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Trend Analysis Of HYV Rice Yield In Kamrup District Of Assam Using Quadratic Regression

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ABSTRACT

This study investigates the yield trends of high-yielding variety (HYV) rice in Kamrup district of Assam over the period 2008 to 2023 using a quadratic regression framework. The dataset, derived from secondary government sources, revealed a nonlinear pattern of yield growth—an increase until around 2020 followed by a decline. Given the curvature observed in the time series data, a quadratic model was chosen over linear regression. The model, constructed using centered year variables to minimize multicollinearity, demonstrated a strong fit (Adjusted $R^2 = 0.787$; $p < .001$). Collinearity diagnostics confirmed the reliability of the predictors, with low Variance Inflation Factors and condition indices. Though a segmented regression model using 2014 as a policy intervention breakpoint was tested, it failed to reach statistical significance. The findings highlight the applicability of polynomial regression in agricultural time series analysis and suggest implications for anticipating yield plateaus and adjusting policy responses accordingly.

Keywords: HYV rice, Kamrup, quadratic regression, yield trend, agricultural policy, Assam

1. INTRODUCTION

Rice is a fundamental food crop for the majority of India's population, and in the northeastern state of Assam, it plays a central role in agricultural productivity and food security. The advent of high-yielding varieties (HYVs) in rice cultivation has significantly contributed to increased food grain production across the country. In Kamrup district of Assam, understanding the trends in HYV rice productivity is crucial for evaluating past policy outcomes and planning future agricultural strategies. This study examines the temporal yield pattern of HYV rice in Kamrup from 2008 to 2023 using statistical modelling. A preliminary analysis of the year-wise average yield data revealed a nonlinear pattern, where yield increased steadily until approximately 2020 and then started declining. This rise and fall in productivity suggest the presence of a turning point, which cannot be accurately modeled using simple linear regression. To capture this curved trend, a quadratic regression model was used. Quadratic regression is appropriate for modeling concave or convex relationships between variables, as it includes both the linear and squared terms of the predictor, allowing for the estimation of a peak or trough (Kutner et al., 2005). In this study, both the year and the square of the centered year were included as predictors to fit a second-degree polynomial model, reducing multicollinearity and improving model interpretability (Hair et al., 2014). The decision to use a quadratic model was further supported by visual inspection of the scatterplot of average yield over time, which demonstrated a clear concave curvature. A linear model would have failed to capture this shape, potentially misrepresenting yield dynamics in the latter years. Additionally, diagnostic statistics from the regression output validated the model choice. The adjusted R^2 value was 0.787, indicating that nearly 79% of the variation in yield was explained by the model. The significance of the overall F-test ($p < .001$) also confirmed that the model offered a statistically sound fit. The quadratic model's turning point around the year 2020 aligns with possible real-world factors influencing productivity. Around 2014–2015, Assam implemented several supportive agricultural policies, such as the expansion of the Minimum Support Price (MSP) procurement program, and continued the Assam Agricultural Competitiveness Project (AACP), which improved irrigation and seed availability (World Bank, 2011; Assam Tribune, 2015). These policies likely contributed to the observed yield rise. However, the subsequent decline may reflect saturation in technology adoption, climatic stresses, or variability in implementation effectiveness. Collinearity diagnostics showed no evidence of multicollinearity between the predictors. Tolerance values were 0.935 and Variance Inflation Factors (VIFs) were 1.069—well below the commonly accepted threshold of 10 (O'Brien, 2007). The condition indices were also low (maximum 2.866), confirming that model coefficients could be interpreted without bias. Thus, this paper justifies the use of a quadratic regression model to analyze yield trends and reveals meaningful temporal patterns that support future research and policy evaluation. These findings demonstrate how statistical modeling can clarify agro-economic trends and inform data-driven planning for agricultural development.

