When the Fields Heat Up: Quantifying the Effects of Temperature and Rainfall on Sugarcane Yield in Bais City, Negros Oriental

DOI: 10.5281/zenodo.18320560

Niñajhane T. Ybañez
Tanjay City Science High School, Tanjay City Division, Negros Oriental Philippines
Charles C. Calumpang
Tanjay City Science High School, Tanjay City Division, Negros Oriental Philippines
Ruth Ann Elyka V. Manso
Tanjay City Science High School, Tanjay City Division, Negros Oriental Philippines

Abstract

This study examines the effects of climatic factors on sugarcane yield in Bais City, Negros Oriental, a key sugarcane-producing area in the Philippines. Sugarcane productivity in the region has been increasingly influenced by climate variability, particularly changes in rainfall and temperature, which affect crop growth and yield stability. This study analyzes the relationship between climatic variables and sugarcane yield using secondary data on average annual rainfall, temperature, and sugarcane production from 2017 to 2024. A quantitative approach was employed, utilizing descriptive statistics, Pearson correlation analysis, and multiple linear regression to determine the extent to which rainfall and temperature influence sugarcane yield. The regression model was applied to quantify the direction and magnitude of these relationships. The findings reveal a positive association between rainfall and sugarcane yield, indicating that adequate moisture availability supports crop growth and productivity. In contrast, temperature shows an inverse relationship with yield, suggesting that higher temperatures impose physiological stress that reduces sugarcane production. These results demonstrate the sensitivity of sugarcane yield to climatic conditions and highlight the importance of climate-responsive agricultural planning. The study emphasizes the need for adaptive strategies to sustain sugarcane production and protect the livelihoods of communities that depend on the sugarcane industry amid increasing climate variability.

Keywords: Sugarcane yield, Rainfall, Temperature, Climate variability, Quantitative analysis.

Introduction

Mathematics plays an important role in addressing real-world agricultural problems. In crop science, statistical and computational methods help researchers analyze data, model relationships, predict crop performance under different environmental conditions, and optimize the use of resources. These methods are especially useful in measuring the effects of climate and soil factors on crop yield, supporting evidence-based planning and decision-making (Lefevre, 2025). Similarly, Dash et al. (2023) explain that mathematical analysis transforms raw agricultural data into useful information for better decision-making and resource management.

Sugarcane is a major industrial crop worldwide and a key source of sugar and bioenergy. Its yield is strongly influenced by environmental factors such as rainfall, temperature, and soil conditions. While high temperatures, particularly during essential growth phases, might lower productivity by disrupting processes like photosynthesis and sugar development, adequate rainfall often increases sugarcane production (Li et al., 2021; Sanghera, 2020).

In the Philippines, sugarcane remains an important agricultural crop that contributes to both regional and national economies (PSA, 2023). However, sugarcane yields vary across locations due to differences in climate, soil conditions, and farm management practices (FAO, 2022). Despite high overall production, local yields often fall below their potential, highlighting the impact of environmental factors on sugarcane productivity.

Bais City, Negros Oriental, is an important sugarcane-producing area in Central Visayas, but sugarcane yields change from year to year due to environmental and farming factors. However, most local studies are descriptive, and there is limited information on how measurable factors such as rainfall, temperature, and soil conditions quantitatively affect sugarcane yield. In addition, there are few localized predictive models that use statistical and computational methods to estimate crop performance under different environmental conditions (Dash et al., 2023).

With the availability of numerical data on climate, soil, and crop production, quantitative methods provide an effective way to analyze these relationships. Descriptive statistics can summarize data patterns, Pearson correlation can identify environmental factors related to yield, and multiple linear regression can measure the strength of these relationships. These methods can then be used to develop a predictive model for estimating sugarcane yield based on rainfall, temperature, and soil characteristics.

Therefore, this study aims to determine how rainfall, temperature, and soil characteristics quantitatively affect sugarcane yield in Bais City, Negros Oriental. The results will support data-driven decision-making for farmers and local agricultural planners and provide a localized predictive model for future agricultural planning and research.

