How to Cite:
Harahap, Q. H., Lubis, Z., & Supriana, T. (2024). Analysis of rice production trends in ten rice production centers in Indonesia. *Tennessee Research International of Social Sciences*, *6*(2), 233–254. Retrieved from https://triss.org/index.php/journal/article/view/72

Analysis of rice production trends in ten rice production centers in Indonesia

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***Abstract*---**Rice production plays a strategic role in meeting food and economic needs in Indonesia, considering that rice is the staple food for the majority of the population. This study analyzes rice production trends in the 10 largest provinces in Indonesia during the period 2009-2023, and identifies the most effective forecasting model to predict future rice production. The quadratic model is identified as the most appropriate forecasting model for most provinces, as evidenced by the high R-squared values, such as in West Java (80.09%), North Sumatra (75.30%), and Aceh (72.90%). However, this model shows limitations in several provinces such as Lampung and Banten, with R-squared of 32.40% and 37.40%, respectively. Production predictions for 2024 indicate a decline in production in most provinces, except for a few that show a more stable decline.

***Keywords*---**Rice Production, Forecasting, Quadratic Model, Food Security, Production Trends.

Tennessee research international of social sciences © 2024.
ISSN: 2766-7464 (Online)
Publisher: Smoky Mountain Publishing
Manuscript submitted: 09 July 2024, Manuscript revised: 18 August 2024, Accepted for publication: 22 Sept 2024

Introduction

Rice plants are the main food source that produces rice as a staple food for 80% of the Indonesian people. The amount of national rice needs continues to increase every year, as a result of the rate of population growth, increased welfare, and changes in people's lifestyles. Rice is still considered a strategic commodity in the Indonesian economy. To the cost of living index, the need for rice remains very dominant (Adiratma, 2004).

Rice is not only a staple food for the Indonesian people but also as one of the commodities that has bright prospects for increasing farmers' income (Yuriah et al., 2024). This motivation encourages farmers to develop and increase their production with the hope that the harvest can meet food needs and obtain high sales results, so that they can meet their living needs (Lusmi, 2013).

Increasing rice production can be done through two main approaches: increasing planting area and increasing productivity. One of the most effective alternatives to increase production is through increasing productivity (Yuriah et al., 2022). This effort can be done in various ways, including the introduction of new technology and increasing efficiency in rice cultivation.

Based on data from the Central Statistics Agency (BPS), national rice production in 2022 reached 32.07 million tons, an increase of 0.72 million tons from 2021. This increase in rice production is in line with the increase in harvested area and rice productivity (Astuti, 2023). The phenomenon of increasing rice production and several other supporting factors have earned Indonesia an award from the International Rice Research Institute (IRRI) for being able to achieve rice self-sufficiency and meet the needs of the community by more than 20 percent.

Rice production data with two main factors, namely harvested area and productivity, is an interesting material to study further, especially the latest data for 2023 (Astuti, 2023). Figure 1 below shows data on the 10 largest provinces producing rice during the period 2009-2023.

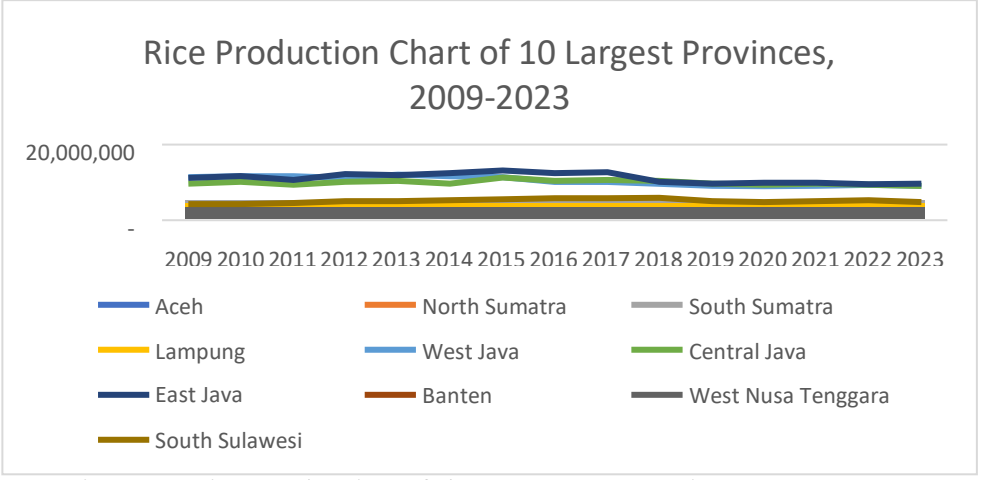

Figure 1. Rice Production of the 10 Largest Provinces, 2009-2023
Source: Central Statistics Agency

Although national rice production shows an increasing trend, challenges remain in ensuring stable production from year to year. Climate change, pest attacks, and weather variability are some of the factors that can significantly affect rice production. Therefore, a comprehensive analysis of rice production trends is needed to forecast future production and identify potential risks that can affect harvest yields. In addition, this study also aims to identify the most appropriate and effective forecasting model to be used in predicting future rice production. Selecting the right model is very important to provide accurate and reliable forecasting results, so that it can be used as a basis for formulating more effective policies in ensuring national food security. This study focuses on 10 provinces in Indonesia that have the highest rice production. By focusing on these areas, it is hoped that the results of the trend analysis and forecasting of rice production can provide a clearer and more relevant picture of the condition of national rice production and support more appropriate decision-making in managing rice production in the future.

Method

This study will focus on the analysis of rice production trends in 10 main provinces of rice production centers in Indonesia during the period 2009 to 2023 as shown in Figure 1. Data search and processing will be carried out from March to June 2024. With an emphasis on historical data for the last 14 years, this study aims to identify rice production patterns that can be used as a basis for forecasting future production.

