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Predicting Rice Harvests: A 2013-2022 Production Trend Analysis using Mathematical Models

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ABSTRACT

Rice is a vital staple food and economic commodity in the Philippines, integral to both livelihood and food security. This study aims to predict the future value of rice production by examining data from 2013 to 2022 and applying various statistical models. Factors such as production volume, area harvested, and yield per hectare were analyzed for their impact on production value. The study employed multiple regression and time series models, including linear, quadratic, exponential, polynomial (cubic, quartic, quintic, sextic), power, moving average, exponential smoothing, and autoregression models. The polynomial (sextic) model emerged as the best fit, with the highest coefficient of determination (R^2 = 0.8724) and the lowest standard error. The findings indicate a significant relationship between the value of rice production and the examined variables, with a forecasted decline in production value for the upcoming year. The study underscores the importance of strategic collaboration among stakeholders to enhance rice production value and calls for further research to explore additional influencing factors and improve predictive accuracy.

1. INTRODUCTION

Rice is a staple food for a significant portion of the world's population and plays a crucial role in global food security. It is a primary source of livelihood for millions of farmers, and its production value holds immense economic significance. In the Philippines, rice is not only a dietary staple but also a cultural rice stone. The development of Philippine agriculture heavily relies on the sustainable and prosperous production of rice. Numerous factors influence the value of rice production, including fluctuations in yield, market prices, production costs, government policies, and global demand. To ensure the stability and growth of the rice sector, it is imperative to understand and anticipate the trends affecting its production value. This research seeks to delve into these dynamics, providing insights that can empower stakeholders to make informed decisions and develop effective strategies.

1.1 Statement of the Problem

This study aimed to identify the factors that affect the value of rice production. Specifically, this study aimed to;

1. Determine the trend of the value of rice manufactured in the year 2013-2022.
2. Find if the value of rice production has a significant linear relationship with the following variables;
    a. volume of production;
    b. area planted/ harvested;
    c. yield per hectare; and
    d. value of production; area planted/ harvested, and yield per hectare altogether.
3. Construct time series model of the value of rice production using the following models to predict the percentage for the year 2023.
    a. Linear
    b. Quadratic
    c. Exponential
    d. Polynomial (cubic, quartic, quintic, sextic)
    e. Power

f. Moving Average

g. Exponential Smoothing

h. Auto Regression

4. Determine the best fit models and predict the value of rice production in the year 2022.

2. METHODS

2.1 Research Design

This research used the descriptive- predictive design. To predict if the value of rice production increases or decreases forecasting was used as a technique.

2.2 Data Sources

In this research *Selected Statistics of Agriculture (2012, 2017, and 2020 edition)* of the Philippine Statistics Authority was used for the data.

2.3 Research Procedure

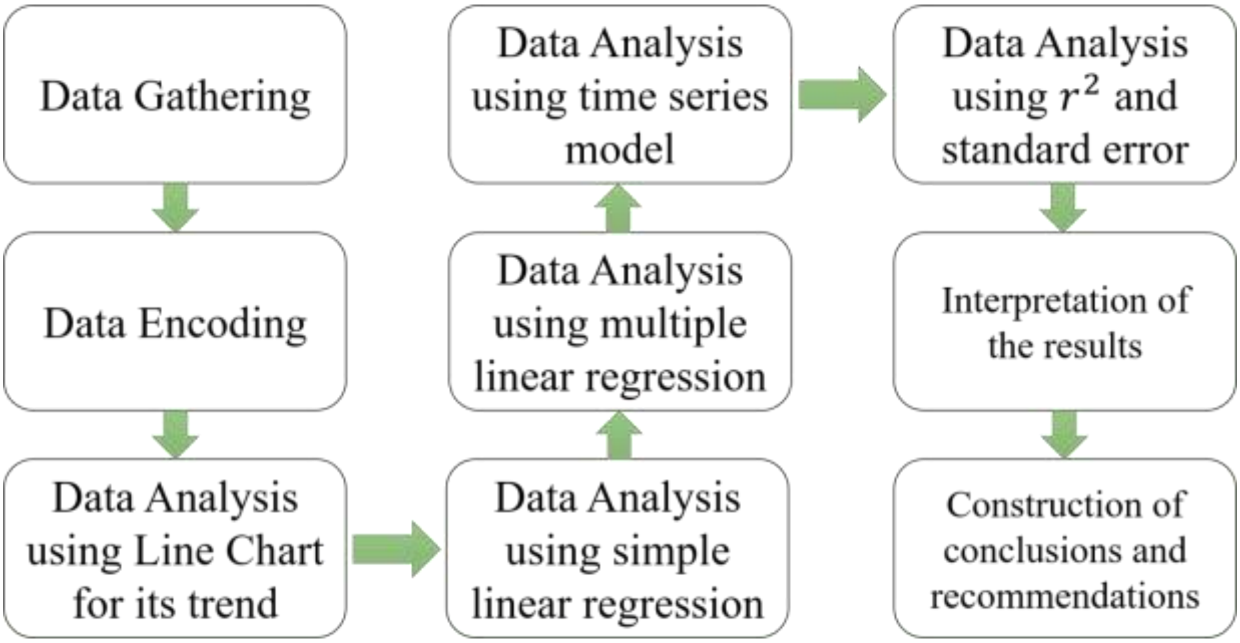


Figure 1: Flow Chart of the Research

The research commenced with a meticulous collection of data through extensive internet browsing. The selection criteria for data sources focused on relevance, accuracy, and suitability for various statistical models. Reputable government agencies, agricultural organizations, and academic databases were prioritized to ensure data integrity.

