

Analysis of drought index and its relationship with Rose (*Rosa* sp.) productivity in Batu City, East Java

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ABSTRACT

Batu City was one of the main centers of cut flower production in East Java, particularly for roses (*Rosa* sp.), where favorable climatic conditions support floriculture development. However, rose productivity has fluctuated in recent years, potentially linked to rainfall variability and meteorological drought influenced by global climate phenomena such as the El Niño–Southern Oscillation (ENSO) and the Indian Ocean Dipole (IOD). This study aimed to analyze the temporal characteristics of meteorological drought in Batu City using the Standardized Precipitation Index (SPI), examine the relationship between SPI values and rose productivity, and determine the sensitivity of rose productivity to drought conditions. The study employed secondary data consisting of monthly rainfall records from 1981–2024 obtained from the CHIRPS dataset and annual rose productivity data from the Batu City Statistics Agency (BPS). SPI values were calculated using SPI-3 through the SPEI package in RStudio, followed by Spearman correlation and simple linear regression analyses. In addition, primary data were collected through interviews with rose farmers in Gunungsari Village, Bumiaji District, to provide field-based perspectives on climate impacts. The results showed a correlation coefficient of 0.278 between SPI values and rose productivity, indicating a weak relationship. Despite this, 91.3% of farmers identified weather conditions as the main factor affecting production and flower quality. These findings suggest that meteorological drought alone cannot fully explain rose productivity variations, as cultivation practices, water management, and other environmental and economic factors also play important roles.

Keywords: climate variability, meteorological drought, rose productivity, rainfall variability, standardized precipitation index (SPI)

INTRODUCTION

Climate variability has become a major challenge to agricultural sustainability, particularly in tropical regions where crop productivity depends heavily on rainfall patterns. Rainfall is one of the most important climatic factors influencing plant growth, water availability, nutrient absorption, and photosynthetic activity. When rainfall occurs at an optimal level, soil moisture can support physiological processes and biomass accumulation, whereas rainfall deficits may cause water stress and reduce crop productivity (Khan et al., 2025). In contrast, excessive rainfall may increase soil moisture beyond the optimal

threshold, resulting in poor root aeration, nutrient leaching, and greater susceptibility to plant diseases (Serrano-Vincenti et al., 2025). Therefore, changes in rainfall distribution may significantly influence agricultural productivity, particularly in horticultural crops that require stable environmental conditions.

Horticultural crops, especially cut flowers, are more sensitive to water availability than staple crops because product quality is strongly influenced by environmental factors during plant growth. Water availability affects stem elongation, flower size, pigment accumulation, and postharvest quality. Environmental factors such as irrigation, humidity, and rainfall patterns influence xylem development, stomatal

regulation, and carbohydrate allocation, which ultimately determine flower quality and vase life (Verdonk et al., 2023). Irregular rainfall patterns may therefore alter flowering cycles, reduce product quality, and affect market supply in floriculture systems (Park et al., 2025).

Among ornamental crops, rose (*Rosa* sp.) is one of the most economically important floricultural commodities. Rose cultivation requires stable water availability because drought stress can negatively affect both vegetative growth and flowering performance. Previous studies reported that drought stress significantly reduces stem length, flower diameter, dry flower biomass, and petal development in roses (Zarif et al., 2025). Water deficit also reduces photosynthetic rate, stomatal conductance, chlorophyll content, and osmotic adjustment, which eventually decreases flower formation and biomass production (Hajizadeh et al., 2022). In addition, genotype variation influences drought tolerance among rose cultivars, resulting in different production responses under water-limited conditions (Li et al., 2024). These findings indicate that rainfall variability has an important role in determining rose productivity.

Meteorological drought is generally defined as a prolonged period of below-normal precipitation that causes water deficits in a region (Wang & Ren, 2025). One of the most widely used methods for monitoring meteorological drought is the Standardized Precipitation Index (SPI), which was first developed by McKee et al. and later recommended by the World Meteorological Organization as a standard drought monitoring tool because it requires only precipitation data and can be applied across different climatic regions (Stagge et al., 2015). SPI has been successfully applied in Indonesia to identify drought events associated with global climate anomalies such as El Niño–Southern Oscillation (ENSO) and Indian Ocean Dipole (IOD), both of which strongly influence rainfall variability in Java (Siswanto et al., 2022).