The data used in this study are secondary data collected from the Central Statistics Agency (BPS). The data to be processed are time series data of rice production in 10 main provinces of rice production centers in Indonesia, covering the period from 2009 to 2023. This secondary data will be used to analyze rice production trends and forecast future production.

Here are four models that will be tested, namely 1) Linear Model Type, 2) Quadratic Model Type, 3) Exponential Growth Model Type, 4) S-Curve Model Type. The main criterion in selecting the best model is the value of the coefficient of determination or R-Squared (R2). Models with higher R2 values indicate better ability to explain variations in rice production data. The best model selected will be used to forecast future rice production, with the aim of increasing the precision and accuracy in decision making related to rice production management in Indonesia.

Results and Discussion

Best Model

This study aims to analyze the trend of rice production in 10 provinces with the largest potential harvest area in Indonesia from 2009 to 2023. Rice production is an important indicator in meeting national food needs and the agricultural economy in Indonesia. The data used comes from the Central Statistics Agency (BPS), which includes the amount of rice production in tons

from each province in the period 2009-2023. The data can be seen in the following table.

Table 1. Rice Production in Ten Provinces (tons), 2009 – 2023

Year/Province	Aceh	North Sumatra	South Sumatra	Lampung	Java West	Central Java	East Java	Banten	Southeast West	South Sulawesi
2009	1,556,858	3,527,899	3,125,236	2,673,844	11,322,681	9,600,415	11,259,085	1,849,007	1,870,775	4,324,178
2010	1,582,393	3,582,302	3,272,451	2,807,676	11,737,070	10,110,830	11,643,773	2,048,047	1,774,499	4,382,443
2011	1,772,962	3,607,403	3,384,670	2,940,795	11,633,891	9,391,959	10,576,543	1,949,714	2,067,137	4,511,705
2012	1,788,738	3,715,514	3,295,247	3,101,455	11,271,861	10,232,934	12,198,707	1,865,893	2,114,231	5,003,011
2013	1,956,940	3,727,249	3,676,723	3,207,002	12,083,162	10,344,816	12,049,342	2,083,608	2,193,698	5,035,830
2014	1,820,062	3,631,039	3,670,435	3,320,064	11,644,899	9,648,104	12,397,049	2,045,883	2,116,637	5,426,097
2015	2,331,046	4,044,829	4,247,922	3,641,895	11,373,144	11,301,422	13,154,967	2,188,996	2,417,392	5,471,806
2016	1,851,968	3,505,176	4,273,168	3,198,608	10,118,952	10,465,840	12,476,288	2,328,440	2,700,200	5,729,808
2017	1,958,464	3,568,323	4,432,314	3,348,434	10,133,821	10,649,070	12,785,824	2,369,495	2,787,725	5,946,034
2018	1,861,567	2,108,285	2,994,192	2,488,642	9,647,359	10,499,588	10.203.213	1,687,783	1,460,339	5,952,616
2019	1,714,438	2,078,902	2,603,396	2,164,089	9,084,957	9,655,654	9,580,934	1,470,503	1,402,182	5,054,167
2020	1,757,313	2,040,500	2,743,060	2,650,290	9,016,773	9,489,165	9,944,538	1,655,170	1,317,190	4,708,465
2021	1,634,640	2,004,143	2,552,443	2,485,453	9,113,573	9,618,657	9,789,588	1,603,247	1,419,560	5,090,637
2022	1,509,456	2,088,584	2,775,069	2,688,160	9,433,723	9,356,445	9,526,516	1,788,583	1,452,945	5,360,169
2023	1,404,235	2,087,474	2,832,774	2,757,898	9,140,039	9,084,108	9,710,661	1,686,483	1,538,537	4,876,386

After collecting rice production data from 10 major provinces in Indonesia during the period 2009 to 2023, the next step is to develop four models with different approaches, namely a linear model, a quadratic model, an exponential growth model, and a curve model.S. Furthermore, the evaluation is carried out using the R-squared criterion (coefficient of determination) to determine the most appropriate model in predicting rice production for the next year. The selection of one year is based on the statistical principle that the further the forecast period, the lower the level of accuracy.

In general, the R-squared value ranges between 0 and 1, where a higher value indicates a better model in explaining the variability of the data. According to Neter et al. (1996), the R-squared value canclassified into certain ranges to facilitate interpretation, and these values can be expressed in percentage form as follows: 0% - 10%: Very Weak, 10% - 25%: Weak, 25% - 50%: Moderate, 50% - 75%: Strong, 75% - 90%: Very Strong, and 90% - 100%: Extremely Strong.

This classification provides guidance on how well a regression model is able to explain the variation in the data (Yuriah & Kartini, 2022). A higher R-squared value indicates a better model in explaining the variability of the observed results.

Based on the results of trend analysis of production data in 10 provinces, it was found that the best model came from the quadratic model because in general the R-squared produced tended to be higher compared to the other three models. This indicates that the quadratic model more accurately explains variations in rice production data compared to other models.

Aceh Province Rice Production Forecast

The following figure presents the output of SPSS software processing for rice production data in Aceh Province during the period 2009-2023.

Table 2. Rice Production Data Forecasting Model for Aceh Province

Model	R Square	Constant	b1	b2
Linear	0.056	1,862,177,898	-11,929,911	
Quadratic	0.729	1,375,349,135	159,892,006	-10,738,870
S	0.056	14,404	-0.12	
Exponential	0.067	1,857,495,019	-0.007	

Table 2 shows that the quadratic model shows the highest R-Squared, which is 0.729 or 72.90%. While the lowest R-squared is found in the linear and S-Curve models with the same value, which is 0.056 or 5.6%. The visualization for the distribution of rice production data in Aceh duringthe period 2009-2023 using the quadratic model is shown in the following figure.

