Journal of Agrometeorology

ISSN : 0972-1665 (print), 2583-2980 (online)
Vol. No. 27 (2) :144-147(June - 2025)
https://doi.org/10.54386/jam.v27i2.2827
https://journal.agrimetassociation.org/index.php/jam

Research Paper

Impact of climate variability on nutmeg production in the Banda Islands, Maluku, Indonesia

JOHANNA AUDREY LEATEMIA[1,2]*, SEMUEL LAIMEHERIWA[2] and HERMAN REHATTA[2]

[1]Agricultural Science Study Program, Post Graduate Program. Pattimura University, Poka-Ambon 97233, Indonesia
[2]Agrotechnology Study Program, Faculty of Agriculture, Pattimura University, Poka-Ambon 97233, Indonesia
**Corresponding author email: jaleatemia@hotmail.com*

ABSTRACT

Maluku, an archipelagic province with many small islands, is a key nutmeg-producing region in Indonesia. However, nutmeg production has declined over time for unclear reasons. This study aims to assess climate change and its impact on nutmeg production in the Banda Islands, Maluku, Indonesia, by analyzing long-term (1964–2023) rainfall trends and the relationship between climate variables and crop productivity. The relationship between climate variables and nutmeg production over a 15-year period was analyzed using Principal Component Analysis (PCA). The results showed annual rainfall in the Banda Islands increased by 13% in 1994–2023 compared to 1964–1993. The frequency of El Niño events decreased from 8 to 4, while La Niña events increased from 4 to 8 over the same periods. Nutmeg production is positively correlated with rainfall and relative humidity, while it is negatively associated with air temperature and sunshine duration.

Keywords: Banda Islands, Nutmeg production, Rainfall, Temperature, Humidity, Solar radiation

Nutmeg (*Myristica fragrans* Houtt.) is native to the Banda Islands, Maluku Province, Indonesia (Janick & Paull, 2008). Today, it is cultivated in Grenada, India, Sri Lanka, Mauritius, South Africa, and the USA (Sasikumar, 2021). Historically, Maluku has been renowned for its high-quality spices, particularly nutmeg, which remains a key source of income for farmers. Indonesia is the world's leading nutmeg exporter, accounting for 61.28% of global exports in 2023, with 19,456.4 tons shipped (BPS Indonesia, 2024; BPS Maluku, 2024; WITS, 2023).

Climate change is a global phenomenon affecting food crop and plantation production, including in Indonesia (Akmalia, 2022; Bhattacharjee *et al*., 2022). El Niño and La Niña events have been closely related to occurrence of floods and droughts in different parts of the globe and their impact on crop production (Mergia, 2024; Lee and Dang 2018). Therefore, this study aims to assess climate change and its impact on nutmeg production in the Banda Islands, Maluku, Indonesia, by analyzing long-term rainfall trends in relation to El Niño and La Niña events and the relationship between climate variables and crop productivity.

MATERIAL AND METHOD

The monthly rainfall data over 60 years (1964–2023) were obtained from the Climate Data and Information Laboratory, Faculty of Agriculture, Pattimura University Ambon, and the Banda Neira Meteorological Station. To analyze rainfall trends, the data was divided into two periods: 1964–1993 and 1994–2023. El Niño and La Niña years were identified based on ENSO History Nino 3.4 data, adjusted to the rainfall time series in the study area. Nutmeg production data for a 15-year period (2009-2023) was obtained from the Central Statistical Bureau of Central Maluku Regency. The relationship between climate variables (rainfall, sunshine duration, temperature, and relative humidity) and nutmeg production was analyzed using Principal Component Analysis (PCA) in Minitab 17." The use of PCA was justified because statistical tests indicated the presence of multicollinearity in the dataset, with Variance Inflation Factor (VIF) values significantly greater than 10.