In East Java, the interaction between ENSO and IOD may intensify rainfall anomalies and increase the risk of drought events, particularly in highland agricultural areas (Nur'utami & Hidayat, 2016; Nurdianti et al., 2022). Batu City is one of the main floriculture production centers in East Java,

especially for rose cultivation, but rose productivity has fluctuated over recent decades. Despite the economic importance of this commodity, studies examining the relationship between meteorological drought and rose productivity remain limited. Therefore, this study aimed to analyze meteorological drought characteristics in Batu City using SPI and evaluate their relationship with rose productivity under long-term climatic variability.

MATERIALS AND METHODS

Research Location

This research was conducted from December 2025 to May 2026 in Batu, East Java, Indonesia. The study area covered three sub-districts, namely Bumiaji, Batu, and Junrejo, which are recognized as important horticultural production areas, particularly for rose cultivation. Geographically, Batu City was located at 7°44'–7°57' S and 112°25'–112°39' E, with an elevation ranging from 700 to 1,700 meters above sea level. The region had a tropical highland climate and was characterized by high rainfall variability, making it suitable for drought analysis.

Materials and Data Collection

This study used both primary and secondary data. Secondary data consisted of monthly rainfall data from 1981 to 2024 obtained from the Climate Hazards Group InfraRed Precipitation with Station data (CHIRPS) through Google Earth Engine. The rainfall dataset was spatially extracted for the Batu City administrative area and exported as a CSV for further analysis. In addition, annual rose productivity data from 2004 to 2024 were collected from Badan Pusat Statistik and the local agricultural office. Supporting climate data, including ENSO and IOD indices, were also used to interpret regional climate variability.

Primary data were obtained through direct interviews with rose farmers in Batu City. Informants were selected using purposive sampling, with a minimum of five farmers who had at least five years of experience in rose cultivation. Interviews were conducted using structured interview guidelines and questionnaires covering cultivation practices, irrigation systems, perceived rainfall changes, drought impacts, and

adaptation strategies implemented by farmers. Responses were recorded and categorized according to major themes for further qualitative interpretation.

Data Processing and Drought Analysis

Monthly rainfall data in Microsoft Excel and converted into a time-series format. Meteorological drought was analyzed using the Standardized Precipitation Index (SPI) at a three-month timescale (SPI-3), which was considered suitable for detecting short-term drought conditions affecting vegetative growth and flowering. SPI calculations were performed using RStudio with the SPEI package. The analysis included transforming monthly rainfall data into a time-series dataset, calculating SPI-3 values for each month, and visualizing temporal drought patterns.

Statistical Analysis

Monthly SPI values were averaged annually and matched with annual rose productivity data for the corresponding observation period. The relationship between drought conditions and rose productivity was analyzed using Pearson or Spearman correlation, depending on the data distribution characteristics. If a significant relationship was observed, simple linear regression analysis was applied to evaluate the direction and magnitude of SPI influence on rose productivity. In addition, interview data were analyzed descriptively using thematic analysis to support and validate the quantitative findings.

RESULTS

The SPI-3 analysis showed that meteorological drought conditions in Batu City varied considerably during 1981–2024. The most severe and longest drought event occurred from October 2006 to March 2007, lasting six consecutive months, with the lowest SPI-3 value recorded in January 2007 (-2.35). In contrast, the wettest period occurred from March to December 2010, with a peak SPI-3 value of 3.02 in September 2010. Overall, normal climatic conditions dominated the observation period, accounting for 68.13% of all recorded months (Figure 1).

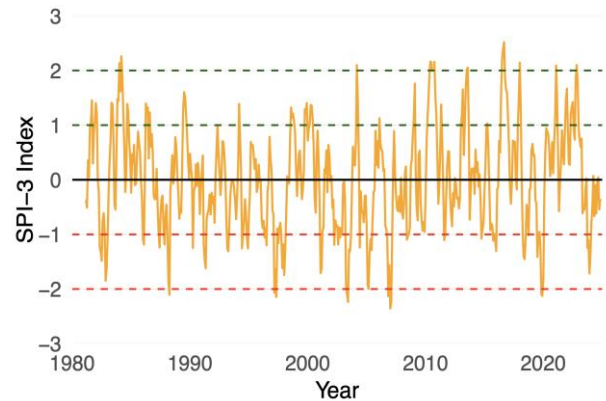


Figure 1. SPI Batu City 1981-2024

Temporal variations in SPI-3 were associated with fluctuations in large-scale climate indices. Negative SPI-3 values occurred more frequently during El Niño episodes, whereas positive SPI-3 values were generally observed during La Niña conditions. Spearman correlation analysis revealed a significant negative relationship between SPI-3 and ENSO ($r=-0.472$; $p<0.001$), as well as between SPI-3 and IOD ($r=-0.347$; $p<0.001$). The stronger correlation coefficient obtained for ENSO indicates a greater influence of ENSO on rainfall variability in Batu City compared with IOD (Figures 2 and 3).