Following the data acquisition, the information was carefully encoded and organized into a structured format, facilitating seamless analysis. To gain initial insights into the temporal patterns of rice production value, line charts were employed. These visual representations allowed for the identification of trends, fluctuations, and potential outliers in the data.Subsequently, the research delved into more sophisticated statistical analyses. Simple linear regression was utilized to examine the relationship between the value of rice production and individual predictor variables, such as yield, area harvested, or fertilizer consumption. Multiple linear regression expanded this analysis by considering the combined influence of multiple factors on production value, providing a more comprehensive understanding of the underlying dynamics.Time series models were then applied to capture the temporal dependencies and forecast future trends in rice production value. These models, including ARIMA (Autoregressive Integrated Moving Average) and exponential smoothing, accounted for seasonality, autocorrelation, and other time-dependent patterns, enhancing the accuracy of predictions. To evaluate the goodness of fit of the models and assess their predictive power, the coefficient of determination (r^2) and standard error were calculated. Higher r^2 values indicated a stronger fit between the model and the observed data, while lower standard errors suggested greater precision in the predictions. The results obtained from these analyses were meticulously interpreted and discussed in the context of existing literature and theoretical frameworks. Comparisons were made with findings from previous studies, and potential explanations were offered for observed trends and relationships. Finally, based on the comprehensive analysis and interpretation of the data, well-founded conclusions were drawn regarding the trend of rice production value, the most influential factors affecting it, and the most suitable model for predicting future values. Additionally, actionable recommendations were formulated to guide policymakers, farmers, and other stakeholders in making informed decisions that could enhance the sustainability and profitability of rice production in the Philippines.

2.4 Data Analysis

In determining the trend of the value of rice production line charts was use. Simple linear regression was used to determine if value of rice production has a significant relationship to the volume of production, area planted/ harvested and yield per hectare. Multiple linear regression was used to determine if the value of rice production has a significant relationship to the three variables altogether. r^2 and standard error was used to determine the best fit model/s that will predict the value of rice production for the year 2023.

3. RESULTS AND DISCUSSIONS

Section 1. Trend of the value of rice production.

Figure 2: Trend line of the Value of Rice Production from 2013-2022

Section 2. Find if the value of rice production has a significant linear relationship with the following variables;