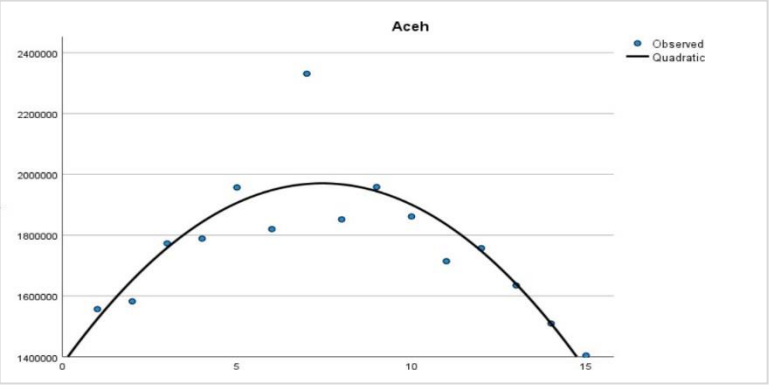

Figure 2. Quadratic Curve of Rice Production Data in Aceh Province

Based on the quadratic model, the rice production forecasting model for Aceh Province is:

Y = 1375349.135 + 159892.006X - 10738.870X2

By using this model, we can obtain a forecast of rice production in 2024 as shown in the following table.

Table 3. Rice Production Forecast for 2024 in Aceh Province

Year	Rice Production (tons)	Rice Production Forecast (tons)
(1)	**(2)**	**(3)**
2009	1,556,858	-
2010	1,582,393	-
2011	1,772,962	-

Year	Rice Production (tons)	Rice Production Forecast (tons)
2012	1,788,738	-
2013	1,956,940	-
2014	1,820,062	-
2015	2,331,046	-
2016	1,851,968	-
2017	1,958,464	-
2018	1,861,567	-
2019	1,714,438	-
2020	1,757,313	-
2021	1,634,640	-
2022	1,509,456	-
2023	1,404,235	-
2024	-	1,184,471

Table 3 shows that the predicted rice production in Aceh Province in 2024 is 1,184,471 tons. This figure shows a decrease from the 2023 production which reached 1,404,235 tons, or a decrease of 15.65%. This decrease can be seen through the analysis model used, with an R-squared value of 0.729. This high R-squared value indicates that around 72.9% of the variation in rice production in Aceh Province can be explained by the model (Yuriah et al., 2023). This decrease in rice production can be explained by several factors, including climate change resulting in extreme weather such as drought or uneven rainfall, a decrease in the area of planting due to land conversion for other uses, and limited resources such as fertilizers and modern agricultural technology. In addition, pest and disease attacks on plants, suboptimal agricultural practices, and economic factors such as price fluctuations and farmer income also contributed to the decrease in production. Although there was a decrease in the amount of production, the high R-squared value indicates that the analysis model may be able to describe the downward trend well.

Rice Production Forecasting in North Sumatra Province

The following figure presents the output of SPSS software processing for rice production data in North Sumatra Province during the period 2009-2023.

Table 4. Rice Production Data Forecasting Model for North Sumatra Province

Model	R Square	Constant	b1	b2
Linear	0.684	4,227,708,928	-150,816,773	
Quadratic	0.753	3,662,730,016	48,587,549	-12,462,770
S	0.195	14,768	0.522	
Exponential	0.698	4,493,231,612	-0.054	

Table 4 shows that the quadratic model shows the highest R-Square, which is 0.753 or 75.30%. While the lowest R-squared is found in the S-Curve model with a value of 0.195 or 19.5%. The visualization of the distribution of rice

production data in North Sumatra during the period 2009-2023 using the quadratic model is seen in the following figure.

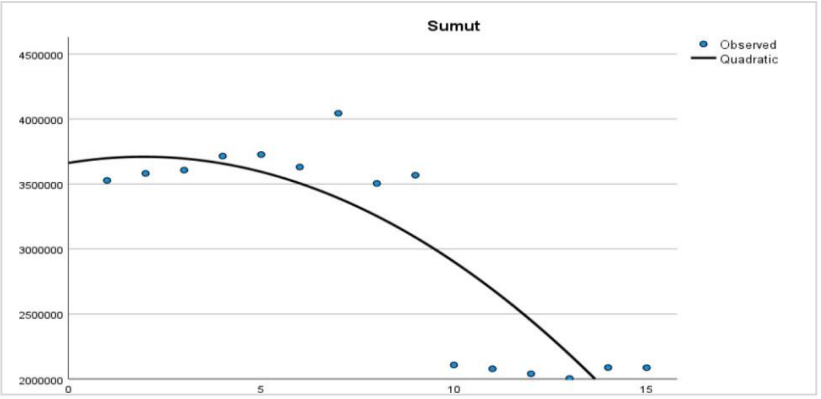

Figure 3. Quadratic Curve of Rice Production Data in North Sumatra Province

Based on the quadratic model, the rice production forecasting model for North Sumatra Province is: Y = 3662730.016 + 48587.549X – 12462.770X2

By using this model, we can obtain a forecast of rice production in 2024 as shown in the following table.

Table 5. Rice Production Forecast for 2024 in North Sumatra Province

Year	Rice Production (tons)	Rice Production Forecast (tons)
(1)	(2)	(3)
2009	3,527,899	-
2010	3,582,302	-
2011	3,607,403	-
2012	3,715,514	-
2013	3,727,249	-
2014	3,631,039	-
2015	4,044,829	-
2016	3,505,176	-
2017	3,568,323	-
2018	2,108,285	-
2019	2,078,902	-
2020	2,040,500	-
2021	2,004,143	-
2022	2,088,584	-
2023	2,087,474	-
2024	-	1,249,662

Table 5 shows that the predicted rice production in North Sumatra Province for 2024 is around 1,249,662 tons, a significant decrease of 40.14% compared to production in the previous year, which reached 2,087,474 tons in 2023. This decrease in production can be attributed to several factors, including: climate change which causes unfavorable weather conditions for agriculture,

such as heavy rain resulting in flooding or prolonged drought which reduces crop yields; a decrease in the area of planting due to land conversion for other purposes such as infrastructure or industrial development; and limited availability of resources, including lack of access to fertilizers and modern agricultural technology. This decrease can be seen through the analysis model used, with an R-squared value of 0.753. The R-squared valueThis high value indicates that around 75.3% of the variation in rice production in North Sumatra Province can be explained by the model.