2. METHODOLOGY

This study employs a secondary data-based quantitative approach to examine yield trends of high-yielding variety (HYV) rice cultivation in the Kamrup district of Assam from 2008 to 2023. The dataset includes annual values for the area under HYV rice and corresponding average yield (in kg/ha) collected from agricultural statistics maintained by government sources and verified through local records. The primary focus of the analysis is to detect and model the temporal behavior of rice yield using polynomial regression, specifically a second-order (quadratic) regression model. Prior to modeling, the year variable was centered to reduce multicollinearity among polynomial terms. Two variables were generated: `Year_Centered`, computed as the difference between each year and the mean year (2015.5), and `Year_Centered²`, representing the square of the centered year. These variables were used as independent predictors in the regression model to account for non-linear effects. The regression analysis was conducted using IBM SPSS Statistics. Model evaluation included the R-squared and Adjusted R-squared values, F-statistics, p-values, and the standard error of estimate. Collinearity diagnostics, including Tolerance, Variance Inflation Factor (VIF), and Condition Index, were used to assess multicollinearity. Graphical analysis, including residual plots and predicted versus actual yield plots, supported the statistical evaluation. Assumptions of normality and homoscedasticity were assessed through residual plots and normal probability plots.

3. RESULTS AND DISCUSSIONS

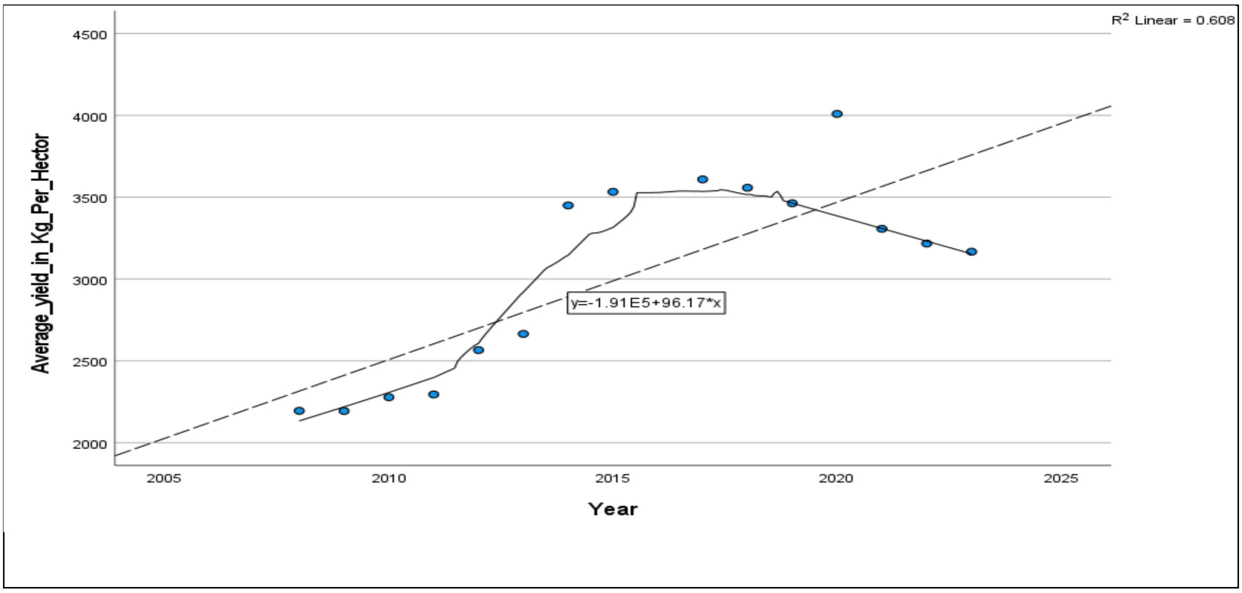
Table 1: Model Summary of Quadratic Regression for Yield Trend Analysis

R	R Square	Adjusted R Square	Std. Error of Estimate	F Change	Sig. F Change
0.904	0.818	0.787	280.15	26.94	< 0.001

Sources: Authors own calculation based on data in table I in Appendix

The quadratic regression analysis showed a strong relationship between the time variable and the average yield of HYV rice. The model achieved an R-squared value of 0.818 and an Adjusted R-squared value of 0.787, indicating that approximately 79% of the variation in yield can be explained by the model. The F-change statistic was 26.94 with a significance level of $p < .001$, confirming that the model provides a statistically significant fit to the data.