3.1 Volume of Production

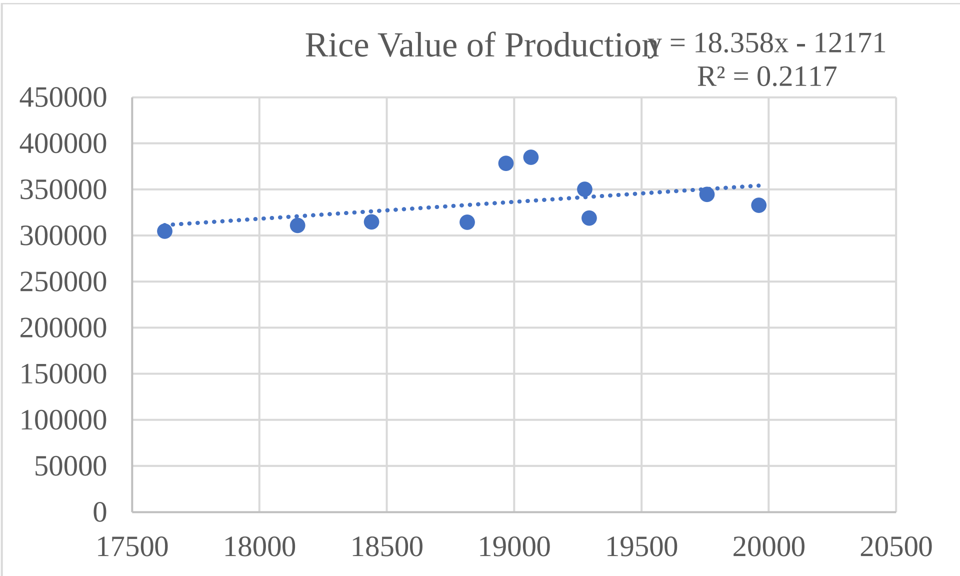


Figure 3: Relationship of the Volume of Production and the Value of Production

3.2 Area planted and harvested

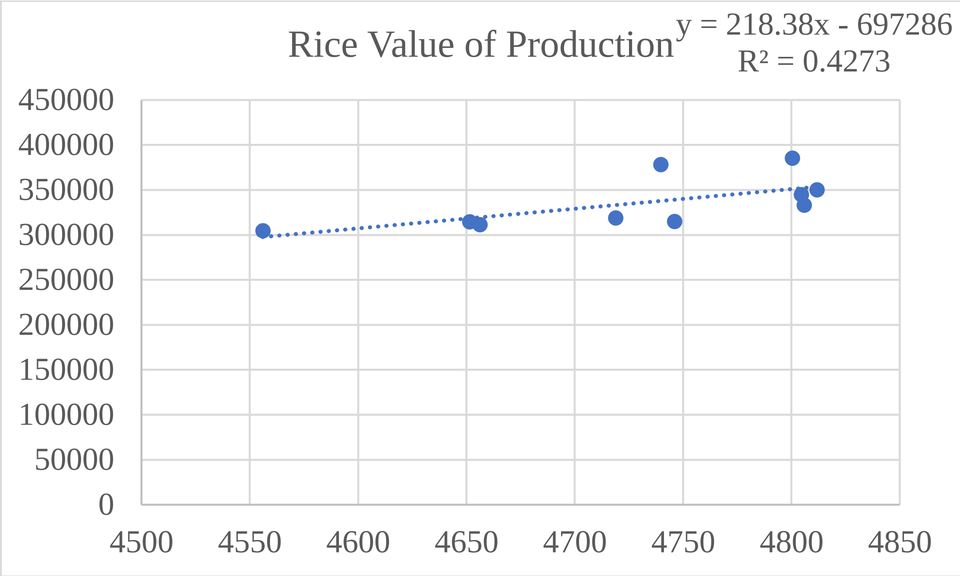


Figure 4: Relationship of Area planted/ harvested and Value of Production

3.3 Yield per hectare

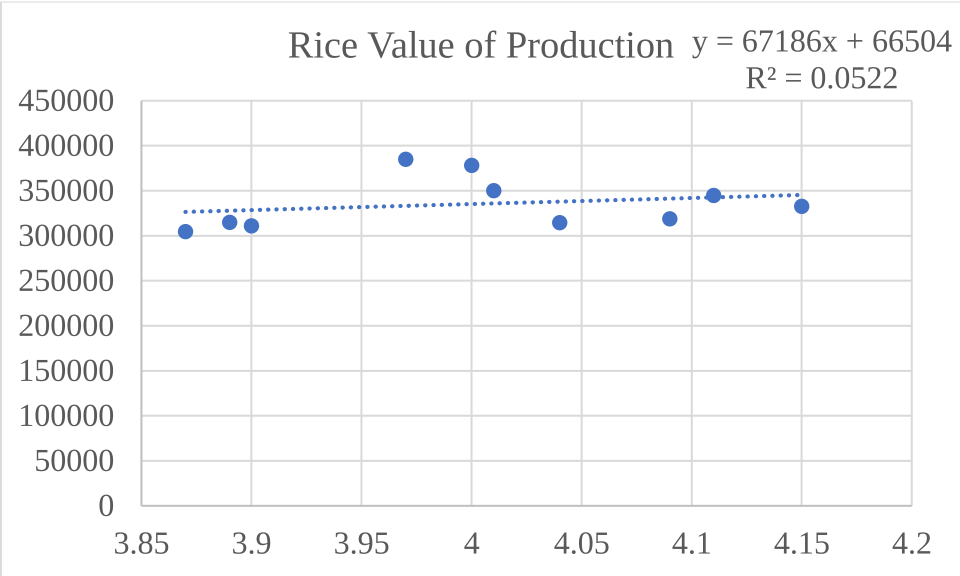


Figure 5: Relationship of Yield per Hectare and Value Production

3.4 Volume of Production, Area Planted/ Harvested and Yield per Hectare altogether

Table 1 presents that value of rice production has a significant linear relationship with the volume of production, area planted/ harvested and yield per hectare.

Table 1. Multiple Regression Results of volume of production; area planted/ harvested, and yield per hectare.

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.774018
R Square	0.599104
Adjusted R Square	0.398656

Standard Error	22065.67
Observations	10

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	3	4.37E+09	1.46E+09	2.988828	0.11769
Residual	6	2.92E+09	4.87E+08		
Total	9	7.29E+09			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	14970760	10775407	1.389345	0.214094	-1.1E+07	41337232	-1.1E+07	41337232
X Variable 1	826.9671	570.461	1.449647	0.197337	-568.901	2222.835	-568.901	2222.835
X Variable 2	-2943.73	2212.222	-1.33066	0.231634	-8356.84	2469.386	-8356.84	2469.386
X Variable 3	-4090188	2779264	-1.47168	0.191521	-1.1E+07	2710425	-1.1E+07	2710425

The regression analysis shows a strong positive relationship between rice production variables and an unspecified outcome, likely total production or revenue.

SECTION 3 TIME SERIES MODEL

Linear

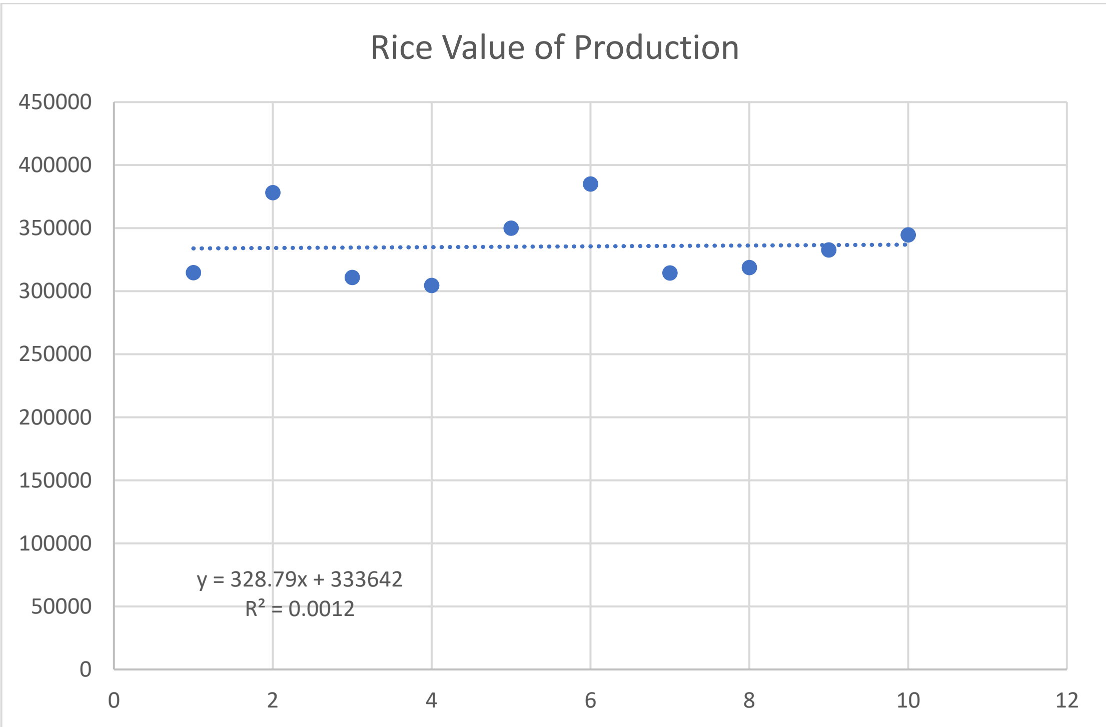


Figure 6: Linear Model of the Value of Rice Production from 2013-2022 The equation of this linear model is y = 328.79x + 333642 and the coefficient of determination is 0.0012.