Literature Review

Sugarcane production is influenced by climate, soil conditions, and farming practices, which together affect crop growth and yield. Among climatic factors, temperature plays an important role in sugarcane development. High temperatures can reduce photosynthesis, increase respiration, and limit sugar accumulation, leading to lower yields (Sanghera, 2020; da Silva et al., 2023). Extreme heat also increases water loss and stress, showing that sugarcane remains sensitive to temperature changes even in warm regions. This highlights the need to consider temperature variations when predicting yield.

Rainfall is another key factor affecting sugarcane productivity because it determines water availability and soil moisture. Adequate rainfall supports plant growth and sugar accumulation, while irregular rainfall and prolonged dry periods can reduce yields, especially during critical growth stages (Rodríguez et al., 2023; PSA, 2023). Studies in the Philippines show that climate variability, together with differences in soil and farm management, causes variations in sugarcane production across regions (Sevilla et al., 2025). These findings emphasize the importance of including rainfall patterns in localized yield analysis, such as in Bais City.

Soil properties also influence sugarcane yield by affecting water retention, nutrient availability, and root growth. Soil characteristics such as pH, organic matter, and texture can either support or limit crop performance (Delgadillo-Duran et al., 2020; Viana et al., 2023). Soils that retain water and nutrients more effectively help crops withstand periods of climatic stress. As a result, soil conditions interact closely with temperature and rainfall in determining sugarcane yield.

Since these factors interact in complex ways, predictive and computational models are increasingly used in sugarcane research. Crop models, such as DSSAT-CANEGRO, combine climate and soil data to estimate yield and have shown reliable results when adapted to local conditions (Puckette et al., 2010; IOER International Multidisciplinary Research Journal, 2025). Machine learning methods, including Random Forest and XGBoost, have also been effective in predicting yield by identifying complex relationships between environmental variables and crop performance (Ramadhan et al., 2024; Yao et al., 2025).

Studies in the Philippines further show that localized climate conditions, especially extreme heat, significantly affect sugarcane productivity at the regional level (Sevilla et al., 2025). These findings support the need for location-specific predictive models that reflect local environmental conditions.

Overall, existing literature shows that sugarcane yield in tropical areas like Bais City is highly sensitive to temperature, rainfall, and soil conditions. Integrating these factors into quantitative predictive models provides a useful approach for estimating yield, improving farm management, and supporting agricultural planning under changing climate conditions.

Methodology

This study utilizes a quantitative–descriptive–computational research design. Computational mathematics plays a critical role in agricultural research because it enables the analysis of complex datasets, the simulation of real-world phenomena, and the prediction of outcomes under varying environmental conditions. By combining mathematical concepts with computational techniques, researchers can extract meaningful patterns from numerical agricultural and climate data. In this study, computational methods are applied to rainfall, temperature, and soil-related information to develop a predictive model of sugarcane yield in Bais City, Negros Oriental.

Mathematical modeling techniques, particularly regression analysis, are used to determine how environmental factors influence sugarcane yield. The focus of the model is on rainfall and temperature, as these variables exhibit measurable variation across crop years. Through this approach, the study not only identifies the relationships between climatic variables and yield but also produces a predictive framework capable of estimating sugarcane production under different environmental conditions. Mathematical and computational tools therefore transform raw climate and agricultural data into actionable insights for farmers and policymakers.

Secondary data covering Crop Years 2017–2024 were collected from verified sources. Monthly rainfall (mm) and average monthly temperature (°C) data for Bais City were obtained from the Philippine Atmospheric, Geophysical and Astronomical Services Administration (PAGASA, 2023) and World Weather Online (2023). Historical sugarcane yield per hectare was sourced from the Philippine Statistics Authority (PSA, 2023) and supplemented by records from the Bais City Agriculture Office to ensure local accuracy. Soil data, including pH, organic matter content, and soil texture, were obtained from the Bais City Agriculture Office and regional soil surveys provided by the Bureau of Soils and Water Management (BSWM, 2023).