RESULTS AND DISCUSSION

Rainfall changes trends

Analysis of 60 years of rainfall data (1964–2023) shows a

Article info - DOI: *https://doi.org/10.54386/jam.v27i2.2827*
Received:28 November 2024; Accepted: 25 February 2025; Published online : 1 June, 2025

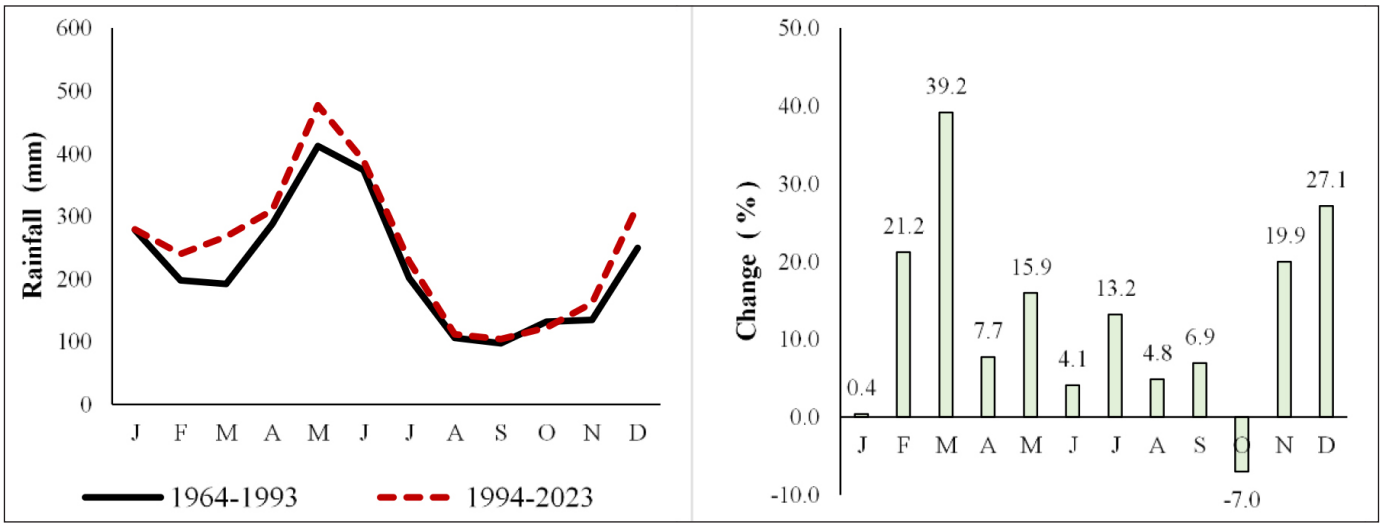

Fig. 1: Rainfall change trends in the Banda Islands: Period 1964-1993 and 1994-2023

Table 1: Rainfall received in El Nino and La Nina events years during 1964-2023

El Nino		La Nina	
Year	Rainfall (mm)	Year	Rainfall (mm)
1965	1747	1970	3733
1972	2284	1983	4276
1979	2333	1988	3406
1982	2399	1989	4491
1986	2340	1998	4234
1987	1293	1999	5660
1991	1657	2000	3448
1992	1797	2008	3383
1997	1167	2010	3539
2002	2038	2017	4484
2015	1513	2021	3775
2023	1981	2022	4210
Mean	1879.08	Mean	4053.25

significant increase in average annual rainfall in the Banda Islands, rising by 13.0% (345 mm) from 2,660 mm (1964–1993) to 3,005 mm (1994–2023) (Fig. 1). Monthly comparisons reveal increased rainfall in nearly all months, ranging from 0.4% (January) to 39.2% (March), except for October, which saw a 7.0% decline. The largest increases (13.2–39.2%) occurred in February, March, May, July, November, and December, while January, April, June, August, and September saw smaller increases (0.4–7.7%) (Fig. 1).

Recent studies indicate an increase in the frequency and intensity of extreme climate events, along with shifts in global climate patterns driven by global warming (Kaimuddin, 2000; Laimeheriwa, 2014). Research in Maluku shows a rise in annual rainfall over the past 30 years compared to the previous 30 years, with increases of 1.5–5.0% in equatorial rainfall areas, 11.2–14.0% in local rainfall areas, and 15.6–17.8% in monsoon rainfall areas (Laimeheriwa, 2014).

El Nino and La Nina rainfall anomalies

El Niño causes below-normal rainfall in most parts of Indonesia, while La Niña leads to above-normal rainfall. However, their intensity and impact vary—some areas may experience strong effects while others are less affected, and in certain years, these phenomena may occur in one region but not in others (Aldrian *et al*., 2007). Studies in Maluku, which has three distinct rainfall patterns, show that El Niño/La Niña affects each region differently. These events typically begin in April and end in December (Aldrian *et al*., 2007; As-Syakur, 2010). Their impact is strongest in areas with monsoonal rainfall patterns, weaker in equatorial rainfall regions, and unclear in areas with local rainfall patterns (Laimeheriwa, 2014; Kelbulan *et al.,* 2021).

