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Original Research Article

A Comprehensive Analysis of Factors Affecting Paddy Production in Malaysia

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Abstract: This study comprehensively investigates the multifaceted factors influencing paddy production in Malaysia, a sector critical for national food security and rural livelihoods. Employing a log-linear regression model on secondary data from 1991 to 2022, the research quantitatively assesses the impact of area harvested, fertilizer consumption, temperature, and rainfall, alongside lagged production and specific historical events. Findings reveal that area harvested, and fertilizer consumption positively and significantly impact paddy production, with coefficients of 0.75 and 0.19, respectively. Conversely, temperature exerts a significant negative influence, with a 1% increase leading to a 0.45% reduction in production. Rainfall, while crucial, did not exhibit direct statistical significance in the aggregated model, suggesting complex underlying dynamics. Dummy variables effectively capture the disruptive effects of the 1997 Asian Financial Crisis and 2006 policy shifts, as well as the positive impact of the 2009 recovery and government interventions. Beyond these quantitative determinants, the study integrates insights from broader literature, highlighting critical socio-economic factors, technological adoption barriers, and governance challenges. Diagnostic tests confirm the model's reliability. The report underscores the urgent need for integrated policies that protect agricultural land, optimize input use, enhance climate resilience, strengthen farmer support, and accelerate sustainable technology adoption to bridge the existing productivity gap and ensure Malaysia's long-term food security.

Keywords: Paddy Production; Malaysia; Food Security; Agricultural Economics

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1. Introduction

Rice stands as a cornerstone of global food security, supporting the daily diets and caloric needs of billions and underpinning livelihoods across many regions. It is the world's second most important food crop, feeding an estimated 3.5 billion people and providing a significant share of dietary protein for about 520 million people living in poverty in Asia, with cultivation spanning more than 100 countries on roughly 162 million hectares and yielding about 496 million tonnes of milled rice annually (roughly 715 million tonnes of paddy). The forthcoming demand surge, projected at an additional 114 million tonnes by 2035, will strain natural resources unless productivity grows with minimal environmental impact, a challenge compounded by the fact that about three-quarters of global rice comes from irrigated lowland systems across approximately 93 million hectares, which face growing water-supply constraints as freshwater resources come under pressure. This interconnected global dynamic means that disruptions in any region can ripple worldwide, and for Malaysia, rising import dependence underscores that national food security is tightly tied to global supply chains, making domestic production enhancements part of the broader effort to stabilize regional and global food systems.

In Malaysia, paddy is a cornerstone of the agricultural sector, the third most significant crop behind rubber and palm oil, contributing around RM2.18 billion to GDP in 2023, while rice remains a daily staple with an average per-capita consumption of about 80 kilograms and supporting roughly 300,000 rural households; its cultural resonance is equally strong, embedded in social structures and traditions (Abas et. al., 2020). In recent years, Malaysia's official data have revealed a worrying decline in rice self-sufficiency. In 2022, the rice self-sufficiency rate (SSR) stood at only 62.6%, meaning that Malaysians produced barely two-thirds of their staple food locally (Business Today Malaysia, 2023). Following the Agriculture and Food Security Ministry's adoption of stricter Food and Agriculture Organization (FAO), i.e., aligned accounting methods, the recalculated SSR for 2023 dropped further to 56.2% (Ministry of Agriculture and Food Security, 2024). In practical terms, this indicates that only about half of Malaysia's rice demand was met through domestic production, where well below the government's official target of 75% by 2025 (Business Today Malaysia, 2023). Even before this methodological revision, the minister acknowledged that the SSR had hovered around 65% in previous years, underscoring a persistent structural weakness in Malaysia's rice sector (Malaysian Insight, 2024).

This downward trend is more than a statistical anomaly; it signals a growing dependence on imported rice, particularly from neighboring producers such as Thailand and Vietnam. Several interrelated factors drive this decline, including limited arable land, rapid urbanization, an aging farming population, and increasing climate variability. Paddy cultivation is highly sensitive to rainfall patterns and temperature fluctuations. For example, higher temperatures, especially during critical growth stages, can significantly reduce yields. Moreover, inefficient fertilizer uses not only limits productivity but also contributes to environmental degradation.