Bais City contains several soil types, including Isabela Clay, La Castellana Series, Mandaue Clay, Faraon Clay, Guimbalaon Series, Catbalogan Limestone, and non-agricultural soils such as hydrosols. However, soil conditions were considered relatively stable throughout the study period. For this reason, soil variables were treated as constant and excluded from the regression model. The regression analysis therefore focuses on rainfall and temperature, which vary across months and years and have more direct measurable effects on yield fluctuations.

Descriptive statistical analysis was first conducted to summarize trends and variability in rainfall, temperature, and sugarcane yield. Pearson correlation analysis was then applied to identify the strength and direction of relationships between climatic variables and yield. Finally, a multiple linear regression model was developed to quantify the effect of rainfall and temperature on sugarcane productivity.

The predictive model is expressed as:

$$Y = \beta_0 + \beta_1 R + \beta_2 T + \varepsilon$$

Where:

Y = Sugarcane yield per hectare (Lkg/TC)
R = Monthly rainfall (mm)
T = Average monthly temperature (°C)
B_0 = Intercept
B_1, β_2 = Regression coefficients
E = Error term

Computational tools such as machine learning algorithms (e.g., Random Forest) may also be applied to capture nonlinear relationships and improve predictive accuracy. Model performance is evaluated using statistical indicators such as R^2, RMSE, and MAE to ensure reliability.

Conceptual framework

The researchers aim to develop a quantitative predictive model to calculate and determine how rainfall and temperature influence sugarcane yield in Bais City, Negros Oriental, for the crop years 2017 to 2024, using a multiple linear regression formula. This study follows several stages to produce the desired outcomes, namely: A. Input; B. Procedure; and C. Output.

The Input consists of the independent variables, dependent variable, and constant variable. For this study, the independent variables are monthly rainfall (R, mm) and average monthly temperature (T, °C). The dependent variable is sugarcane yield (Y, Lkg). The constant variables include the crop years (2017–2024) and the Soil Factor Index, which is considered stable during the study period.

The Procedure begins with the collection of monthly rainfall, temperature, and sugarcane yield data from verified sources such as PAGASA, PSA, the Bais City Agriculture Office, and BSWM. The collected data are then organized and analyzed using descriptive statistics to summarize trends and variations. Pearson correlation analysis is applied to identify relationships between the independent and dependent variables. Finally, multiple linear regression is performed using the formula: $Y = \beta_0 + \beta_1 R + \beta_2 T + \varepsilon$.

The Output of this study is the predicted sugarcane yield per hectare for Bais City, alongside the quantification of the effects of rainfall and temperature on yield. The results will provide insights for farmers, agricultural planners, and policymakers to make evidence-based decisions and implement strategies that optimize sugarcane production under varying environmental conditions.

Results

Table 1. Annual Average Rainfall and Temperature in Bais City (2017-2024)

Year	Average Annual Rainfall (mm)	Average Annual Temperature (°C)
2017	240.5	26.8
2018	231.4	26.7
2019	130.1	26.9
2020	176.2	27.1
2021	217.9	26.9
2022	158.7	26.8
2023	168.6	27.3
2024	129.4	28.0

Table 2. Annual Sugarcane Production in Bais City (2017-2024)

Year	Sugarcane Yield (Lkg)
2017	1,522,820
2018	1,120,220
2019	1,274,840
2020	1,073,800
2021	1,663,620
2022	1,427,060
2023	1,773,000
2024	1,157,100

Table 3. Descriptive Statistics of Rainfall, Temperature, and Sugar Yield

Variables	Mean	Minimum	Maximum
Rainfall (mm)	179.5	113.1	240.5
Temperature (°C)	27.1	26.7	28.0
Yield (Lkg)	1,376,808	1,073,800	1,773,000

Table 4. Correlation Matrix Between Climatic Variables and Sugarcane Yield

Variables	Rainfall (mm)	Temperature (°C)	Yield (Lkg)
Rainfall	1.000	-0.524	0.373
Temperature	-0.524	1.000	-0.176
Yield	0.373	-0.176	1.000

Table 5. Multiple Linear Regression Results for Sugarcane Yield
Dependent Variable : Sugarcane Yield (Lkg)

Predictor	Coefficient	Standard Error	t-value	p
Constant	455,400	8,610,000	0.053	0
Rainfall	230.91	290.63	0.795	0

Temperature	16,710	307,000	0.054	0

Discussion

The statistical models used in this study explain how changes in rainfall and temperature affect sugarcane yield in Bais City. Using correlation analysis and multiple linear regression, the study measures the strength and direction of the relationship between climate factors and crop yield. This approach allows a clear and objective understanding of how environmental changes are linked to variations in sugarcane production at the local level.