Based on the Oceanic Niño Index (ONI), derived from NOAA's sea surface temperature (SST) measurements in the Niño 3.4 region, Indonesia experienced 21 El Niño events between 1964 and 2023, occurring every 1–5 years, with an average frequency of once every 3 years. In the Banda Islands, 12 out of 20 below-normal rainfall events coincided with El Niño occurrences recorded in Niño 3.4, averaging once every 5 years, with a range of 1–13 years (Table 1).

The occurrence of below-normal rainfall (drought) in the Banda Islands does not always coincide with El Niño, nor does El Niño always cause drought. In 1964, 1967, 1973, 1974, 1975, 1990, 1993, 2003, and 2019, annual rainfall in the Banda Islands fell below normal levels (<2408 mm/year) (Fig. 1), yet these years were not classified as El Niño years. Conversely, El Niño events in 1968, 1969, 1976, 1977, 1994, 2004, 2006, 2009, and 2018 (ENSO History Niño 3.4 data) did not result in below-normal rainfall or drought in the region. In the Banda Islands, 12 of 23 above-normal rainfall years coincided with La Niña events in Indonesia, with a frequency of 1–13 years and an average of 5 years (Table 1).

Similar to El Niño, above-normal rainfall does not always coincide with La Niña, nor does La Niña always result in above-normal rainfall (Kaimuddin, 2000). In 1969, 1980, 1984, 2001, 2012, 2013, and 2014, rainfall in the Banda Islands exceeded 3,257

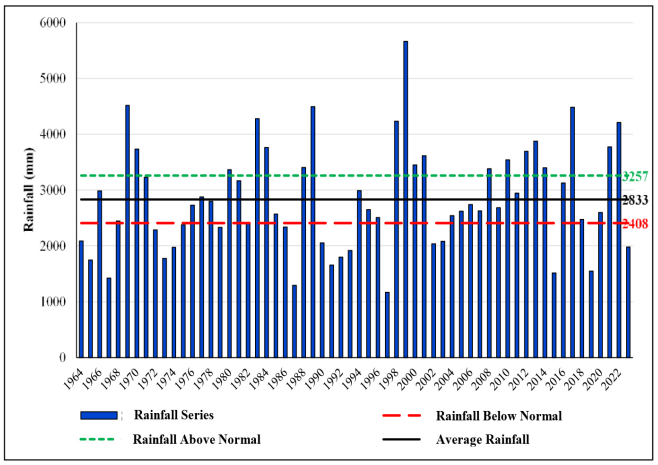

Fig. 2: Distribution of annual rainfall in the Banda Islands for the period 1964-2023

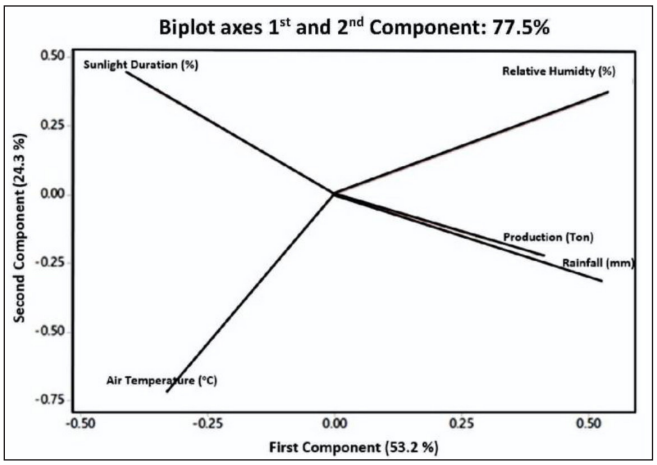

Fig. 3: Principal component analysis (PCA) of climate variables and nutmeg production in Banda Island

mm/year but were not classified as La Niña years (ENSO History Niño 3.4 data). Conversely, La Niña events did not lead to above-normal rainfall in the region.

As shown in Fig. 2 and Table 1, extreme rainfall events linked to El Niño and La Niña have each occurred 12 times. However, their frequency has shifted over time—El Niño-related events decreased from 8 (1964–1993) to 4 (1994–2023), while La Niña-related events increased from 4 to 8 over the same periods. This trend aligns with the observed 13% increase in rainfall in 1994–2023 compared to 1964–1993, suggesting a wetter climate in the Banda Islands. To mitigate potential flooding and plant growth disruptions, especially during the peak rainy season (April–June), anticipatory measures should be implemented in vulnerable planting areas.