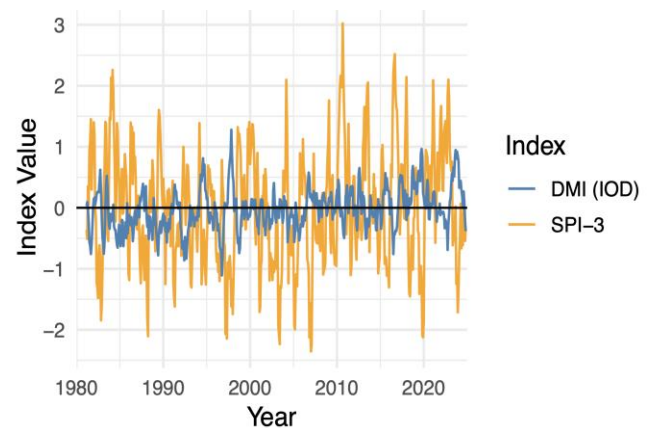


Figure 2. Comparison of SPI and DMI (IOD)

Rose productivity in Batu City fluctuated annually during 2004–2024. Productivity values ranged from 11.53 to 33.98 stems $\text{m}^{-2}/\text{year}$, with an average of 20.87 stems $\text{m}^{-2}/\text{year}$ (Figure 4). The highest productivity was recorded in 2016, while lower productivity values were observed in several years associated with unfavorable climatic conditions.

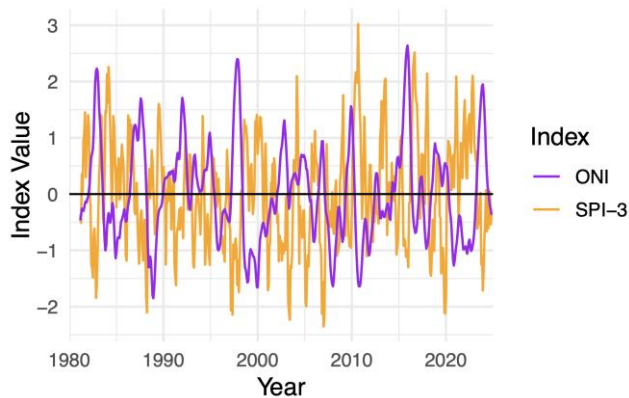


Figure 3. Comparison of SPI and ENSO (ONI)

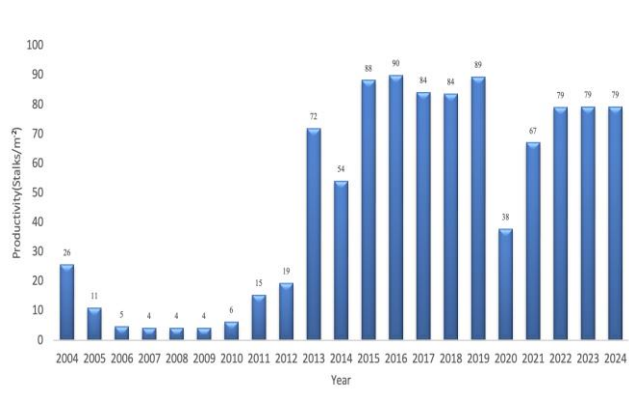


Figure 4. Rose productivity (Stalks m-2/year)

Spearman correlation analysis between annual SPI-3 values and rose productivity resulted in a correlation coefficient of 0.278, indicating a weak positive relationship between the two variables (Table 1). The positive coefficient suggests that higher SPI-3 values tended to be associated with increased productivity; however, the relationship strength was relatively low.

Table 1. Results of Spearman correlation test between SPI and rose flower productivity

Index	Correlation Coefficient (r)	p-value	Information
SPI-3	0.278	0.2217	insignificant

Note: (Significance level $\alpha=0.05$)

Simple linear regression analysis produced a positive regression coefficient between SPI-3 and rose productivity. The regression model indicated that increases in SPI-3 were followed by slight increases in productivity. Nevertheless, the coefficient of determination (R^2) was low, indicating that only a small proportion of productivity variation could be explained by SPI-3 values (Table 2).