In response, the government has placed rice production at the center of its National Agrofood Policy 2.0, which aims to raise the SSR to 75% by 2025 and 80% by 2030. Achieving these targets will require more than increased subsidies; it will demand coordinated reforms in land use, climate adaptation strategies, and technological innovation to strengthen both food security and economic resilience in the years ahead. Hence, this study mainly aims to estimate the driving factors affecting Malaysia's paddy production, thereby offering a more comprehensive understanding of productivity challenges and actionable guidance for policy and practice.

2. Literature Review

The literature review on paddy production in Malaysia reveals a complex interplay of environmental, economic, socio-economic, and technological factors that collectively influence yields and national food security. Theoretically, agricultural productivity is understood through production functions, which describe how various inputs, such as land, labor, capital, and fertilizers, are transformed into agricultural outputs. A key economic principle, particularly for fertilizer use, is diminishing returns, where excessive application can lead to reduced marginal gains and negative environmental externalities. Technological progress and human capital, encompassing farmer knowledge and effective management practices, are crucial for enhancing efficiency and shifting production frontiers. A nation's reliance on imports, as seen in Malaysia's paddy sector, highlights the strategic imperative of domestic production for food security.

Empirical studies consistently demonstrate a significant inverse relationship between the reduction of paddy land and paddy production in Malaysia. Research by Wan and Nor (2017) and Arshad *et al.* (1997) observed that continuous land reduction due to urbanization and industrial activities leads to a corresponding decline in production, underscoring the critical role of land availability. This conversion represents a permanent loss of fertile agricultural capital, making land preservation a long-term strategic imperative. Strategies such as rehabilitating unused fields and designating protected agricultural zones are crucial to safeguard cultivation areas. Innovation diffusion in agricultural practices and efficient water management, informed by technologies like remote sensing, is also essential for sustaining production amidst land reduction.

Fertilizer consumption positively impacts paddy yields by supplying essential nutrients, with studies by Nasir et al. (2015), and Adekayode and Ogunkoya (2010) highlighting that increased usage contributes to enhanced productivity. However, the literature also warns against suboptimal or excessive application, which can lead to soil acidification, nutrient imbalances, and severe environmental degradation, particularly with nitrogen fertilizers. Malaysian farmers have been observed applying more than the recommended rate of 170 kg N/ha, contributing to unsustainable yield increases. This suggests a need for smarter, site-specific nutrient management and comprehensive farmer education to promote sustainable practices like Integrated Soil Fertility Management (ISFM) and precision agriculture. Research also suggests that targeting photosynthesis per unit nitrogen could be a sustainable solution, as some Malaysian paddy varieties show lower sensitivity to nitrogen deficiency.

Climatic factors, especially temperature, significantly affect paddy production. Elevated temperatures negatively impact growth, reduce grain filling, shorten growing periods, and increase sterility. Peng *et al.* (2004) found that rice yields can decline with higher night temperatures, with every 1°C rise during the growing season potentially reducing yields by 10%. This "silent threat" from rising average temperatures, coupled with increased evaporation rates, exacerbates water stress and poses significant risks to Malaysia's granary areas. Climate shifts also bring unpredictable crop production due to extreme events like heavier rainfall and prolonged droughts, and increased salinity in coastal areas.

Rainfall is unequivocally critical for paddy cultivation, a water-intensive crop. Both insufficient rainfalls, leading to drought stress, and excessive rainfall, causing waterlogging and flooding, negatively impact yields. Inconsistent rainfall patterns, particularly during critical flowering and grain filling stages, profoundly affect paddy yield. Kogan (2013) further highlighted that changes in precipitation patterns increase the vulnerability of agricultural systems, especially those dependent on rain-fed irrigation. Innovations in irrigation and water-saving technologies like Alternate Wetting and Drying (AWD) are vital for mitigating the adverse effects of fluctuating precipitation and enhancing resilience.

