaca*, vol. 22, no. 2, pp. 51–59, 2021.

[21] N. Tulak, Y. Bungkang, and H. Huda, "Analisis Periodisitas dan Tren Curah Hujan di Kota Jayapura, Papua pada Periode 2001-2018," *J. Meteorol. dan Geofis. dan*, vol. 23, no. 1, pp. 45–52, 2022.

[22] A. K. Salma, E. Pratiwi Adi, W. Handayani, and S. Prayoedhie, "Analisis Koefisien Korelasi Peak Ground Acceleration dengan Metode Oliviera dan Shakemap BMKG, Studi Kasus Gempa Bumi Bantul 16 Januari 2022," *J. Stasiun Geofis. Sleman*, vol. 1, no. 1, pp. 15–18, 2023.

[23] L. M. Prayogo, "Pemetaan Suhu Permukaan Laut (SPL) dan Karakteristik Pasang Surut di Perairan Pulau Bali, Indonesia," *J. Laot Ilmu Kelaut.*, vol. 3, no. 1, pp. 1–12, 2021.

[24] E. M. Lesik, H. L. Sianturi, A. S. Geru, and B. Bernandus, "Analisis Pola Hujan dan Distribusi Hujan Berdasarkan Ketinggian Tempat di Pulau Flores," *J. Fis. Fis. Sains dan Apl.*, vol. 5, no. 2, pp. 118–128, 2020.

[25] M. W. Priyanto, A. P. Pratama, and I. Y. Prasada, "The Effect Of Fertilizer And Agricultural Machinery Subsidies On Paddy Productivity: A Feasible Generalized Least Squares Approach," *SEPA J. Sos. Ekon. Pertan. Dan Agribisnis*, vol. 20, no. 1, pp. 56–68, 2023.

[26] K. Muhammad Tahir, Y. Yin, Y. Wang, Z. A. Babar, and D. Yan, "Impact assessment of orography on the extreme precipitation event of July 2010 over Pakistan: a numerical study," *Adv. Meteorol.*, vol. 2015, no. 1, p. 510417, 2015.

[27] S. Dwiratna, E. Suryadi, and K. D. Kamaratih, "Optimasi Pola Tanam Pada Lahan Sawah Tadah Hujan Di Kecamatan Cimanggung Kabupaten Sumedang," *J. Teknotan*, vol. 10, no. 1, pp. 37–45, 2016.

[28] U. Hidayat, S. Prasetyo, Y. Donni Haryanto, and N. Florida Riama, "Pengaruh ENSO Terhadap Curah Hujan dan Kelembapan Relatif serta Suhu Permukaan Laut di Sulawesi," *Bul. GAW Bariri*, vol. 2, no. 2, pp. 88–96, 2022.

[29] A. Nurlatifah and E. P. Wulandari, "Analysis of Rainfall Conditions Over Nusa Tenggara Barat During Enso Events Based on TRMM Data (Analisis Kondisi Curah Hujan Di Nusa Tenggara Barat Selama Terjadinya Enso Berdasarkan Data TRMM)," *J. Sains Dirgant.*, vol. 17, no. 1, pp. 49–60, 2020.

[30] S. Suhadi *et al.*, "Morlet's Wavelet Analysis on El-Niño Southern Oscillation (ENSO) and The Indian Ocean Dipole (IOD) for 84 Years: 1940-2023," *Indones. Phys. Rev.*, vol. 7, no. 3, pp. 552–561, 2024.