Quadratic

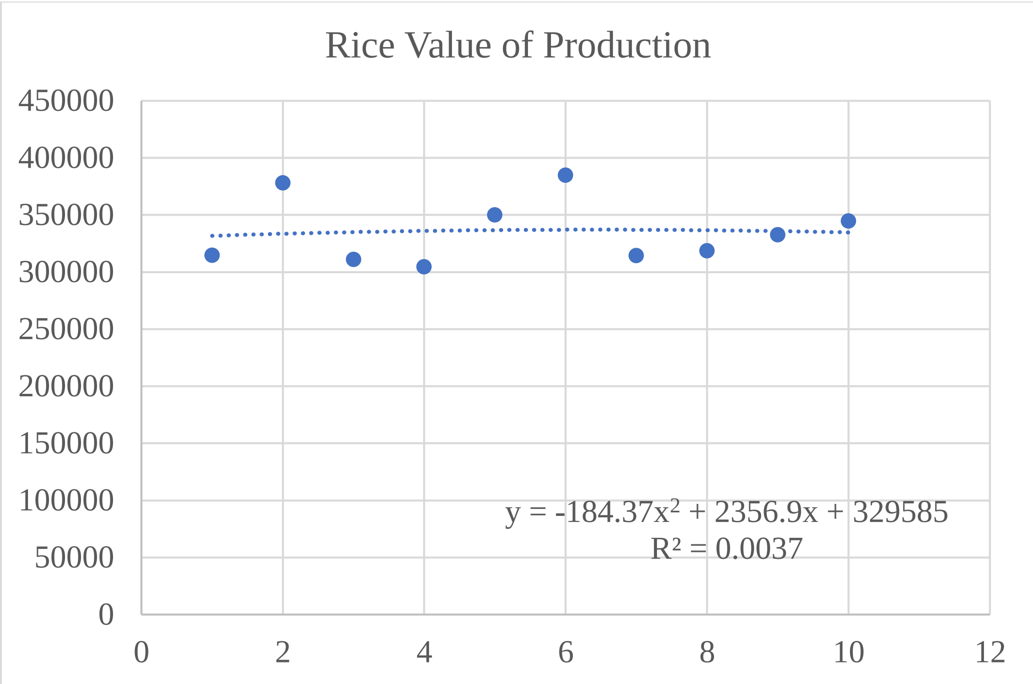


Figure 7: Quadratic Model of the Value of Rice Production from 2013-2022. The quadratic model of the value of rice production has an equation of $y = -184.37x^2 + 2356.9x + 329585$ and a coefficient of determination of 0.0037.

Exponential

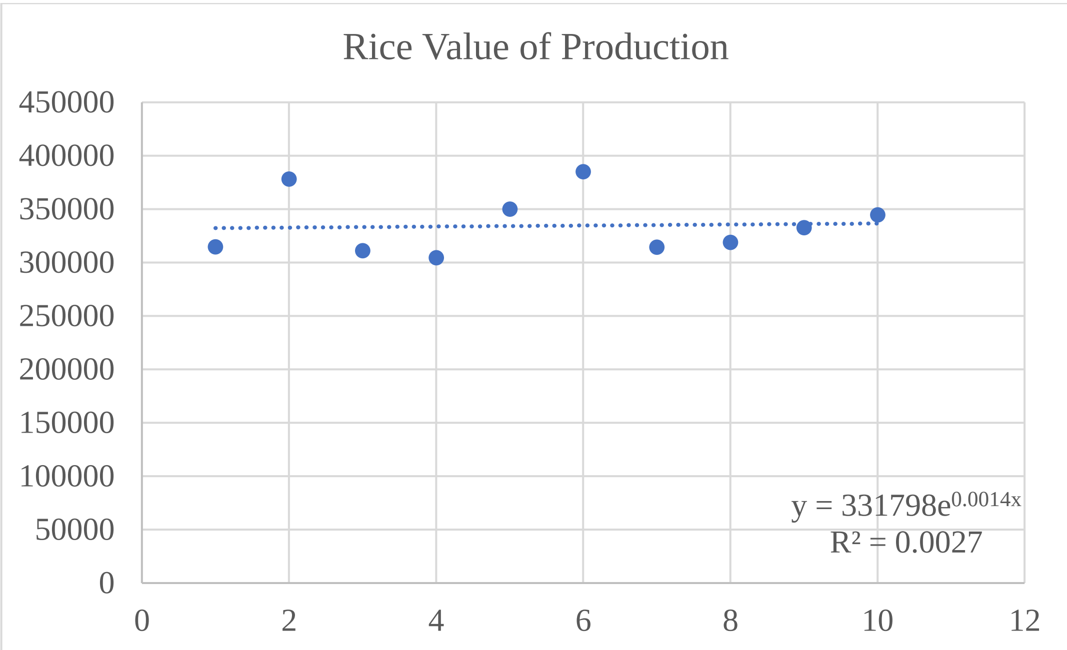
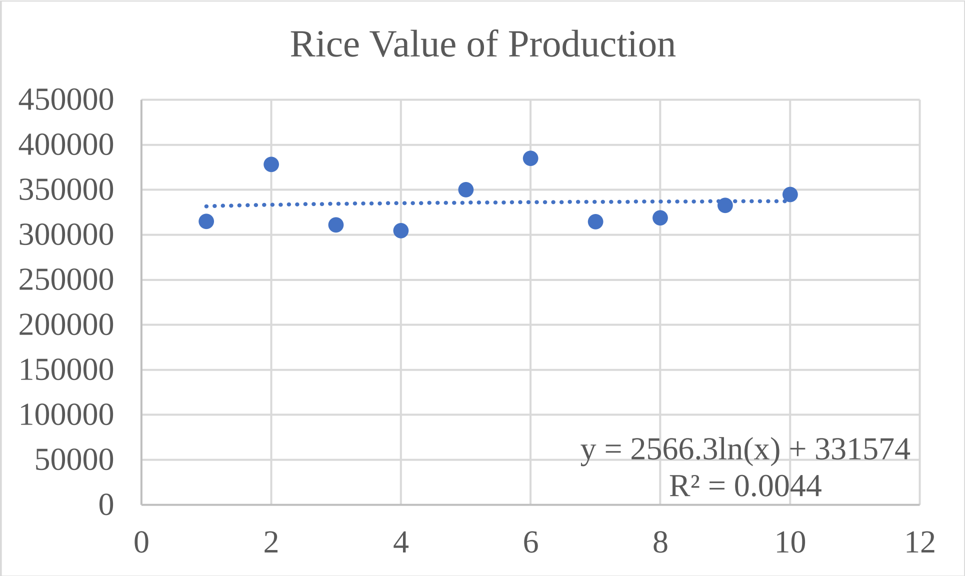


Figure 8: Exponential Model of the Value of Rice Production from 2013-2022

Exponential Model of the value of rice production produced an equation $y = 331798e^{0.0014x}$ and a coefficient of determination of 0.0012.

Logarithmic



Logarithmic Model of the value of rice production produced an equation y = 2566.3ln(x) + 331574 and a coefficient of determination of 0.5265.

