
Impact of El Niño–Southern Oscillation (ENSO) and Rainfall Variability on Rice Production in East Java during 2018–2025

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ABSTRACT

El Niño –Southern Oscillation (ENSO) is one of the climate variability factors that can affect rainfall patterns and agricultural production systems . This study aimed to analyze the relationship between ENSO variability , rainfall , harvested area, and rice production in East Java during 2018–2025. The research used a quantitative descriptive method with secondary data obtained from the Meteorology , Climatology , and Geophysical Agency and the Central Bureau of Statistics . Data analysis was performed using Pearson correlation analysis to determine the relationship among variables . The results showed that ENSO had a very strong negative correlation with rainfall ($r = -0.959$; $p < 0.01$), indicating that stronger El Niño conditions were associated with lower rainfall . However , ENSO and rainfall did not show a significant direct relationship with rice production . Rice production showed a very strong positive correlation with harvested area ($r = 0.979$; $p < 0.01$), indicating that harvested area was the main factor associated with production changes during the observation period . These findings indicate that although ENSO strongly influences rainfall variability , its impact on rice production can be reduced by agricultural management factors such as irrigation systems , cultivation practices , adaptive varieties , and farmer adaptation strategies

Keywords : ENSO; rainfall variability ; rice production ; harvested area; East Java

INTRODUCTION

Paddy is one of the commodities important in Indonesia because as source carbohydrate main For food daily . Request to rice produced by plants paddy the more increase Because increase population (Rohman et al, 2017). Required improvement production plant paddy For produce rice so that it can sufficient need food community . Plants paddy in the production process influenced by internal factors and external factors external . Internal factors are found in genetics inherited plants from its parent , while factor external is external factors plants that include factor edaphic and climate micro as well as climate macro . Rainfall be one of factor external influences growth and development plant rice . Water will have a big impact with production paddy irrigation and especially in the area cistern rain . In conditions of sufficient water plant will own optimal conditions at the ratio root title , accumulation weight dry , speed authenticity clean , and condition other physiology that has an impact direct growth and development plant paddy(Liu et al, 2024).

Prediction to rainfall Rain No easy For done Because influenced by direction wind , temperature air , pressure air , and factors others . The existence of diversity Rain Good decline rainfall sharp rain or improvement rainfall very heavy rain will result in weather extreme . Anomaly to rainfall Rain called El Niño and La Niña, p the Can trigger existence disaster natural like landslides , floods flash , and prolonged drought . El Niño is marked with existence deviation climate characterized by with decline rainfall rain and increase temperature air , while La Niña is characterized by existence improvement rainfall above normal rainfall . El Niño and La Niña are anomaly the climate that will influence Lots condition life man and animals and plants (Nugraheni et al, 2023). Change climate cause various condition like existence rainfall varying rainfall , changes temperature , the emergence of resistance to weeds and pathogens, waterlogging , salinity

, and conditions drought in some triggering place decline production agriculture (Zaini and Saitama, 2023).

Change production in the province East Java which is one of the center production paddy national. Production rice in the province East Java is experiencing change from In 2018, 10.54 tons of GKG became 9.27 tons of GKG in 2024 based on a BPS survey. The dynamics area abundant harvest caused by the change type plant and over function land cause decline. Another factor that is one of the factors that influences condition the is change condition climate. Expansion land agriculture paddy will increase production paddy East Java however ENSO conditions are factors that are not Can off in influence productivity plant.

variation in East Java is in the phase neutral, La Niña, to strong El Niño. Dynamics climate regionally, especially in Java East will impact on the production system rice. Research Lots done For count influence from ENSO to production paddy However No always show same pattern. Response the influenced by use adaptive varieties to stress climate, technology proper cultivation and farmer strategies For adapt. With thus important For done study For looking NESO influence with indicator production in East Java in general quantitative. Objectives from study This is For analyze ENSO relationship, rainfall rain, wide harvest and production rice in East Java in 2018–2025.