Beyond biophysical factors, socio-economic and human elements significantly influence productivity. Farmer demographics, knowledge, and training initiatives play a crucial role, as farmers participating in government courses demonstrate higher yields. However, low training attendance rates, with only 9.5% of farmers in IADA Batang Lupar attending such courses, contribute to a pervasive lack of agricultural knowledge, suboptimal practices, and consequently, low farm yields. Access to subsidies and advisory services is also critical, though implementation gaps mean many farmers receive only a fraction of available support. A pervasive challenge for small-scale farmers is the lack of sufficient capital to invest in modern technology or mechanization, often forcing them to rely on less efficient traditional methods. Farm management practices, including consistent monitoring and adherence to cultivation manuals, are also crucial, with deviations contributing to lower yields.

Technological interventions, particularly through mechanization and advanced fertilizer application methods, are recognized as important contributors to paddy yield. The adoption of modern machinery like small harvesters, high-tolerance tractors, drones, and trans-planters has the potential to significantly boost productivity. However, the Malaysian rice production system faces challenges due to poor technology deployment, a lack of awareness and knowledge among farmers, and notable hesitancy towards genetically modified (GM) planting materials. Effective farmer-researcher communication is identified as a key to success, facilitating meaningful laboratory-to-farm translational research and acceptance of new technologies. Malaysia lags in yield and productivity due to "unattended/widening gaps" in the use of GM planting materials, nano fertilization, and other technology-driven farming practices.

Overall, the literature confirms the critical influence of land use, fertilizer, temperature, and rainfall, while also highlighting significant research gaps in the quantitative modeling of socio- economic factors, farmer behavior, and the nuances of technology adoption and policy implementation. A comprehensive understanding requires integrating these qualitative and human- centric factors with quantitative analysis to develop holistic and actionable policy frameworks.

3. Methodology

3.1 Mathematical Model Specification (Log-Linear Regression)

The analytical framework employed in this study is a log-linear multiple regression model, specified as follows:

$$lnY_t = \beta_0 + \beta_1 lnY_{t-1} + \beta_2 lnAH_t + \beta_3 lnFC_t + \beta_4 lnTemp_t + \beta_5 lnRF_t + \beta_6 DUM_t + \beta_7 DUM2_t + \beta_8 DUM3_t + u_t \quad (1)$$

Where; lnY = Paddy production transformed into natural logarithm

lnAH = Area harvested transformed into natural logarithm

lnFC = Fertilizer consumption transformed into natural logarithm

lnTemp = Average temperature transformed into natural logarithm

lnRF = Rainfall transformed into natural logarithm

DUM = 1 in year 1998 and 0 for other years

DUM2 = 1 in year 2006 and 0 for other years

DUM3 = 1 in year 2009 and 0 for other years

In this model, the dependent variable, paddy production (Yt), is transformed into its natural logarithm (lnYt). This log-linear specification allows for the direct interpretation of the estimated coefficients as elasticities. Specifically, each coefficient (βi) indicates the percentage change in paddy production for a 1% change in the corresponding independent variable, assuming all other factors remain constant. This proportional specification is particularly suitable for agricultural and economic studies aiming to understand input-output dynamics and assess policy impacts.

In addition to these continuous variables, the model incorporates dummy variables to capture discrete changes or significant time-specific effects that may have influenced paddy production. DUM is a dummy variable representing the period of the Asian Financial Crisis in 1997/98, designed to capture its negative effects on resource access and production. DUM2 is a dummy variable for 2006, capturing the effects of global fertilizer price surges and potential policy shifts during that year. Furthermore, DUM3 is a dummy variable for 2009, reflecting a period of recovery-driven increases in production, possibly influenced by government policies and economic stabilization.

The term u_t represents the error term, accounting for unobserved factors or random fluctuations affecting paddy production that are not explicitly included in the model. The choice of a log-linear model is strategic because it allows for direct interpretation of coefficients as elasticities. This is highly valuable for policy formulation, as it provides a clear quantitative measure of the proportional responsiveness of paddy production to changes in inputs or environmental conditions.