Rice Production Forecasting in South Sumatra Province

The following table presents the output of SPSS software processing for rice production data in South Sumatra Province during the period 2009-2023.

Table 6. Rice Production Data Forecasting Model for South Sumatra Province

Model	R Square	Constant	b1	b2
Linear	0.166	3,776,401,453	-56,391,016	
Quadratic	0.488	2,847,579,786	271,428,396	-20,488,713
S	0.002	14,994	0.033	
Exponential	0.211	3,800,344,700	-0.019	

Table 6 shows that the quadratic model shows the highest R-Squared, which is 0.488 or 48.80%. While the lowest R-squared is found in the S-Curve model with a value of 0.002 or 0.2%. The visualization of the distribution of rice production data in South Sumatra during the period 2009-2023 using the quadratic model is seen in the following figure.

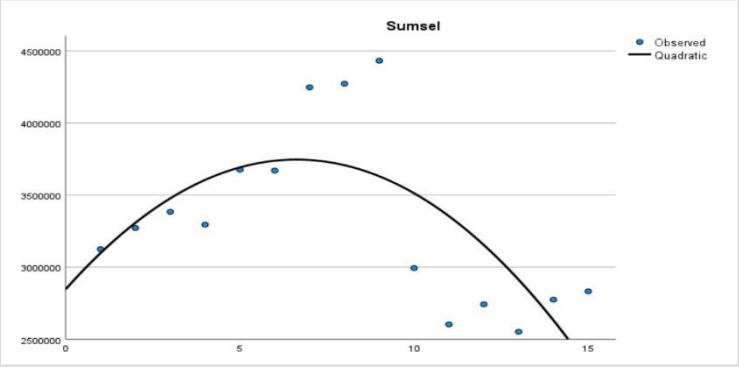

Figure 4. Quadratic Curve of Rice Production Data in South Sumatra Province

Based on the quadratic model, the rice production forecasting model for South Sumatra Province is: Y = 2847579.786 + 271428.396X – 20488.713X2 By using this model, the rice production forecast for 2024 can be obtained as shown in the following table.

Table 7. Rice Production Forecast for 2024 in South Sumatra Province

Year	Rice Production (tons)	Rice Production Forecast (tons)
(1)	(2)	(3)
2009	3,125,236	-
2010	3,272,451	-
2011	3,384,670	-
2012	3,295,247	-
2013	3,676,723	-
2014	3,670,435	-
2015	4,247,922	-
2016	4,273,168	-
2017	4,432,314	-
2018	2,994,192	-
2019	2,603,396	-
2020	2,743,060	-
2021	2,552,443	-
2022	2,775,069	-
2023	2,832,774	-
2024	-	1,945,324

Table 7 shows that in 2024, rice production in South Sumatra Province is predicted to reach 1,945,324 tons, showing a decrease from production in 2023 which reached 2,832,774 tons, or a decrease of 31.33%. This decrease was caused by increased pest and disease attacks on rice plants which could reduce productivity, while inefficient agricultural practices and fluctuations in agricultural commodity prices could also affect production results. Although the R-squared value of the quadratic model on the South Sumatra Province data is relatively small, namely 0.488 or 48.80%, this significant decrease in production highlights the need for coordinated and data-driven efforts to address its impacts and maintain the stability of the agricultural sector in South Sumatra.

Lampung Province Rice Production Forecast

The following table presents the output of SPSS software processing for rice production data in Lampung Province during the period 2009-2023.

Table 8. Rice Production Data Forecasting Model for Lampung Province

Model	R Square	Constant	b1	b2
Linear	0.139	3,163,862,201	-33,196,901	
Quadratic	0.324	2,710,391,756	126,851,491	-10,003,025
S	0.001	14,874	-0.013	
Exponential	0.148	3,161,439,575	-0.012	

Table 8 shows that the quadratic model shows the highest R-Squared, which is 0.324 or 32.40%. While the lowest R-squared is found in the S-Curve model with a value of 0.001 or 0.1%. The visualization of the distribution of rice production data in Lampung Province during the period 2009-2023 using the quadratic model is seen in the following figure.

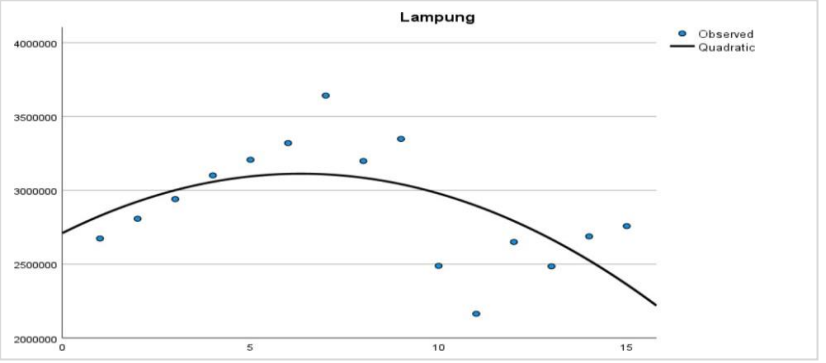

Figure 5. Quadratic Curve of Rice Production Data in Lampung Province

Based on the quadratic model, the rice production forecasting model for Lampung Province is: Y = 2710391.756 + 126851.491X – 10003.025X2

By using this model, we can obtain a forecast of rice production in 2024 as shown in the following table.