METHOD

Study This done with use method descriptive quantitative research done with using secondary data obtained The Meteorology, Climatology, and Geophysics Agency (BMKG) and the Central Statistics Agency (BPS). The variables used are: in study is ENSI index, climate variables, average rainfall Rain annual total rainfall annual, area harvest, production rice. ENSO data is calculated with based on the average index value Annual. Calculation of rainfall data Rain obtained from total annual data in period observation.

Analysis conducted using IBM SPSS Statistics with Pearson correlation test for know connection between variables, with moreover formerly conduct distribution tests normality in order to fulfill assumptions analysis parametric. Pearson correlation test was performed with level significance 5% ($\alpha = 0.05$). Direction and level of closeness connection between variables shown with mark coefficient correlation (r). The r value is positive show that addition variable x increases variable y , whereas negative r value show variable x does not correlated increase variable y . Strength connection correlation refers to the coefficient correlation, r value 0.00–0.19 indicates the relationship is very weak, 0.20–0.39 weak, 0.40–0.59 moderate, 0.60–0.79 strong, and 0.80–1.00 very strong. Connection intervariable stated significant if mark significance (Sig. 2-tailed) < 0.05 . Formula analysis Pearson correlation is:

$$r = \frac{n \sum XY - (\sum X)(\sum Y)}{\sqrt{[n \sum X^2 - (\sum X)^2][n \sum Y^2 - (\sum Y)^2]}}$$

Information: r = Pearson correlation coefficient; X = independent variable (e.g. ENSO index or rainfall); Y = dependent variable (e.g. rice production); n = number of observation data; $\sum XY$ = sum of multiplication results X and Y values; $\sum X^2$ = sum of squares of X values; $\sum Y^2$ = sum of squares of Y values.

Period seasonal stated in three-month intervals, namely DJF (December–January–February), JFM (January–February–March), FMA (February–March–April), MAM (March–April–May), AMJ (April–May–June), MJJ (May–June–July), JJA (June–July–August), JAS (July–August–September), ASO (August–September–October), SON (September–October–November), OND (October–November–December), and NDJ (November–December–January). The value in each period indicates the magnitude of the seasonal climate index anomaly used to describe ENSO variability in the period 2018–2025.

RESULTS AND DISCUSSION

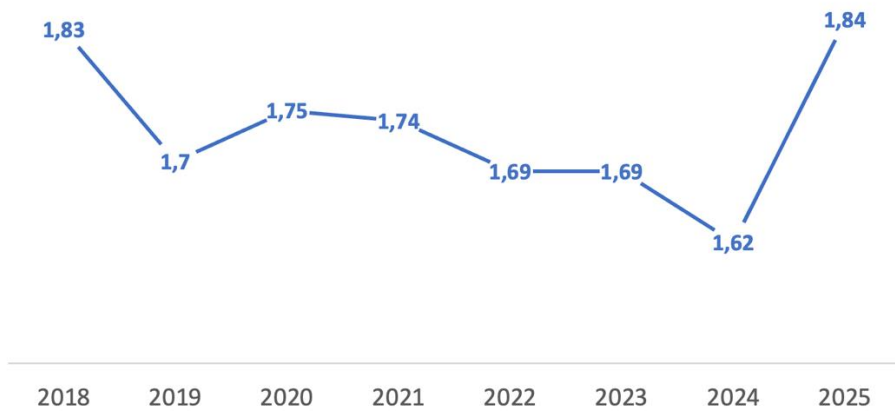


Figure 1. Harvested area (million hectares) of rice East Java 2018-2025

Based on Figure 1 shows existence fluctuations wide harvest rice in 2018-2025 . In 2018 the area harvest of 1.83 million ha , then in 2019 experienced decline become area harvest of 1.7 million hectares. There is a little an increase of 0.5 million ha in 2020 , then decrease area harvest paddy until 2024 up to 1.62 million ha. In 2025 there will be effort improvement area harvest For province Java east so that area harvest rice at 1.84 million ha , figure the more tall compared to 2018. Increase the Enough impact on the results harvest paddy and rice in Java east .