3.2 Data Sources and Collection

This study collected secondary time series (annually) data spanning the period from 1991 to 2022. The data collection framework is structured to obtain comprehensive information on the key variables identified as influencing paddy production. The four key variables and their respective sources are the data for paddy production (tonnes), and area harvested (hectares) were obtained from the Department of Statistics Malaysia. The data on fertilizer consumption, measured in thousands of tonnes, was acquired by the International Fertilizer Association (IFA), ensuring access to reliable information on fertilizer usage trends. Moreover, the climatic data, including average temperature in degrees Celsius and total rainfall in millimeters, were collected from the World Bank Climate Change Knowledge Portal. This portal offers extensive climate-related datasets crucial for analyzing the environmental factors affecting paddy production.

4. Results and Findings

4.1 Descriptive Analysis of Key Variables

The descriptive analysis provides a summary of the central tendency, variability, and distribution for the key variables related to paddy production: Paddy Production (Y), Area Harvested (AH), Temperature (Temp), Fertilizer Consumption (FC), and Rainfall (RF). This analysis is based on 32 observations, with no missing data, offering insights into the characteristics of each variable. The results of the descriptive analysis are presented in Table 1.

Table 1: Result of descriptive analysis

Variable	Mean	Median	Std. Dev.	Jarque-Bera	Probability
Y	2,330,087	2,354,701	244,606.2	1.39	0.50
AH	676,705.4	675,995	15,330.4	4.40	0.11
Temp	27.31	27.50	0.83	0.07	0.96
FC	1,607.19	1,570	426.24	2.70	0.26
RF	3,020.65	3,097.02	312.94	1.74	0.42

Paddy production (Y) has an average of 2,330,087 tonnes, with a standard deviation of 244,606.2, indicating moderate variability in output over the study period. Production ranged from a minimum of 1,926,354 tonnes to a maximum of 2,848,560 tonnes. The skewness of 0.32 and kurtosis of 2.20 suggest a slightly right-skewed distribution that is relatively close to a normal distribution. The Jarque-Bera test statistic of 1.39, with a probability value of 0.50, confirms that the production data does not significantly deviate from normality.

The Area Harvested (AH) averaged 676,705.4 hectares, with a relatively small standard deviation of 15,330.4 hectares, suggesting consistent land use across observations. Its distribution is negatively skewed (−0.85), indicating a slight concentration of values towards the higher end of the range, and has a kurtosis of 3.65. The Jarque-Bera statistics of 4.40 (probability 0.11) indicate no significant departure from normality for this variable.

Mean temperature (Temp) was 27.31 ℃, with a very narrow standard deviation of 0.83 ℃, highlighting minimal variation in average temperatures over the years. The skewness (0.01) and kurtosis (2.74) figures suggest a symmetric and nearly normal distribution, which is further supported by a high Jarque-Bera probability of 0.96.

Fertilizer Consumption (FC) averaged 1,607.19 thousand tonnes, with a standard deviation of 426.24 thousand tonnes, indicating moderate variability in fertilizer usage. The distribution is nearly symmetric (skewness 0.03) and slightly flatter than a normal distribution (kurtosis 1.58). The Jarque-Bera test statistic of 2.70 (probability 0.26) confirms normality for fertilizer consumption data.

Rainfall (RF) exhibited a mean of 3,020.65 mm and a standard deviation of 312.94 mm, suggesting consistent annual precipitation levels. A slight leftward skew (−0.16) and a relatively flat distribution (kurtosis 1.91) were observed. The Jarque-Bera probability of 0.42 supports the assumption of normality for the rainfall data.

Overall, the descriptive statistics indicate that all variables are relatively well distributed with no significant deviations from normality. This provides a robust basis for the subsequent multiple regression analysis, ensuring that the assumptions underlying the statistical model are met. This table is crucial as it provides the foundational statistical properties of the data used in the regression. It allows readers to understand the typical values, spread, and distribution of each variable. Confirming normality via the Jarque-Bera test is important for the validity of subsequent regression assumptions. This table serves as a data quality check and contextualizes the subsequent regression results, showing the range and typical conditions of paddy production and its determinants over the study period.