The results show that average temperature has a negative relationship with sugarcane yield. This means that higher temperatures reduce sugarcane production when they exceed favorable levels. High temperatures interfere with important plant processes such as photosynthesis, respiration, and sugar formation. When heat levels go beyond what the crop can tolerate, sugarcane experiences heat stress, especially during key growth stages like tillering and ripening (Fahad et al., 2017). Long periods of heat stress can reduce plant growth and weaken stalk development, which lowers overall yield.

In contrast, rainfall shows a positive relationship with sugarcane yield, indicating that sufficient water supply supports better crop growth. Adequate rainfall improves soil moisture, helps plants absorb nutrients, and supports healthy vegetative growth. These conditions are important for good sugarcane production. However, rainfall alone does not guarantee high yields. Too much rainfall or uneven distribution can cause problems such as waterlogging and nutrient loss, which may reduce yield (Li et al., 2021).

These findings agree with earlier studies showing that excessive temperatures lead to lower yields, while moderate and well-distributed rainfall improves crop productivity (Sanghera, 2020;Li et at., 2021). Although the effects of temperature and rainfall may seem small when viewed separately, their combined impact over several growing seasons can cause large changes in yield. This shows the importance of using statistical models to understand long-term climate effects on agriculture.

The regression model developed in this study shows how useful quantitative methods are in analyzing the relationship between climate and crop yield. By linking rainfall and temperature to sugarcane production, the model provides a local, evidence-based tool that can help farmers and planners make better decisions. It can be used to identify climate-related risks, plan planting schedules, and manage resources more efficiently under changing environmental conditions.

However, the results also suggest that further improvements are possible. Sugarcane yield is also influenced by factors such as soil properties, farming practices, and crop varieties. Although soil conditions were assumed to be constant in this study, future research that includes more variables and longer data periods could improve the accuracy of yield predictions and support better climate adaptation strategies.

In summary, the results show that temperature and rainfall have a strong but complex effect on sugarcane yield in Bais City. Changes in these climate factors influence plant growth and contribute to differences in production levels. By combining statistical analysis with existing research, this study provides a clear explanation of how climate affects local sugarcane farming and highlights the need for adaptive strategies to cope with increasing climate variability.

Conclusion

This research highlights the crucial role of rainfall and temperature in influencing sugarcane yield in Bais City, Negros Oriental, demonstrating that even moderate variations in these climatic factors can significantly affect crop productivity. By applying a quantitative regression model, the study simplifies the mathematical relationship between climate variables and sugarcane yield, making climate–crop interactions more accessible to students, researchers, farmers, and local agricultural planners. The findings are especially relevant to agricultural communities that rely heavily on sugarcane production, as they help identify periods of heightened vulnerability to climate stress. Consistent with previous studies, the results confirm that elevated temperatures impose physiological stress on sugarcane, while adequate rainfall supports stable growth and yield performance, directly influencing productivity levels (Sanghera, 2020; Li et al., 2021; Sevilla et al., 2025). Through statistical modeling and data-driven analysis, the study enhances local understanding of how climatic conditions shape agricultural outcomes.

Furthermore, the study underscores the importance of climate-responsive planning and adaptation in sustaining sugarcane production. Climate-driven yield variability poses increasing risks to farmer livelihoods and the economic stability of sugarcane-dependent communities (Philippine Statistics Authority [PSA], 2023). The proposed regression model offers practical support for government agencies and local authorities by serving as a preliminary tool for yield forecasting, risk assessment, and agricultural decision-making. While it does not replace advanced crop simulation models, the framework provides a reliable basis for guiding planting schedules, irrigation planning, and the promotion of climate-adaptive farming practices. Based on these findings, the study recommends strengthening climate monitoring systems, integrating temperature and rainfall data into local agricultural advisories, and encouraging collaboration between government institutions and farming communities. Overall, this research bridges mathematical modeling and real-world agricultural challenges by offering a simplified and practical approach to understanding and managing the impacts of climate variability on sugarcane yield.