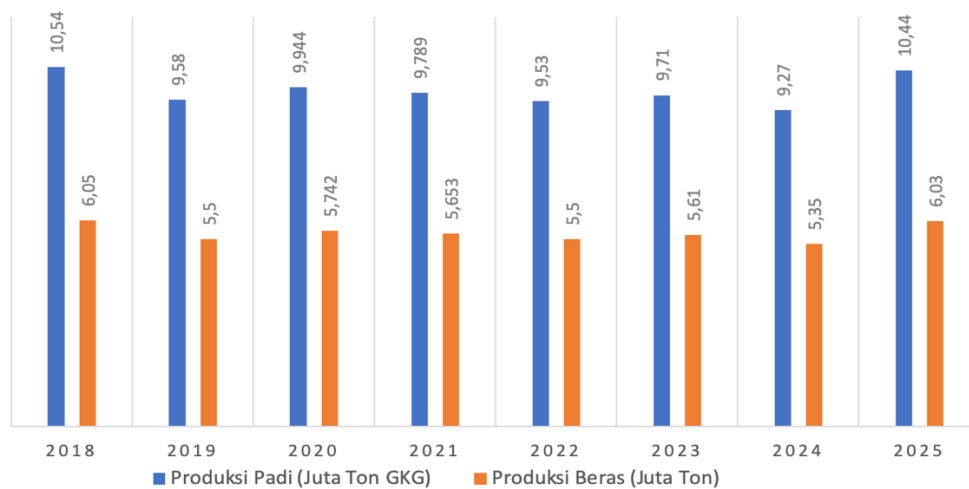


Figure 2. Rice Production (Million Tons of GKG) and Rice Production (Million Tons)

fluctuation pattern in 2018-2025 (figure 2) shows fluctuations However tend experience decline in 2018 to 2024. There is an increase back in the year 2025. In 2018 experienced production paddy highest namely 10.54 million tons of GKG with production 6.05 million tons of rice . Variation production resulting from change wide harvest , productivity plants , and conditions environment also occurred in 2019-2023 with production 9.53–9.94 million tons of GKG . A considerable increase sharp occurred in 2025 which was caused by addition area harvest with production 10.44 million tons of GKG or equivalent to 6.03 million tons of rice . Variability production harvest can influenced by several factor that is current water availability vegetative phase that affects growth plants . Deep water condition excessive or lack can caused by rainfall variability and the El Niño –Southern Oscillation (ENSO) phenomenon .

Table 1. Variation of Seasonal Climate Index (DJF–NDJ) 2018–2025 as an Indicator of ENSO Variability

| Year | DJF | JFM | FMA | MAM | AMJ | MJJ | JJA | JAS | ASO | SON | OND | NDJ |
|------|------|------|------|------|------|------|------|------|------|------|------|------|
| 2018 | -0.8 | -0.7 | -0.6 | -0.4 | -0.1 | 0.1 | 0.1 | 0.3 | 0.5 | 0.8 | 1 | 0.9 |
| 2019 | 0.9 | 0.9 | 0.8 | 0.8 | 0.6 | 0.5 | 0.3 | 0.2 | 0.2 | 0.4 | 0.6 | 0.7 |
| 2020 | 0.6 | 0.6 | 0.5 | 0.3 | 0 | -0.2 | -0.4 | -0.5 | -0.8 | -1.1 | -1.2 | -1.1 |
| 2021 | -0.9 | -0.8 | -0.7 | -0.5 | -0.4 | -0.3 | -0.3 | -0.4 | -0.6 | -0.8 | -0.9 | -0.9 |
| 2022 | -0.8 | -0.8 | -0.9 | -1 | -0.9 | -0.8 | -0.8 | -0.9 | -1 | -0.9 | -0.8 | -0.7 |
| 2023 | -0.5 | -0.3 | 0 | 0.3 | 0.6 | 0.8 | 1.1 | 1.4 | 1.6 | 1.8 | 2 | 2.1 |
| 2024 | 1.9 | 1.6 | 1.3 | 0.8 | 0.5 | 0.2 | 0.1 | -0.1 | -0.2 | -0.2 | -0.3 | -0.4 |
| 2025 | -0.4 | -0.2 | -0.1 | 0 | 0 | 0 | -0.1 | -0.3 | -0.4 | -0.5 | -0.6 | -0.5 |