Polynomial (Cubic)

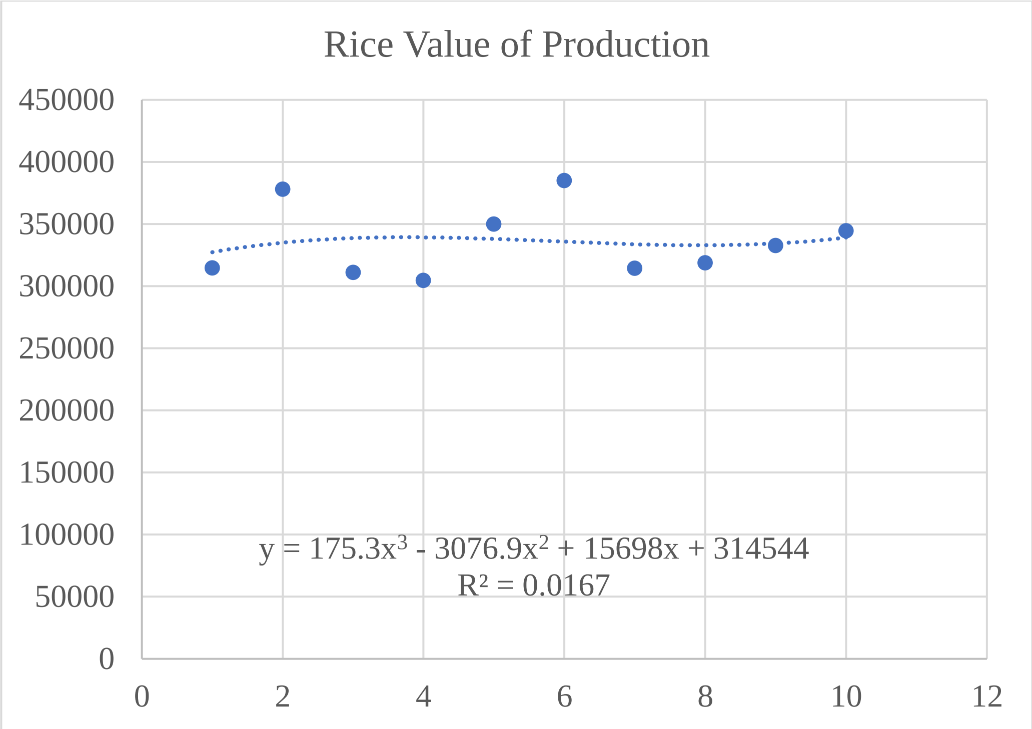


Figure 9: Polynomial (Cubic) Model of the Value of Rice Production from 2013-2022. The equation of this polynomial cubic model of the value of corm production is $y = 175.3x^3 - 3076.9x^2 + 15698x + 314544$ and its r^2 is equivalent to 0.0167.

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Polynomial (Quartic)

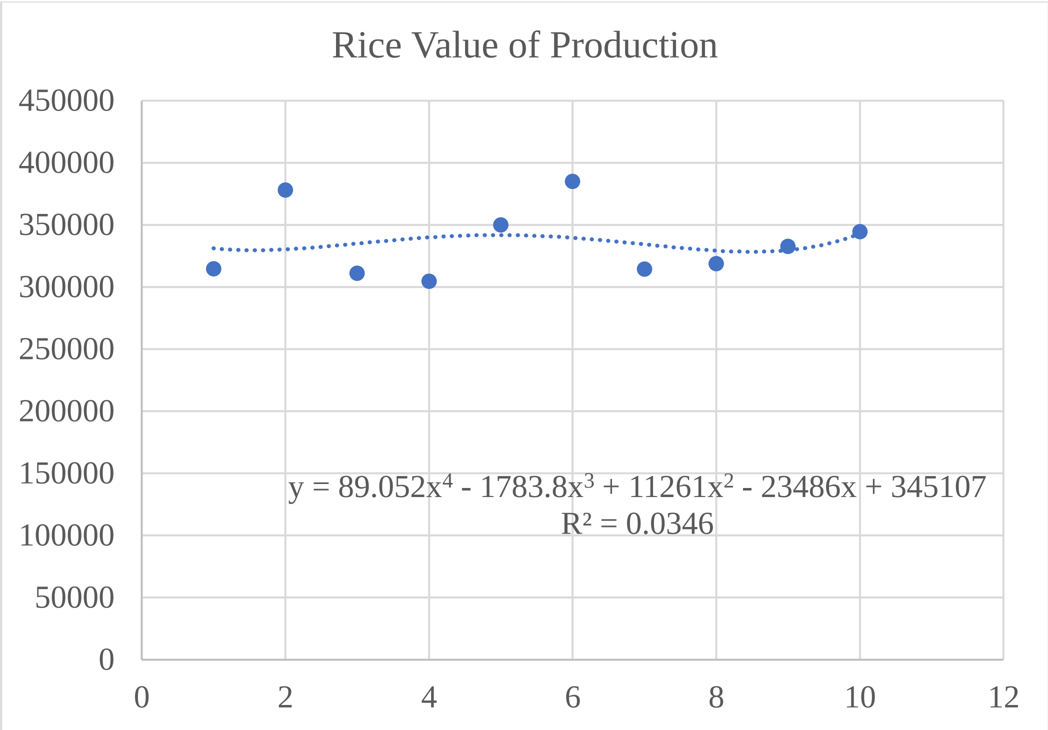

Figure 10: Polynomial (Quartic) Model of the Value of Rice Production from 2013-2022. The figure shows an equation of $y = 89.052x^4 - 1783.8x^3 + 11261x^2 - 23486x + 345107$ and a coefficient of determination of 0.0346

Polynomial (Quintic)