Table 9. Rice Production Forecast for 2024 in Lampung Province

Year	Rice Production (tons)	Rice Production Forecast (tons)
(1)	(2)	(3)
2009	2,673,844	-
2010	2,807,676	-
2011	2,940,795	-
2012	3,101,455	-
2013	3,207,002	-
2014	3,320,064	-
2015	3,641,895	-
2016	3,198,608	-
2017	3,348,434	-
2018	2,488,642	-
2019	2,164,089	-
2020	2,650,290	-
2021	2,485,453	-
2022	2,688,160	-
2023	2,757,898	-
2024	-	2,179,241

Table 9 shows that in 2024, the predicted rice production in Lampung Province is 2,179,241 tons. This figure shows a decrease of 20.98% when

compared to production in 2023 which reached 2,757,898 tons. This decrease in production can be caused by several factors, such as changes in rainfall patterns that affect the rice growth cycle, as well as decreased soil quality due to erosion or unsustainable use. In addition, limited access to efficient agricultural technology and inputs such as fertilizers and superior seeds can hinder productivity. Other contributing factors are pest and disease attacks that may not be optimally detected, as well as inadequate agricultural management practices. Given the R-Squared valuequite low, namely 0.324 or 32.40%. This analysis highlights the need for more in-depth research to understand the dynamics of rice production in Lampung Province, as well as the development of more accurate prediction models to support more appropriate decision making.

West Java Province Rice Production Forecast

The following table presents the output of SPSS software processing for rice production data in West Java Province during the period 2009-2023.

Table 10.West Java Province Rice Production Data Forecasting Model

Model	R Square	Constant	b1	b2
Linear	0.804	12,306,094,676	-231,962,628	
Quadratic	0.809	12,077,582,836	-151,311,390	-5,040,702
S	0.283	16,103	0.241	
Exponential	0.809	12,429,095,518	-0.022	

Table 10 shows that the quadratic and exponential models have the same R-Squared value, which is 0.809 or 80.09%. While the lowest R-squared value is found in the S-Curve model with a value of 0.283 or 28.30%. The visualization of the distribution of rice production data in West Java Province during the period 2009-2023 using the quadratic model is shown in the following figure.

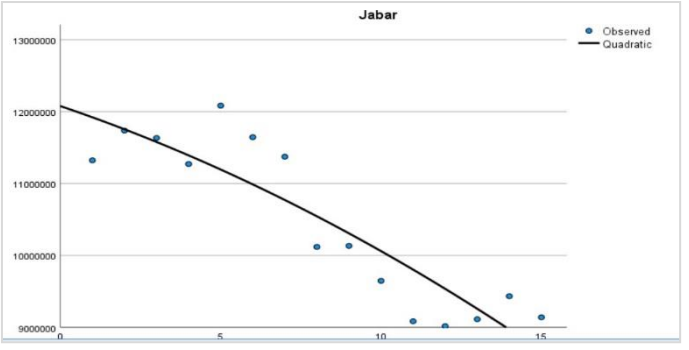

Figure 6. Quadratic Curve of Rice Production Data in West Java Province

Based on the quadratic model, the rice production forecasting model for West Java Province is: Y = 12077582.836 – 151311.390X – 5040.702X2

By using this model, we can obtain a forecast of rice production in 2024 as shown in the following table.

Table 11. Rice Production Forecast for 2024 in West Java Province

Year	Rice Production (tons)	Rice Production Forecast (tons)
(1)	**(2)**	**(3)**
2009	11,322,681	-
2010	11,737,070	
2011	11,633,891	-
2012	11,271,861	
2013	12,083,162	-
2014	11,644,899	
2015	11,373,144	-
2016	10,118,952	
2017	10,133,821	-
2018	9,647,359	
2019	9,084,957	-
2020	9,016,773	
2021	9,113,573	-
2022	9,433,723	
2023	9,140,039	-
2024	-	8,366,181

Table 11 shows a total of 8,366,181 tons, indicating a decrease of about 8.47% compared to the previous year. This decrease in production was caused by changes in weather patterns that affected the rice growing cycle, such as changes in temperature and unpredictable rainfall. In addition, although agricultural techniques in West Java are relatively advanced, it is possible that some areas experienced a decrease in efficiency due to the lack of adoption of new technologies or changes in managerial practices. Although this figure reflects a decrease in absolute numbers, the percentage decrease is relatively small, suggesting a relative stability in the productivity of the agricultural sector in West Java. This phenomenon can be seen as part of a model of annual changes in crop production, where fluctuations in crop yields can be influenced by factors such as weather conditions, agricultural techniques used, and variability in regional agricultural policies.

Rice Production Forecasting in Central Java Province

The following table presents the output of SPSS software processing for rice production data in Central Java Province during the period 2009-2023.

Table 12. Rice Production Data Forecasting Model for Central Java Province

Model	R Square	Constant	b1	b2
Linear	0.083	10,277,521,945	-39,281,858	
Quadratic	0.551	9,178,765,748	348,514,447	-24,237,269
S	0.008	16,118	-0.022	
Exponential	0.09	10,273,203,458	-0.004	

Table 12 shows that the quadratic model has the largest R-square value of 0.551 or 55.10%. Meanwhile, the model with the lowest R-squared is in the S-Curve with an R-squared value of 0.008 or 0.8%. The visualization of the distribution of rice production data in Central Java Province during the period 2009-2023 using the quadratic model is shown in the following figure.