Table 2. Results of the SPI linear regression equation on rose flower productivity

Parameter	Value
Regression Equation	$Y = 46.718 + 9.408X$
Coefficient of Determination (R^2)	0.031

Note: Y = Rose productivity (stems/m²/year), X = Annual SPI value

Interviews with rose farmers revealed that weather conditions were perceived as the most influential factor affecting productivity. Approximately 91.3% of respondents identified prolonged dry periods and excessive rainfall as the primary causes of yield fluctuations. Farmers also reported implementing adaptation strategies, including irrigation management, adjustment of planting schedules, and more intensive crop maintenance during extreme weather conditions.

DISCUSSION

The temporal variability of SPI-3 in Batu City indicates that meteorological drought remains an important climatic phenomenon despite the region's relatively high annual rainfall. The occurrence of severe drought during 2006–2007 and extremely wet conditions in 2010 reflects the strong influence of large-scale climate variability on local rainfall patterns. Similar findings have been reported in several regions of Indonesia, where drought and wet anomalies were closely associated with fluctuations in atmospheric-oceanic circulation systems (Ainayyah et al., 2024; Firmansyah et al., 2022).

The significant negative correlations between SPI-3 and both ENSO and IOD demonstrate that these climate drivers play an important role in controlling rainfall variability in Batu City. The stronger correlation observed between SPI-3 and ENSO compared with IOD suggests that ENSO exerts a greater influence on local precipitation conditions. This finding was consistent with previous studies showing that El Niño events generally reduce rainfall across Java, while La Niña events increase rainfall and contribute to wetter conditions. Likewise, positive IOD events have been reported to suppress rainfall over southern Indonesia, whereas negative IOD events tend to enhance precipitation. The agreement between the present study and previous findings confirms the sensitivity of Batu City's rainfall

regime to large-scale ocean-atmosphere interactions (Mardiansyah et al., 2018).

Although SPI-3 showed a positive relationship with rose productivity, the correlation coefficient was relatively weak ($r = 0.278$). This result indicates that meteorological drought alone cannot fully explain variations in rose productivity. Rose production is influenced by multiple factors, including irrigation management, fertilization practices, pest and disease control, plant density, pruning techniques, and cultivar characteristics. Therefore, favorable rainfall conditions do not necessarily guarantee high productivity when other agronomic constraints are present. Conversely, productivity may remain relatively stable during dry periods when adequate irrigation is available (Putri et al., 2025).

The weak relationship observed in this study differs from findings reported in several horticultural crops where drought conditions significantly reduced yield and growth performance. Water deficit limits photosynthesis, nutrient uptake, biomass accumulation, and flower development. In roses, prolonged drought may reduce stem length, flower diameter, and overall flower quality. However, the relatively low correlation found in Batu City suggests that local farmers have implemented adaptation strategies that reduce the direct impact of rainfall variability on crop performance (Pooja et al., 2024).

Interview results support this interpretation. Most farmers identified weather variability as an important production constraint, yet they also reported implementing adaptive measures such as irrigation management, modified cultivation schedules, and more intensive crop maintenance during dry periods. These practices likely helped buffer the effects of meteorological drought on productivity, thereby weakening the statistical relationship between SPI-3 and production data (Tiasmalomo et al., 2025). A notable finding of this study is that meteorological drought occurred repeatedly in Batu City and was significantly associated with ENSO and IOD variability, yet its influence on rose productivity remained limited. This suggests that the resilience of rose production systems in the study area is not solely determined by climatic conditions but also by farmers' adaptive capacity and crop management practices. Such evidence highlights the importance of

integrating climatic information with agronomic management when evaluating production risks in floriculture systems (Aalam et al., 2024). The findings have practical implications for rose cultivation and climate-risk management in Batu City. Monitoring SPI-3, together with ENSO and IOD indicators, can provide an effective early warning system supporting decision-making in irrigation scheduling and crop management. Integrating climate monitoring with adaptive cultivation practices may improve the resilience and sustainability of rose production under increasing climate variability (Sarku et al., 2025).

CONCLUSION

This study demonstrated that meteorological drought in Batu City, East Java, exhibited considerable temporal variability during 1981–2024, as indicated by the SPI-3 index. Significant negative correlations were observed between SPI-3 and both ENSO and IOD, indicating that these large-scale climate phenomena influence rainfall variability in the study area, with ENSO showing a stronger effect than IOD. The relationship between SPI-3 and rose productivity was positive but weak ($r = 0.278$), suggesting that meteorological drought alone was not the primary determinant of productivity fluctuations. Interview results further indicated that farmers perceived climate variability as an important production constraint, while adaptive cultivation practices helped mitigate its impact on rose production. These findings highlight the importance of integrating climate information, particularly SPI-3, ENSO, and IOD monitoring, with farm management strategies to support sustainable rose cultivation under changing climatic conditions.

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