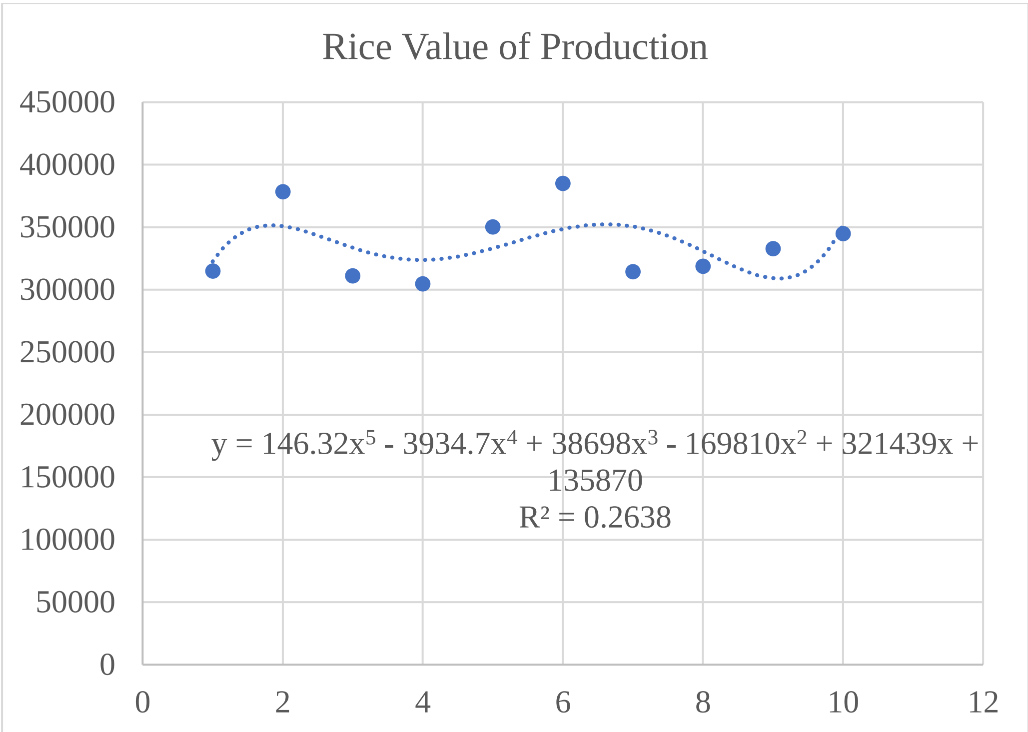

Figure 11: Polynomial (Quintic) Model of the Value of Rice Production from 2013-2022 presents an equation of $y = 146.32x^5 - 3934.7x^4 + 38698x^3 - 169810x^2 + 321439x + 135870$ and a coefficient of determination of 0.3628.

Polynomial (Sextic)

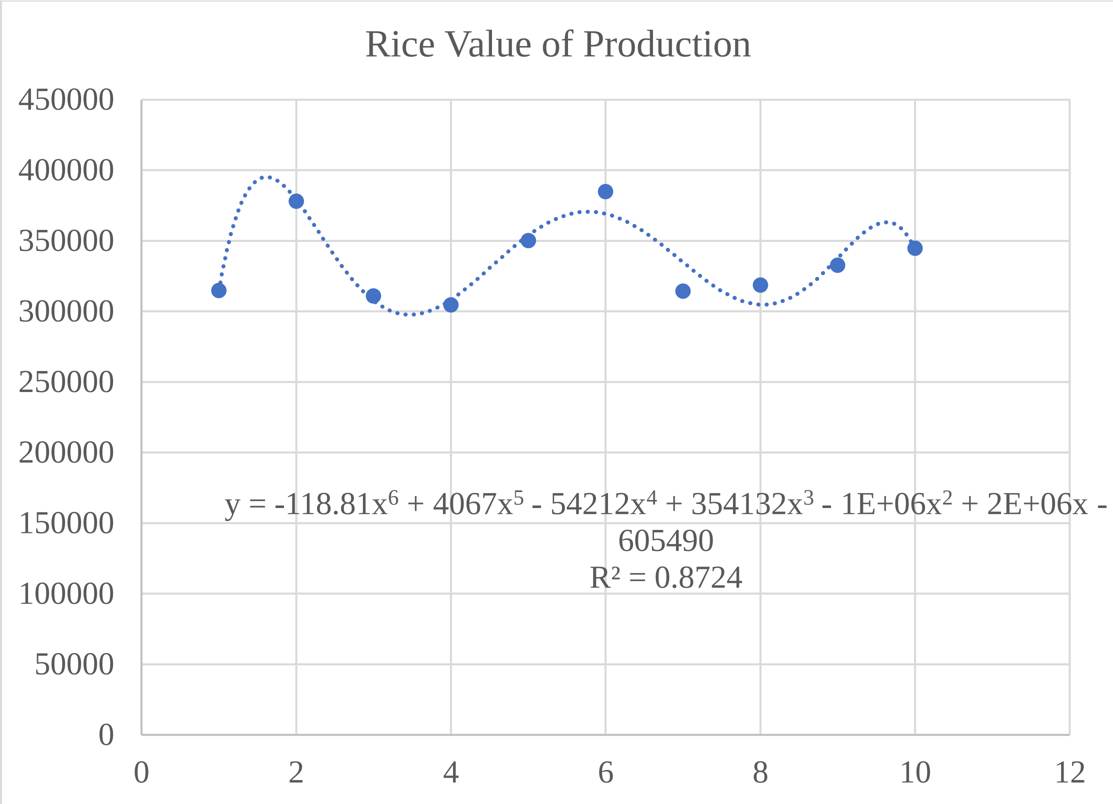

Figure 12: Polynomial (Sextic) Model of the Value of Rice Production from 2013-2022 produced an equation of $y = -118.81x^6 + 4067x^5 - 54212x^4 + 354132x^3 - 1E{+}06x^2 + 2E{+}06x - 605490$ and $r^2 = 0.8724$.