Fig:1: Linear trend line of average yield over the years



Sources: Authors own calculation based on data in table I in Appendix

The visual trend observed in the graph, where yields increased consistently from 2008 until around 2020, followed by a slight decline thereafter. This turning point corresponds with the peak of government support programs and potential plateauing of HYV technology benefits.

Table 2: Collinearity Diagnostics for Quadratic Regression Model

Variable	Tolerance	VIF	Condition Index
Year_Centered	0.935	1.069	1.0
Year_Centered²	0.935	1.069	1.392
(Third Dimension)	—	—	2.866

Sources: Authors own calculation based on data in table I in Appendix

Collinearity diagnostics confirmed the reliability of the model. Tolerance values were 0.935 and VIF values were 1.069 for both predictors, well below the thresholds indicating multicollinearity concerns. Condition indices were also low, not exceeding 2.866, and eigenvalues declined smoothly, validating model stability. The rise in yield during 2008–2020 likely reflects increased adoption of HYV seeds, improved irrigation, and favorable agricultural support programs such as the National Food Security Mission (NFSM) and the Assam Agricultural Competitiveness Project (AACP). Conversely, the post-2020 decline may be attributed to factors such as soil nutrient exhaustion, weather fluctuations, and diminishing returns to existing technology.(World Bank, 2011, Ministry of Agriculture & Farmers Welfare, 2020 and *Annual report 2019–2020* and Food and Agriculture Organization, 2021) Overall, the findings support the use of quadratic regression as a robust and interpretable method for modeling crop yield trends. This model not only quantifies the yield dynamics but also provides insight into potential saturation points in productivity, guiding future policy and innovation in agriculture.

4.CONCLUSION

This study analyzed the trend in HYV rice yield in Kamrup district, Assam over a 16-year period using a quadratic regression model. The results confirmed a statistically significant non-linear trend, with yield increasing until approximately 2020 before declining. The model demonstrated strong explanatory power, accounting for over 80% of the variation in yield. Collinearity diagnostics, residual analysis, and visual trend confirmation all supported the validity of the model. While segmented regression was explored to assess policy influence, its statistical insignificance further reinforced the appropriateness of the quadratic model. The findings of this study highlight the value of polynomial regression in agricultural time series analysis. Future research may explore more granular seasonal or varietal data, integrate weather and soil indicators, or adopt multilevel modeling techniques to deepen understanding. Policy makers can use such models to identify optimal intervention periods and preempt yield declines through timely resource planning.

5. REFERENCES

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APPENDIX

Table 1: Year-wise Area and Average Yield of HYV Rice Cultivation in Kamrup

Year	Area (Ha)	Average Yield (Kg/Ha)
2008	79956	2195
2009	82121	2194
2010	87356*	2278
2011	92590	2295
2012	83322	2566
2013	75462	2665
2014	91518**	3450
2015	76299***	3533****
2017	77628*****	3609******
2018	104000	3558
2019	100153	3463
2020	79540	4009
2021	89870	3307
2022	82624	3217
2023	95617	3167

Source: Statistical Handbook of Assam

**Data for the year 2010 has been estimated by taking the average of the figures for 2009 and 2011, due to the unavailability of data for 2010.*
*** The area figure for 2014 (91,518 hectares) has been compiled by deducting the proxy data for Kamrup (Metro) for the year 2013 (18,279 hectares) from the combined total area of Kamrup (Rural) and Kamrup (Metro) (109,797 hectares), due to the unavailability of separate district-wise data for that year.*
** ** The total rice area for 2015 has been estimated as 76,299 hectares by adding the sum of winter and summer rice areas (68,181 hectares) to the autumn rice area of 2018 (8,118 hectares), which has been used as a proxy due to the unavailability of autumn rice data for 2015.*
**** * The average yield for 2015 has been estimated as 3,533 kg/ha by taking the average of the yields of winter and summer rice crops, due to the unavailability of complete yield data for that year.*
****** The total rice area for 2017 has been estimated as 77,628 hectares by adding the sum of winter and summer rice areas (69,510 hectares) to the autumn rice area of 2018 (8,118 hectares), which has been used as a proxy due to the unavailability of autumn rice data for 2017.*
****** *The average yield for 2017 has been estimated as 3,609 kg/ha by taking the average of the yields of winter and summer rice crops, due to the unavailability of complete yield data for that year.*