Based on Table 1 shows variation index climate seasonal consists of from DJF (December -January-February) to NDJ (November-December-January) which is used For ENSO indicator . For the period 2018-2025, the ENSO index shows dynamic phase. In 2018 still happen transition from La Niña to El Niño, while 2019 was in a weak El Niño condition . In 2020-2022 , transition from neutral to La Niña, until a strong La Niña event in 2022 has the potential to occur increase rainfall rain . In 2023 it happened strengthening against El Niño with index 2.1 which triggered occurrence drought Because decline rainfall rain . In 2024-2025 it happened condition transition from El Niño to neutral . In 2025 there will be trend La Niña occurs but still in a weak condition . ENSO variations are related with change climate between years that influence rainfall rain and production plant paddy in a way special. As for the ENSO status, it can seen in table 2.

Table 2. ENSO Status and Average Index Climate Seasonal 2018-2025 East Java

| Year | Average | ENSO Status |
|------|---------|------------------------------------|
| 2018 | 0.091 | La Niña → El Niño transition |
| 2019 | 0.575 | El Niño |
| 2020 | -0.275 | Transition Neutral → La Niña |
| 2021 | -0.625 | La Niña |
| 2022 | -0.858 | Strong La Niña |
| 2023 | 0.908 | Strong El Niño |
| 2024 | 0.433 | El Niño Transition → Neutral |
| 2025 | -0.258 | Neutral (tending towards La Niña) |

Average index climate seasonal show difference ENSO character in East Java (table 2). In 2023 it shows mark index highest (0.908) which is marked with a strong El Niño . Lowest value occurred in 2022 with value -0.858 with marked existence Strong La Niña. 2021-2022 still condition La Niña and variability climate the changes are very fast with 2023 condition is a strong El Niño . ENSO dynamics trigger change pattern climate that needs For become attention in effort guard production paddy still stable in the East Java region .

Table 3. Average rainfall Rain monthly and total rainfall Rain annual

| Year | Average rainfall rainfall (mm/ month) | Annual total (mm/ year) |
|------|--|--------------------------|
| 2018 | 190 | 2,280 |
| 2019 | 125 | 1,500 |
| 2020 | 230 | 2,760 |
| 2021 | 260 | 3,120 |
| 2022 | 254.9 | 3,058.8 |
| 2023 | 132.4 | 1,588.8 |
| 2024 | 178.9 | 2,146.8 |
| 2025 | 234 | 2,808.4 |

Based on the data in table 3 it shows variation rainfall rain in East Java in 2018-2025 . In 2021 there will be rainfall the highest rainfall with average monthly rainfall of 260 mm/ month and annual total of 3058.8 mm/ year . In 2019 there was a total rainfall of 260 mm/month and annual total of 3058.8 mm/year. Rain annual lowest 1500 mm/ year with average monthly 125 mm/ month . Fluctuation happen between 2018-2021 however tend experience increase . Increase sharp happen from 2020 to 2021 , before experience decline Again . Until 2025 it will experience increase rainfall Rain up to 2808.4 mm/ year . Conditions rainfall varying rainfall every year will influence water availability . Impact main from water availability occurs under conditions growth plants , especially in the phase critical namely in the phase generative Where plant start do flowering and filling grain (Anggraeni et al, 2025).

Table 4. Analysis Pearson correlation between ENSO Index , Rainfall , Harvested Area , and Production Paddy East Java 2018–2025

| ENSO | ENSO | Rainfall | Production Paddy | Harvested Area |
|-------------------------|----------|----------|------------------|----------------|
| Pearson Correlation | 1 | -0.959** | -0.104 | -0.266 |
| Sig. (2-tailed) | | 0,000 | 0.824 | 0.564 |
| N | 8 | 8 | 7 | 7 |
| Rainfall | | | | |
| Pearson Correlation | -0.959** | 1 | 0.107 | 0.240 |
| Sig. (2-tailed) | 0,000 | | 0.819 | 0.604 |
| N | 8 | 8 | 7 | 7 |
| Production Paddy | | | | |
| Pearson Correlation | -0.104 | 0.107 | 1 | 0.979** |
| Sig. (2-tailed) | 0.824 | 0.819 | | 0,000 |
| N | 7 | 7 | 7 | 7 |
| Harvested Area | | | | |
| Pearson Correlation | -0.266 | 0.240 | 0.979** | 1 |
| Sig. (2-tailed) | 0.564 | 0.604 | 0,000 | |
| N | 7 | 7 | 7 | 7 |