Power

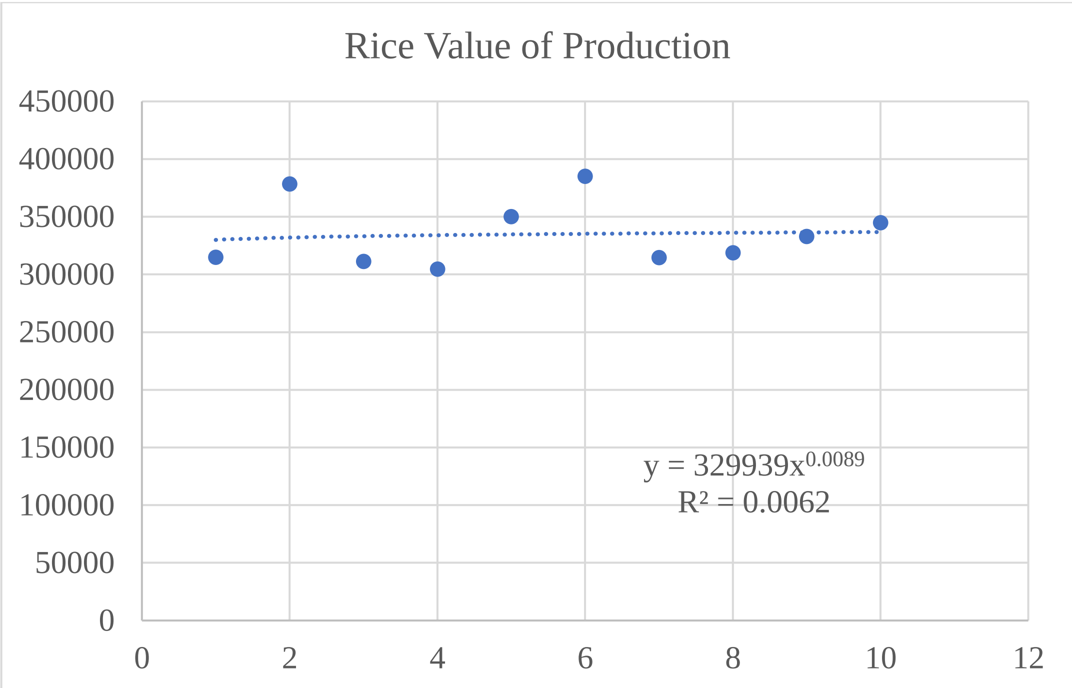

Figure 13: Power Model of the Value of Rice Production from 2013-2022. The equation of this power model of value of rice productionis $y = 329939x^{0.0089}$ and the coefficient of determination is 0.0043.

Moving Average

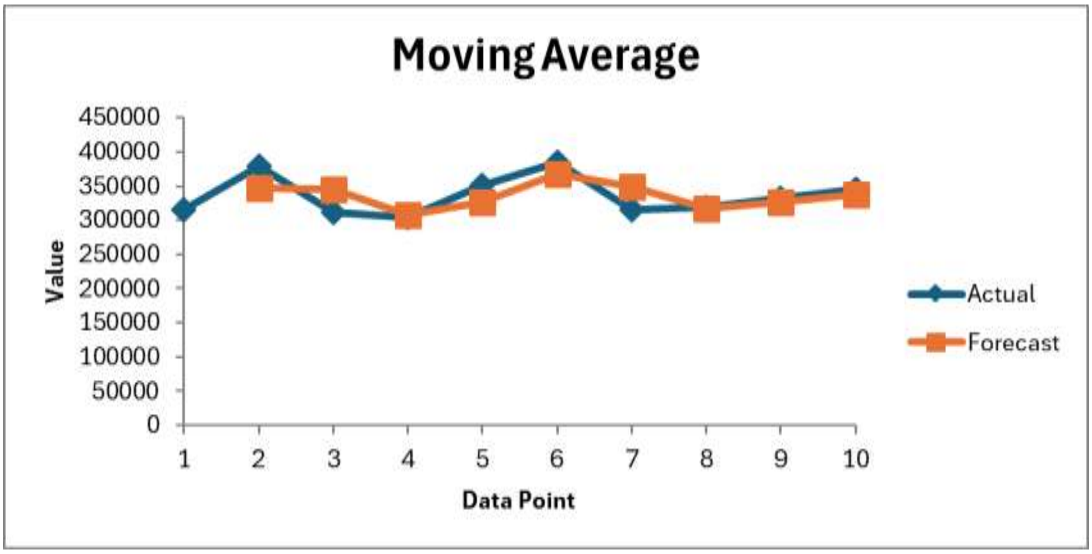

Figure 14: Moving Average Model of the Value of Rice Production from 2013-2022

Exponential Smoothing

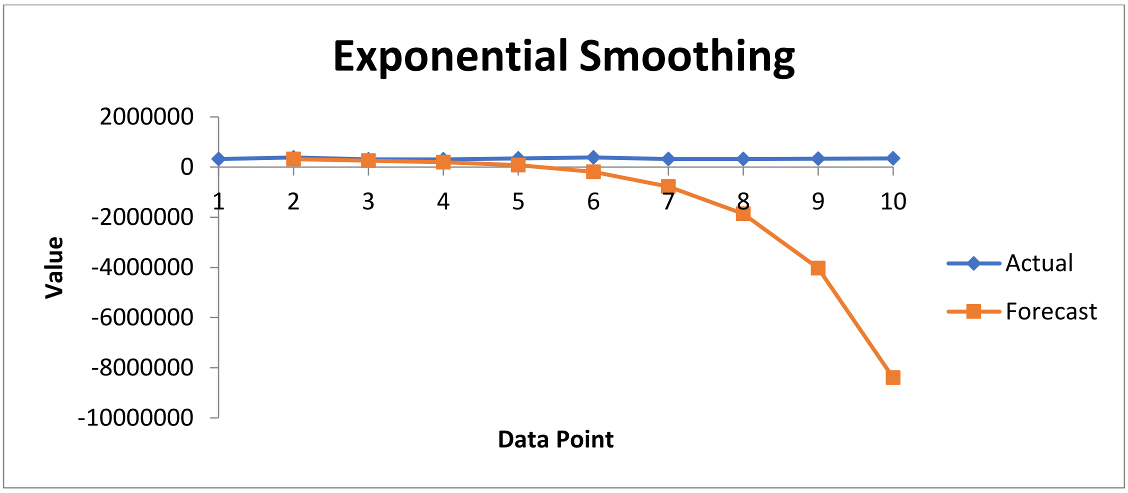

Figure 15: Exponential Smoothing Model of the Value of Rice Production from 2013-2022

Auto Regression

Table 2 presents the results of the auto regression model of the value of rice production from 2013-2022

Table 2. Auto regression model of the value of rice production from 2013-2022.

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.221404
R Square	0.04902
Adjusted R Square	-0.08683
Standard Error	30419.92
Observations	9

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	3.34E+08	3.34E+08	0.360825	0.566981
Residual	7	6.48E+09	9.25E+08		
Total	8	6.81E+09			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	409807.3	120388.1	3.404051	0.01138	125134.6	694479.9	125134.6	694479.9
x variable 1	-0.21547	0.358712	-0.60069	0.566981	-1.06369	0.632745	-1.06369	0.632745

Table 2 has an R-squared (r^2) of **0.04902**. Using the coefficients of intercept and x variable 1, we can produce the following equation: $y = 409807.3 - 0.21547x_{n-1}$.

Summary Table

Table 3 presents the summary of all models used in the value of rice production from year 2013- 2022 and the equation of different models.

Table 3. Summary Table of different models and the equation of each model.