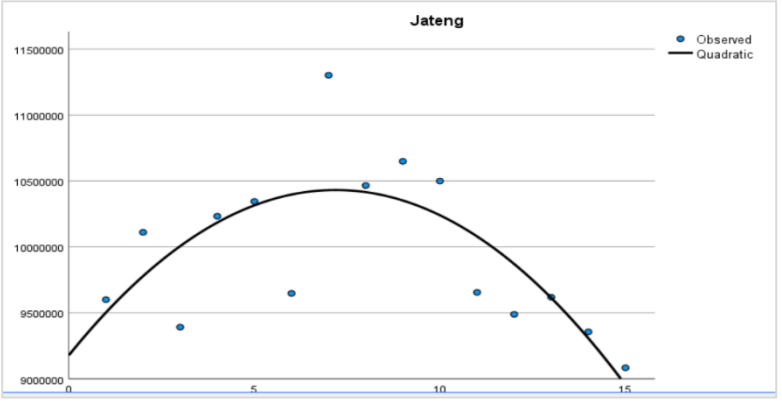

Figure 7. Quadratic Curve of Rice Production Data in Central Java Province

Based on the quadratic model, the rice production forecasting model for Central Java Province is: Y = 9178765.748 + 348514.447X – 24237.269X2

By using this model, we can obtain a forecast of rice production in 2024 as shown in the following table.

Table 13. Rice Production Forecast for 2024 in Central Java Province

Year	**Rice Production (tons)**	**Rice Production Forecast (tons)**
(1)	**(2)**	**(3)**
2009	9,600,415	-
2010	10,110,830	
2011	9,391,959	-
2012	10,232,934	
2013	10,344,816	-
2014	9,648,104	
2015	11,301,422	-
2016	10,465,840	
2017	10,649,070	-
2018	10,499,588	

Year	Rice Production (tons)	Rice Production Forecast (tons)
2019	9,655,654	-
2020	9,489,165	
2021	9,618,657	-
2022	9,356,445	
2023	9,084,108	-
2024	-	8,550,256

Table 13 shows that the prediction of Central Java's rice production for 2024 is 8,550,256 tons, decreasing by around 5.88% compared to the previous year. This decrease is influenced by several factors, including changes in climate conditions that can cause irregularities in rainfall or extreme temperatures that affect rice growth. In addition, although the agricultural techniques applied in Central Java are quite advanced, it is possible that some areas experience decreased yields due to decreased soil quality or reduced availability of resources.such as water and fertilizer. This decline can be seen through the quadratic analysis model used, with an R-squared value of 0.551. This R-squared value indicates that approximately 55.1% of the variation in Central Java rice production can be explained by the quadratic model used to make the prediction. Although there was a decline in absolute production volume, the relatively small percentage decline indicates stability in the rice production model in Central Java.

Rice Production Forecasting in East Java Province

The following table presents the output of SPSS software processing for rice production data in East Java Province during the period 2009-2023.

Table 14. Rice Production Data Forecasting Model for East Java Province

Model	R Square	Constant	b1	b2
Linear	0.354	12,543,306,601	-173,771,423	
Quadratic	0.61	10,798,577,215	442,015,419	-38,486,678
S	0.039	16,200	0.095	
Exponential	0.383	12,619,946,981	-0.016	

Table 14 shows that the quadratic model has the largest R-square value of 0.610 or 61.00%. While the model with the lowest R-squared is in the S-Curve with an R-squared value of 0.39 or 39.00%. The visualization of the distribution of rice production data in East Java Province during the period 2009-2023 using the quadratic model is shown in the following figure.

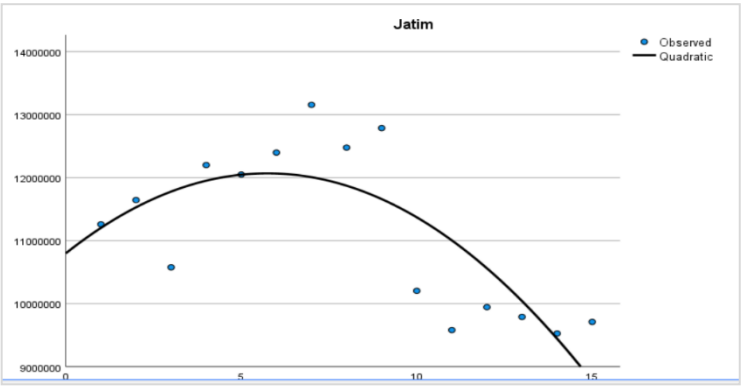

Figure 8. Quadratic Curve of Rice Production Data in East Java Province

Based on the quadratic model, the rice production forecasting model for East Java Province is: Y = 10798577.215+ 442015.419X – 38486.678X2

By using this model, we can obtain a forecast of rice production in 2024 as shown in the following table.

Table 15. Rice Production Forecast for 2024 in East Java Province

Year	ProductionRice (tons)	Rice Production Forecast (tons)
(1)	(2)	(3)
2009	11,259,085	-
2010	11,643,773	
2011	10,576,543	-
2012	12,198,707	
2013	12,049,342	-
2014	12,397,049	
2015	13,154,967	-
2016	12,476,288	
2017	12,785,824	-
2018	10.203.213	
2019	9,580,934	-
2020	9,944,538	
2021	9,789,588	-
2022	9,526,516	
2023	9,710,661	-
2024	-	8,018,234

Table 15 shows that the prediction of East Java's rice production for 2024 of 8,018,234 tons has decreased by around 17.43% compared to the previous year. This decrease is influenced by several factors, including climate change which can result in unfavorable weather conditions, such as unstable rainfall or extreme temperatures that affect rice growth. In addition, there is a possibility that soil quality has decreased due to less sustainable agricultural practices or suboptimal management. This decrease can be interpreted through the quadratic analysis model used, with an R-squared value of 0.610.