Correlation between climate variables and nutmeg production

The correlation between climate variables and nutmeg production in Banda Island was analyzed using Principal Component Analysis (PCA) (Fig. 3). The analysis resulted in two principal components with eigenvalues greater than 1. The first principal component (PC1) has an eigenvalue of 2.66, explaining 53.2% of the total variance, while the second principal component (PC2) has an eigenvalue of 1.22, accounting for 24.3% of the variance. Together, these two components explain 77.5% of the total variation in the dataset, which is considered reasonably reliable for dimensionality reduction (Jolliffe, 2002).

The PCA results revealed that air temperature and sunshine duration are positively correlated with each other, while they are negatively correlated with relative humidity, rainfall, and production. Sunlight is the primary energy source for photosynthesis. However, if air temperature exceeds the optimal threshold for nutmeg plants, respiration increases more than photosynthesis, leading to excessive energy loss. This energy, which would otherwise support growth and fruit production, is instead used for maintenance, ultimately reducing yield. While air temperature and sunshine duration are positively correlated, an increase in both does not always enhance nutmeg production. When temperature rises beyond optimal levels and water availability is limited, photosynthetic efficiency declines, respiration intensifies, and plants experience physiological stress, leading to reduced production (Zhou and Lin, 2023).

At optimal temperatures, photosynthesis, cell division, and transpiration are enhanced, supporting plant growth and fruit formation. However, excessive heat increases respiration, disrupts photosynthesis, and triggers heat stress, which can impair enzyme function, destabilize cellular membranes, and reduce yields (Nobel, 2020; Bhattacharjee *et al*., 2022). Conversely, temperatures that are too low slow metabolic activity, inhibit flowering, and limit fruit development. These temperature-related physiological constraints explain why nutmeg production is closely linked to climatic conditions (Chinnusamy *et al.,* 2007).

Relative humidity, rainfall, and production exhibit a positive relationship, suggesting that higher humidity and adequate rainfall contribute to increased nutmeg production. Sufficient soil moisture prevents water stress, which is often a limiting factor in crop growth. These conditions promote the development of broader leaves, enhancing light capture and photosynthetic efficiency. With optimal photosynthesis and nutrient uptake, fruit production improves in both quantity and quality (Lee and Park, 2023).

Rainfall determines soil moisture levels, directly influencing key physiological processes such as photosynthesis, transpiration, and cell division. Adequate water availability enhances nutrient transport, protein synthesis, and fruit filling, all of which contribute to increased yield. However, excessive rainfall can lead to soil saturation, reducing oxygen availability in the root zone. This condition weakens root function, limits nutrient uptake, and ultimately suppresses fruit production (Kramer and Boyer, 1995). Relative humidity influences transpiration, a critical process for leaf temperature regulation and nutrient absorption. High humidity reduces transpiration, which can limit carbon dioxide uptake and negatively affect photosynthesis and plant growth. Conversely, excessively low humidity accelerates transpiration, increasing the risk of water stress, especially when rainfall is insufficient. The interaction between adequate rainfall and optimal relative humidity is essential to maintaining a balance between water uptake by roots and water loss through transpiration, ensuring stable growth and production

CONCLUSION

Annual rainfall in the Banda Islands increased by 13% in 1994–2023 compared to 1964–1993. The frequency of El Niño events decreased from 8 to 4, while La Niña events increased from 4 to 8 over the same periods. Nutmeg production is positively correlated with rainfall and relative humidity, while it is negatively associated with air temperature and sunshine duration. An optimal balance of these climate variables creates favorable conditions for growth and maximum production. Conversely, an imbalance in one or more of these factors may lead to reduced yields. Farmers have observed changes in climate patterns, particularly the increasing unpredictability of seasonal transitions.

ACKNOWLEDGEMENT

The authors want to thank DRTPM, Directorate of Higher Education, Research and Technology, Ministry of Education, Culture, Research and Technology of the Republic of Indonesia for funding this research and BMKG Pattimura Ambon for providing necessary data.

Conflict of Interests: The authors declare that there is no conflict of interest related to this article.

Data availability: to be provided on request

Author's contribution: **J.A. Leatemia**: Conceptualization, methodology writing-review, editing; **S. Laimeheriwa**: Methodology, data collection & analysis, writing; **H. Rehatta**: Methodology. data collection & analysis, writing.