Description: Pearson correlation test at $\alpha = 0.05$; ** indicates a significant correlation at $p < 0.01$. The r value indicates the direction and strength of the relationship between variables.

Based on Table 4, it shows that the ENSO index has a strong negative correlation with rainfall ($r = -0.959$; $p < 0.05$), with the El Niño tendency having an impact on decreasing rainfall.

rice ($r = -0.104$) and area harvest (-0.266) against ENSO shows results that are not significant. This shows that the influence of ENSO to production rice is not visible directly in the period observation. Strong relationship occurs in a wide area harvest and production rice ($r = 0.979$; $p < 0.05$), meaning that factor strong that causes improvement production paddy is wide harvest

Discussion

The relationship between ENSO and rainfall Rain tend influential strong in East Java. El Niño causes decline rainfall rain, while in more favorable conditions wet triggered by La Niña conditions. In strong El Niño conditions in 2023, there will also be conditions Where rainfall rain that falls. Variability rainfall rain on the island Java related close with ENSO phenomenon. Strong influence from interaction atmosphere ocean in a way strong influence rainfall rain in the Java region, especially in the Indonesian Pacific. The El Niño phenomenon causes higher sea levels cold (SST which is an anomaly for the Indonesian region. Circulation *Walker* who tends to weakening which is significant trigger decline rainfall Rain (Prapanca et al, 2024)

Production paddy Not yet own direct influence in a way significant facing ENSO. Conditions This gives the meaning that existence decline rice production own factor complex determinants. In the production system agriculture Lots factors that can influence production, internal and external factors give a big influence on production plants. In conditions global The presence of ENSO affects agricultural systems. The El Niño and La Niña phases impact production. majority food main including rice, corn, and wheat (Zhu et al, 2025). Decline GKG results and straw can caused by water stress. The affected parameters Can occurs at length panicle, number grain per panicle, up to test weight of 100 grains grain. There is possibility improvement grain empty in affected plants stress that occurs from phase tillering, flowering, and phases harvest. Water stress that occurs in the harvest phase young children who are still in condition vegetative No direct lower production plant rice, if phase flowering and harvest Still in sufficient water conditions (Venkatesan et al, 2005).

Harvest area and production paddy Of course own strongest relationship. Improvement production from plant paddy influenced area land is also increasing, so Can be one of factor determinant main. Management from production become the basics compared to with ENSO variability in East Java. Many factors trigger it. existence decline and rise production paddy in a way common in various regions in Indonesia, including activity on-farm and off-farm (Herho et al, 2021) techniques. Research in other Southeast Asian countries, namely Thailand, shows that ENSO induces occurrence stress drought in plants so that impact straight to the bottom results harvest (Wannasingha et al, 2025) Variability climate in various regions can own difference response, thing the can influenced by technology cultivation, irrigation systems, and management farmers who have survival strategies in face change climate. Stability production paddy Can overcome with various method management appropriate cultivation for farmers in each region. This Can done with utilise wisdom local with combination of technology renewable in the field agriculture.

CONCLUSIONS

Based on results research, ENSO has strong relationship to variability rainfall rain in East Java, especially show that improvement El Niño conditions tend to followed by a decline rainfall rain. However, changes in ENSO and rainfall Rain Not yet show influence direct to production paddy during 2018–2025 period. Production paddy more close related with wide harvest that shows the relationship is very strong, so factor management production become factor important in determine results rice. Condition This show that adaptation strategy like management irrigation, use varieties adaptive, and implementation technology cultivation can play a role in reduce impact variability climate to production rice in East Java.

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