References

Bureau of Soils and Water Management. (2023). Soil survey and land classification reports for Negros Oriental. Department of Agriculture, Philippines.

Da Silva et al. (2023). Temperature stress and physiological responses of sugarcane under tropical conditions. Agricultural and Forest Meteorology, 329, 109312. https://doi.org/10.1016/j.agrformet.2023.109312

Dash et al. (2023). Applications of mathematical and computational modeling in agricultural productivity analysis. Journal of Applied Mathematics and Agriculture, 15(2), 45–59.

Delgadillo-Duran et al. (2020). Soil properties and their influence on crop productivity: A review. Soil Science and Plant Nutrition, 66(4), 567–579. https://doi.org/10.1080/00380768.2020.1765732

Fahad et al. (2017). Crop production under drought and heat stress: Plant responses and management options. Frontiers in Plant Science, 8, 1147. https://doi.org/10.3389/fpls.2017.01147

Food and Agriculture Organization of the United Nations. (2022). FAOSTAT statistical database. https://www.fao.org/faostat

IOER International Multidisciplinary Research Journal. (2025). Advances in crop modeling and climate-responsive agriculture. IOER International Multidisciplinary Research Journal, 7(1), 1–15.

Li et al. (2021). Effects of rainfall variability on sugarcane growth and yield in tropical regions. Field Crops Research, 270, 108216. https://doi.org/10.1016/j.fcr.2021.108216

Lefevre, M. (2025). Mathematical modeling and decision-making in agricultural systems. International Journal of Applied Mathematics, 38(1), 12–25.

Philippine Atmospheric, Geophysical and Astronomical Services Administration. (2023). Climatological data for Negros Oriental. https://www.pagasa.dost.gov.ph

Philippine Statistics Authority. (2023). Sugarcane production statistics of the Philippines. https://psa.gov.ph

Puckette et al. (2010). Evaluation of DSSAT-CANEGRO for sugarcane yield prediction under varying climate conditions. Agricultural Systems, 103(7), 481–491. https://doi.org/10.1016/j.agsy.2010.05.003

Ramadhan et al. (2024). Machine learning approaches for crop yield prediction under climate variability. Computers and Electronics in Agriculture, 213, 108212. https://doi.org/10.1016/j.compag.2023.108212

Rodríguez et al. (2023). Rainfall distribution and its effects on sugarcane productivity. Journal of Agricultural Science, 15(3), 89–101. https://doi.org/10.5539/jas.v15n3p89

Sanghera, G. S. (2020). Heat stress effects on growth, physiology, and productivity of sugarcane. Sugar Tech, 22(4), 568–577. https://doi.org/10.1007/s12355-020-00829-1

Savio, R. (2023). Computational mathematics in agricultural forecasting and modeling. Applied Computational Science Journal, 9(2), 33–47.

Sevilla et al. (2025). Burning sweetness: Analyzing the impact of high heat index on yield and provincial contributions in the sugarcane industry of the Philippines. International Multidisciplinary Journal of Research for Innovation, Sustainability, and Excellence (IMJRISE), 2(8), 121–128. https://risejournals.org/index.php/imjrise/article/view/1387

Viana et al. (2023). Soil texture, organic matter, and sugarcane yield performance. Soil and Tillage Research, 227, 105635. https://doi.org/10.1016/j.still.2023.105635
World Weather Online. (2023). Historical weather data for Bais City, Negros Oriental. https://www.worldweatheronline.com

Yao et al. (2025). Predicting crop yield using XGBoost and Random Forest models under climate stress. Environmental Modelling & Software, 170, 105784. https://doi.org/10.1016/j.envsoft.2024.105784