Disclaimer: The contents, opinions and views expressed in the research article published in the Journal of Agrometeorology are the views of the authors and do not necessarily reflect the views of the organizations they belong to.

Publisher's Note: The periodical remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

REFERENCES

Aldrian, E., Gates, L.D. and Widodo, F.H. (2007). Seasonal variability of Indonesian rainfall in ECHAM4 simulations and in the reanalyzes: The role of ENSO. *Theor. Appl. Climatol.*, 87: 41–59.

Akmalia, H. A. (2022). The Impact of Climate Change on Agriculture In Indonesia And Its Strategies: A Systematic Review. *Agritepa,* 9 (1): 145-160.

As-Syakur, A.R. (2010). Spatial pattern of the influence of La Nina event on rainfall in Indonesia in 1998/1999: Observation using TRMM Multisatellite Precipitation Analysis (TMPA) 3B43 data. Prosiding Pertemuan Ilmiah Tahunan MAPIN XVII "Teknologi Geospasial Untuk Ketahanan Pangan dan Pembangunan Berkelanjutan" pp 230-234.

Bhattacharjee, P., Warang, O., Das, S. and Das, S. (2022). Impact of climate change on fruit crops- A review. *Curr. World Environ.,* 17(2): 319-330. http://dx.doi.org/10.12944/CWE.17.2.4.

BPS (Badan Pusat Statistik) Indonesia. (2024). Statistical Yearbook of Indonesia 2024. BPS, Jakarta. pp. 804.

BPS (Badan Pusat Statistik) Maluku. (2024). Maluku Province in Figure. BPS, Ambon. pp. 650

Chinnusamy, V., Zhu, J., and Zhu, J. K. (2007). Cold stress regulation of gene expression in plants. *Trends Plant Sci*., 12(10): 444–451. https://doi.org/10.1016/j.tplants.2007.07.002

Janick, J. and Paull, R. E. (2008). The Encyclopedia of Fruit & Nuts. Wallingford: CABI. pp. 487-488. ISBN: 978-0-85199-638-7.

Jolliffe, I. T. (2002). Principal Component Analysis (2nd ed.). Springer. DOI: 10.1007/b98835

Kaimuddin. (2000). The impact of climate change and land use on the water balance of South Sulawesi: a case study of the Walanae Hulu watershed and the Saddang watershed. Dissertation. IPB, Bogor.

Kelbulan, E., Laimeheriwa, S. and Patty, J.R. (2021). Analysis of El Nino events and their impact on the growing season and productivity of peanut (*Arachis hypogaea* L) in Kei Kecil Island, Maluku Tenggara Regency. *J. Budidaya Pertanian,* 17(1):52-58. https://doi.org/10.30598/jbdp.2021.17.1.52.

Kramer, P. J., and Boyer, J. S. (1995). Water Relations of Plants and Soils. Academic Press.

Laimeheriwa, S. (2014). Trend analysis of rainfall change at three regions with different rain pattern in Maluku Province. *J. Budidaya Pertanian,* 10(2):71-78.

Lee, Seung Kyu, and Truong An, Dang. (2018). Evaluating drought events under influence of El-Nino phenomenon: A case study of Mekong delta area, Vietnam. *J. Agrometeorol.*, 20(4): 275–279. https://doi.org/10.54386/jam.v20i4.565

Lee, H. and Park, S. (2023) "Synergistic Effects of Rainfall and Humidity on Crop Yield and Quality." *J. Agri. Meteorol.,* 80(1): 98-110.

Mergia, G. (2024). Spatiotemporal analysis of meteorological drought in El Niño years over Oromia region, Ethiopia. *J. Agrometeorol.*, 26(1): 109-114. https://doi.org/10.54386/jam.v26i1.2329

Nobel, P. S. (2020). Physicochemical and Environmental Plant Physiology (5th ed.). Academic Press.

Sasikumar, B. (2021). Nutmeg - Origin, diversity, distribution and history: Journey of nutmeg, *J. Spices Aromatic Crops,* 30 (2): 131-141. DOI:10.25081/josac.2021.v30.i2.7250

WITS (World Integrated Trade Solution) (2023). Nutmeg exports by country in 2023.

Zhou, X. and Lin, H. (2023). Effects of High Temperature and Light Intensity on Plant Growth and Yield. *Environ. Exp. Bot.*, 207: 105165.