MODEL	EQUATION
LINEAR	$y = 328.79x + 333642$
EXPONENTIAL	$y = 331798e^{0.0014x}$
LOGRARITHMIC MODEL	$y = 2566.3\ln(x) + 331574$
QUADRATIC	$y = -184.37x^2 + 2356.9x + 329585$
CUBIC	$y = 175.3x^3 - 3076.9x^2 + 15698x + 314544$
QUARTIC	$y = 89.052x^4 - 1783.8x^3 + 11261x^2 - 23486x + 345107$
QUINTIC	$y = 146.32x^5 - 3934.7x^4 + 38698x^3 - 169810x^2 + 321439x + 135870$
SEXTIC	$y = -118.81x^6 + 4067x^5 - 54212x^4 + 354132x^3 - 1E+06x^2 + 2E+06x - 605490$
POWER	$y = 329939x^{0.0089}$

SECTION 4: BEST FIT MODEL AND PREDICTION

Table 4 presents the different models used in the value of rice production from 2013-2022, the equation, coefficient of determination and the standard error of each model.

BEST FIT MODEL			
MODEL	EQUATION	R^2	SE
LINEAR	$y = 328.79x + 333642$	0.0012	28437.74
EXPONENTIAL	$y = 331798e^{0.0014x}$	0.0012	28437.74
LOGRARITHMIC MODEL	$y = 2566.3\ln(x) + 331574$	0.0044	28392.15
QUADRATIC	$y = -184.37x^2 + 2356.9x + 329585$	0.0037	28402.13
CUBIC	$y = 175.3x^3 - 3076.9x^2 + 15698x + 314544$	0.0167	28216.22
QUARTIC	$y = 89.052x^4 - 1783.8x^3 + 11261x^2 - 23486x + 345107$	0.0346	27958.22
QUINTIC	$y = 146.32x^5 - 3934.7x^4 + 38698x^3 - 169810x^2 + 321439x + 135870$	0.3628	22714.01

SEXTIC	$y = -118.81x^6 + 4067x^5 - 54212x^4 + 354132x^3 - 1E+06x^2 + 2E+06x - 605490$	0.87224	10170.76
POWER	$y = 329939x^{0.0089}$	0.0043	28393.58

Table 4. Summary of different models used in in the value of rice production from 2013-2022, the equation, coefficient of determination and the standard error of each model.

Table 4 shows that the polynomial (sextic) model has a coefficient of determination (R^2) of **0.87224**, which is very close to 1. It also has a standard error (SE) of **10170.76**, which is the lowest among the standard errors of the other models. Therefore, the best fit model to predict the value of rice production in the following year is the polynomial, specifically the sextic model. The equation for the sextic model is $y = -118.81x^6 + 4067x^5 - 54212x^4 + 354132x^3 - 1E + 06x^2 + 2E + 06x - 605490$

5. Summary, Conclusion and Recommendations

5.1 Summary

Rice is an essential staple and economic commodity in the Philippines, influencing both livelihood and food security. This study aimed to predict the value of rice production using various statistical models, based on data from 2013 to 2022. Factors such as production volume, area harvested, and yield per hectare were analyzed to determine their impact on production value. Different time series models were evaluated to find the best fit for predicting future trends, with the polynomial (sextic) model emerging as the most accurate.

5.2 Summary of Findings

1. The trend of the value of rice production from 2013 to 2022 showed variability with significant fluctuations. The highest value was recorded in 2018.
2. There is a significant linear relationship between the value of rice production and the volume of production, area planted/harvested, and yield per hectare. When combined, these variables also show a significant relationship with the production value.
3. The time series models applied to predict future values of rice production include:
   - Linear: y=328.79x+333642y = 328.79x + 333642y=328.79x+333642
   - Quadratic: y=−184.37x2+2356.9x+329585y = -184.37x^2 + 2356.9x + 329585y=−184.37x2+2356.9x+329585
   - Exponential: y=331798e0.0014xy = 331798e^{0.0014x}y=331798e0.0014x
   - Polynomial (cubic): y=175.3x3−3076.9x2+15698x+314544y = 175.3x^3 - 3076.9x^2 + 15698x + 314544y=175.3x3−3076.9x2+15698x+314544
   - Polynomial (quartic): y=89.052x4−1783.8x3+11261x2−23486x+345107y = 89.052x^4 - 1783.8x^3 + 11261x^2 - 23486x + 345107y=89.052x4−1783.8x3+11261x2−23486x+345107
   - Polynomial (quintic): y=146.32x5−3934.7x4+38698x3−169810x2+321439x+135870y = 146.32x^5 - 3934.7x^4 + 38698x^3 - 169810x^2 + 321439x + 135870y=146.32x5−3934.7x4+38698x3−169810x2+321439x+135870
   - Polynomial (sextic): y=−118.81x6+4067x5−54212x4+354132x3−1E+06x2+2E+06x−605490y = -118.81x^6 + 4067x^5 - 54212x^4 + 354132x^3 - 1E+06x^2 + 2E+06x - 605490y=−118.81x6+4067x5−54212x4+354132x3−1E+06x2+2E+06x−605490
   - Power: y=329939x0.0089y = 329939x^{0.0089}y=329939x0.0089
   - Auto Regression: y=409807.3−0.21547yn−1y = 409807.3 - 0.21547y_{n-1}y=409807.3−0.21547yn−1
4. The polynomial (sextic) model, with the highest coefficient of determination (R^2 = 0.8724) and the lowest standard error, was identified as the best fit model. Using this model, the predicted value of rice production for the next year shows a potential decrease to 35910.879 million pesos.

5.3 Conclusions

The study reveals a significant relationship between the value of rice production and various agricultural factors. The polynomial (sextic) model provides the most reliable predictions, indicating a potential decline in rice production value in the upcoming year. These findings highlight the necessity for strategic planning and intervention to mitigate the forecasted decrease.

5.4 Recommendations

1. **Collaborative Efforts**: The rice industry, including farmers, corporations, and government agencies, should collaborate to develop strategies aimed at increasing the value of rice production. This could involve enhancing farming techniques, investing in technology, and providing better support and resources to farmers.
2. **Further Research**: Future research should explore additional factors influencing rice production value and refine predictive models. This will help in developing more robust strategies to sustain and improve rice production in the Philippines.

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