4.2 Paddy Production Analysis

The multiple regression analysis provides quantitative insights into how various factors influence paddy production in Malaysia. The results of the regression are summarized in Table 2. The lagged dependent variable, lnYt−1, exhibits a positive and statistically significant relationship with current paddy production at the 1% level, with a coefficient of 0.47. This indicates that a 1% increase in the previous period's production is associated with a 0.47% increase in the current period's production, holding other factors constant. This suggests that past productivity influences current yields, likely due to cumulative factors such as improved soil quality, persistent farming practices, and farmers' adaptive strategies based on historical success. Liu *et al.* (2018) emphasized the critical role of past yields in guiding current agricultural practices, particularly in rice-based systems.

Table 2: Multiple regression analysis

Variable	**Coefficient**	**Std. Error**	**t-Statistic**	**Prob.**
C	1.83	1.09	1.68	0.10
LnY(-1)	0.47	0.11	4.27	0.00
LnAH	0.75	0.21	3.61	0.00
LnFC	0.19	0.04	4.92	0.00
LnTEMP	–0.45	0.21	-2.13	0.04
LnRF	–0.08	0.06	-1.43	0.17
DUM	–0.05	0.01	-3.66	0.00
DUM2	–0.05	0.01	-3.66	0.00
DUM3	0.02	0.00	4.92	0.00
R-squared	0.96	Mean dependent var	14.65	
Adjusted R-squared	0.94	S.D. dependent var	0.11	
F-statistic	61.46	Durbin-Watson stat	1.94	
Prob(F-statistic)	0.00			

The relationship between the area harvested (lnAHt) and paddy production reveals a significant positive impact. Specifically, every 1% increase in the area harvested leads to a 0.75% increase in paddy production, holding all other variables constant. This finding underscores that expanding the land under cultivation plays a crucial role in boosting paddy production. Historically, the expansion of cultivated land contributed significantly to the rise in rice production, particularly in Asia during earlier decades. However, this positive relationship is challenged by ongoing industrialization, which has led to a decline in paddy land, thereby detrimentally affecting paddy production. As highlighted by Arshad *et al.* (1997), industrial growth has contributed to the continuous reduction of paddy fields, which directly correlates with the observed decline in production. Furthermore, Wan and Nor (2017) pointed out that the shrinking of paddy land over time has been a major factor behind the observed decrease in paddy production, reinforcing the idea that maintaining and expanding the area under cultivation is critical for sustaining agricultural output. The high elasticity of paddy production to area harvested (0.75) emphasizes that land remains a fundamental and irreplaceable factor. This is particularly critical in Malaysia, where land is being lost to urbanization. This implies that even significant improvements in yield per hectare might not fully offset the impact of shrinking land area, making land preservation policies not just desirable but economically imperative for maintaining production levels.

Fertilizer consumption (lnFCt) also demonstrates a positive and significant effect on paddy production, with every 1% increase in fertilizer usage leading to a 0.19% increase in paddy production, holding all other variables constant. Fertilizers are crucial for enhancing the soil's nutrient content, which directly improves plant growth and subsequently boosts yield. A willingness to invest in fertilizers is key to improving agricultural productivity. Fertilizers provide essential nutrients at different stages of growth, contributing to optimal plant development. However, it is important to acknowledge that excessive use of chemical fertilizers or improper timing of their application can have adverse effects, potentially hindering paddy production. As Zaid *et al.* (2023) pointed out, a balanced and well-timed application of fertilizers is critical to ensuring their positive impact on crop yields. While the model shows a positive effect, the literature review warns about diminishing returns and environmental costs of excessive use. The relatively lower coefficient (0.19) compared to area harvested (0.75) might implicitly suggest that current fertilizer use is approaching or has reached a point of diminishing returns, or that its effectiveness is mediated by other factors not in the model, such as soil health or application method. This means that future interventions should focus on precision agriculture and integrated nutrient management to maximize efficiency and minimize negative externalities, rather than simply increasing overall consumption.