This R-squared value indicates that around 61.0% of the variation in East Java's rice production can be explained by the quadratic model. Although there was a significant decrease in the amount of production in generalIn absolute terms, this relatively large percentage decline reflects fluctuations in crop production models in the East Java region.

Banten Province Rice Production Forecast

The following table presents the output of SPSS software processing for rice production data in Banten Province during the period 2009-2023.

Table 16. Rice Production Data Forecasting Model for Banten Province

Model	R Square	Constant	b1	b2
Linear	0.208	2,126,476,610	-27,302,468	
Quadratic	0.374	1,837,937,861	74,534,738	-6,364,825
S	0.015	14,437	0.071	
Exponential	0.235	2,135,611,655	-0.015	

Table 16 shows that the quadratic model has the largest R-square value of 0.374 or 37.40%. Meanwhile, the model with the lowest R-squared is in the S-Curve with an R-squared value of 0.015 or 1.5%. The visualization of the distribution of rice production data in Banten Province during the period 2009-2023 using the quadratic model is shown in the following figure.

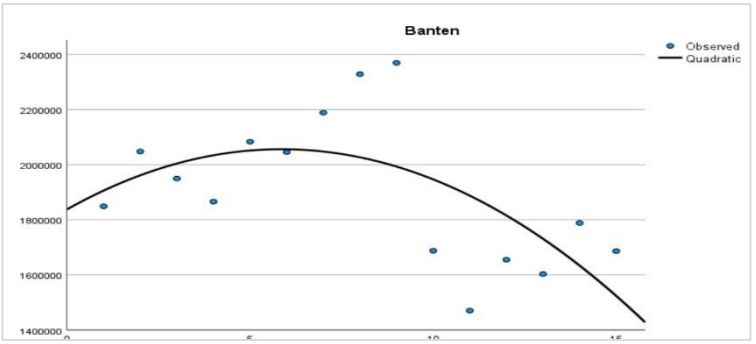

Figure 9. Quadratic Curve of Rice Production Data in Banten Province

Based on the quadratic model, the rice production forecasting model for Banten Province is: Y = 1837937.861 + 74534.738X – 6364.825X2

By using this model, we can obtain a forecast of rice production in 2024 as shown in the following table.

Table 17. Rice Production Forecast for 2024 in Banten Province

Year	ProductionRice (tons)	Rice Production Forecast (tons)
(1)	(2)	(3)
2009	1,849,007	-
2010	2,048,047	
2011	1,949,714	-
2012	1,865,893	
2013	2,083,608	-
2014	2,045,883	
2015	2,188,996	-
2016	2,328,440	
2017	2,369,495	-
2018	1,687,783	
2019	1,470,503	-
2020	1,655,170	
2021	1,603,247	-
2022	1,788,583	
2023	1,686,483	-
2024	-	1,401,098

Table 17 shows that the predicted rice production of Banten Province for 2024 shows a total of 1,401,098 tons, a decrease of around 16.92% compared to the previous year. This decrease in production is likely caused by several factors, such as changes in rainfall patterns that can result in weather conditions that are less supportive for rice growth, as well as a decrease in soil quality that may be caused by unsustainable agricultural practices or lack of maintenance. This decrease can be seen through the quadratic analysis model used, with an R-squared value of 0.374. This relatively low R-squared value indicates that around 37.4% of the variation in Banten Province's rice production can be explained by the quadratic model. However, although this model provides an overview of the downward trendproduction, the low R-squared value indicates that there are other factors outside this model that can influence production variation.

West Nusa Tenggara Province Rice Production Forecast

The following table presents the output of SPSS software processing for rice production data in West Nusa Tenggara Province during the period 2009-2023.

Table 18. NTB Province Rice Production Data Forecasting Model

Model	R Square	Constant	b1	b2
Linear	0.215	2,308,808,394	-49,992,326	
Quadratic	0.459	1,679,213,076	172,217,786	-13,888,132
S	0.018	14,403	0.135	
Exponential	0.281	2,348,711,377	-0.03	

Table 18 shows that the quadratic model has the largest R-square value of 0.459 or 45.90%. Meanwhile, the model with the lowest R-squared is in the S-Curve with an R-squared value of 0.018 or 1.8%. The visualization of the distribution of rice production data with the quadratic model in West Nusa Tenggara Province during the period 2009-2023 is seen in the following figure.

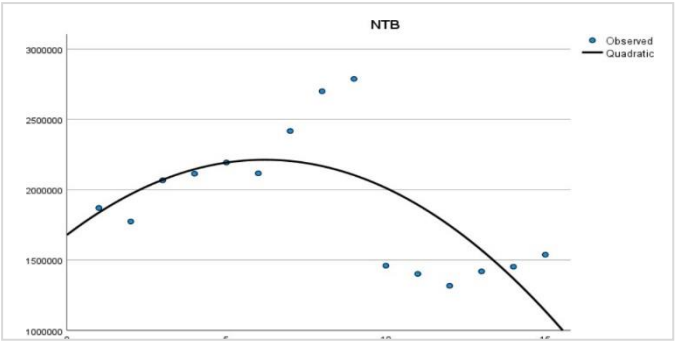

Figure 10. Quadratic Curve of Rice Production Data in NTB Province

Based on the quadratic model, the rice production forecasting model for West Nusa Tenggara Province is: Y = 1679213.076 + 172217.786X – 13888.132X2 By using this model, the rice production forecast for 2024 can be obtained as shown in the following table.

Table 19.Rice Production Forecast for 2024 in West Nusa Tenggara Province

Year	Rice Production (tons)	Rice Production Forecast (tons)
(1)	(2)	(3)
2009	1,870,775	-
2010	1,774,499	
2011	2,067,137	-
2012	2,114,231	
2013	2,193,698	-
2014	2,116,637	
2015	2,417,392	-
2016	2,700,200	
2017	2,787,725	-
2018	1,460,339	
2019	1,402,182	-
2020	1,317,190	
2021	1,419,560	-
2022	1,452,945	
2023	1,538,537	-
2024		879,336

Table 19 shows that the predicted rice production of West Nusa Tenggara Province for 2024 of 879,336 tons has decreased significantly by around 42.85% compared to the previous year. This significant decrease was caused by several factors, including extreme climate conditions, such as prolonged

drought or uneven rainfall, which greatly affected rice yields in this region. This decrease can be seen through the quadratic analysis model used, but the R-squared value of only 0.459 indicates that only around 45.9% of the variation in rice production in West Nusa Tenggara Province can be explained by the model. This low R-squared value indicates that the quadratic analysis model may not be fully adequate in predicting large fluctuations such as those that occurred in this case.

Rice Production Forecasting in South Sulawesi Province

The following table presents the output of SPSS software processing for rice production data in South Sulawesi Province during the period 2009-2023.

Table 20. Rice Production Data Forecasting Model for South Sulawesi Province

Model	R Square	Constant	b1	b2
Linear	0.159	4,752,588,250	46,537,741	
Quadratic	0.675	3,761,129,573	396,464,333	-21,870,412
S	0.421	15,504	-0.27	
Exponential	0.176	4,722,729,249	0.01	

Table 20 shows that the quadratic model has the largest R-square value of 0.675 or 67.50%. Meanwhile, the model with the lowest R-squared is the linear model with an R-squared value of 0.159 or 15.9%. The visualization of the distribution of rice production data in South Sulawesi Province during the period 2009-2023 using the quadratic model is shown in the following figure.

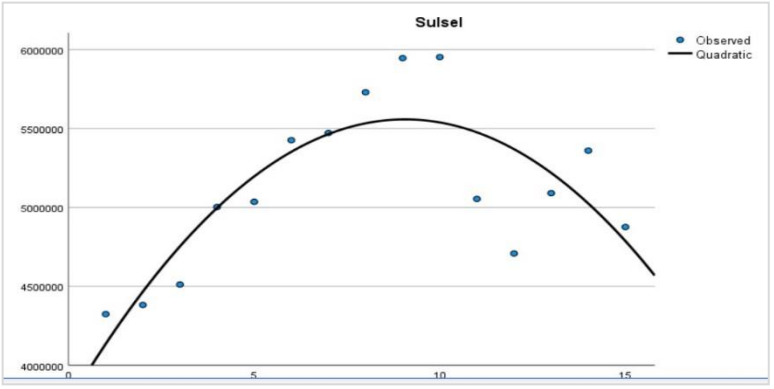

Figure 11. Quadratic Curve of Rice Production Data in South Sulawesi Province

Based on the quadratic model, the rice production forecasting model for South Sulawesi Province is: Y = 3761129.573 + 396464.333X – 21870.412X2

By using this model, we can obtain a forecast of rice production in 2024 as shown in the following table.

Table 21. Rice Production Forecast for 2024 in South Sulawesi Province

Year	Production Rice (tons)	Rice Production Forecast (tons)
(1)	(2)	(3)
2009	4,324,178	-
2010	4,382,443	
2011	4,511,705	-
2012	5,003,011	
2013	5,035,830	-
2014	5,426,097	
2015	5,471,806	-
2016	5,729,808	
2017	5,946,034	-
2018	5,952,616	
2019	5,054,167	-
2020	4,708,465	
2021	5,090,637	-
2022	5,360,169	
2023	4,876,386	-
2024		4,505,733

Table 21 shows the prediction of rice production in South Sulawesi Province for 2024 of 4,505,733 tons, decreasing by around 7.6% compared to the previous year. This decline may be influenced by several factors, such as changes in rainfall patterns that affect rice growth, as well as a decrease in soil quality that can be caused by intensive use or lack of soil conservation practices. This decline can be seen through the quadratic analysis model used, but the R-squared value of only 0.675 indicates that around 67.5% of the variation in rice production in South Sulawesi Province can be explained by the model. Although this model provides an overview of the trend of decreasing production, the R-squared value that does not reach 1 indicates that there are other factors outside this model that can affect variations in rice production.

Conclusion

This study highlights the importance of rice production in Indonesia as a major source of food and strategic commodities. By analyzing rice production data in the 10 largest provinces during the period 2009-2023, this study successfully identified production trends and formulated accurate forecasting models. 1) Rice Production Trends, rice production in Indonesia shows an overall increasing trend, but there is significant variability among provinces. Several provinces experienced a marked decline in production in 2024, such as North Sumatra (a

decrease of 40.14%) and West Nusa Tenggara (a decrease of 42.85%). 2) Forecasting Model, the quadratic model proved to be the most appropriate forecasting model for most provinces, with the highest R-squared values in various provinces, such as West Java (80.09%), North Sumatra (75.30%), and Aceh (72.90%). However, the quadratic model also showed limitations in explaining production variations in several provinces, such as Lampung (32.40%) and Banten (37.40%). 3) 2024 Production Prediction, rice production predictions for 2024 show a decline in most provinces compared to 2023. West Java and South Sulawesi provinces show a relatively more stable decline, which is around 8.47% and 7.6% respectively.

Development of Agricultural Technology and Practices is advised to conduct further research and focus on the development of agricultural technology and practices that can help farmers increase yields. Technologies such as efficient irrigation systems, the use of organic fertilizers, and environmentally friendly pesticides need to be researched and implemented. This is in line with the benefits of research that provides farmers with accurate predictions of rice production, so that they can plan more effective cultivation strategies. It is important to hold socialization and training programs for farmers on the use of rice production prediction results and rice price fluctuations. This will help them adjust the timing of harvest and sales, so that they can get better prices and increase income.

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