The analysis reveals a significant negative relationship between temperature (lnTempt) and paddy production. Specifically, every 1% increase in temperature leads to a 0.45% decrease in paddy production, holding all other variables constant. This effect underscores the vulnerability of paddy production to rising temperatures, particularly during critical growth phases. Higher temperatures can lead to increased sterility, especially during the reproductive stage, which affects grain quality and reduces yields. Additionally, elevated temperatures impact the development rate of leaves and delay the maturity of the paddy, ultimately leading to lower production. The increase in temperature also leads to higher evaporation rates, which reduces moisture availability for the plants, further exacerbating the decline in paddy production. The p-value associated with this relationship is statistically significant (0.04), reinforcing the reliability of the result. The findings demonstrate that temperature plays a critical role in determining paddy yields, with higher temperatures contributing to a decline in production. The direct negative impact of temperature is a clear and present danger, exacerbated by global warming trends. This effect is not just about yield reduction but also about the physiological stress on the plant, making it more vulnerable to other factors like pests or diseases. This emphasizes that climate change adaptation strategies, including the development of heat-tolerant varieties and improved water management to counteract increased evapotranspiration, are non-negotiable for future paddy sustainability.

The analysis shows that rainfall (lnRFt) has a coefficient of −0.08, meaning every 1% increase in rainfall is associated with a 0.08% decrease in paddy production, holding all other variables constant. However, the effect of rainfall is statistically insignificant in this model (p-value 0.17), suggesting that rainfall does not have a strong or reliable direct impact on paddy production within the context of this study. While rainfall is essential for paddy cultivation, its timing and amount are critical. Excessive rainfall or poorly timed rainfall events can have detrimental effects on yields. As Arifah *et al.* (2022) observed, a reduction in rainfall or limited access to irrigation can negatively impact paddy production by reducing water availability. On the other hand, excessive rainfall can cause flooding, which disrupts crop growth and leads to lower yields. Fageria (2007) emphasized the importance of optimal water availability for paddy production, pointing out that both excessive and insufficient rainfall can harm productivity. Despite these insights from the literature, the statistical insignificance of rainfall in this model suggests that other factors might have a more significant influence on paddy production, or that the aggregate annual data used may not capture the nuanced effects of rainfall timing and distribution. The model's finding of statistical insignificance for rainfall, despite the general understanding of rice as a water-intensive crop, is a key area for nuanced discussion. The literature clearly states that both insufficient and excessive rainfall negatively impact yields. The insignificance in the model likely stems from using aggregate annual rainfall data, which fails to capture critical temporal (e.g., timing during growth stages) and spatial (regional variability, localized droughts/floods) nuances. Effective irrigation systems might also buffer the impact of overall annual rainfall variability. This implies that while the model does not show a direct linear relationship, rainfall's importance cannot be dismissed. Future research needs more granular data (e.g., seasonal, regional) to capture its true, complex influence. Policies should focus on robust water management infrastructure and climate-smart practices to manage rainfall extremes.

The inclusion of dummy variables in the analysis reflects significant historical events that impacted paddy production during specific years. The dummy variable for 1997 (DUM), representing the Asian Financial Crisis, shows a significant negative coefficient (−0.05, p-value <0.01). This confirms the disruptive impact of the crisis, likely through reduced access to critical resources such as fertilizer and labor, thereby adversely impacting agricultural production. Pingali (2007) supports this by noting the negative effects of such crises on agricultural sectors. Dummy 2 (DUM2), representing 2006, also has a significant negative coefficient (−0.05, p-value <0.01). This captures the effects of the global fertilizer price surge during that period, which led to reduced fertilizer usage by farmers, resulting in lower yields. Additionally, abnormal rainfall patterns during this period may have further affected paddy production. Dummy 3 (DUM3), representing 2009, shows a significant positive coefficient (0.02, p-value <0.01). This reflects a positive shock in the agricultural sector, where the Malaysian government implemented policies to support farmers, including fertilizer subsidies and the promotion of modern farming techniques. By 2009, economies had started recovering from the 2008 global crisis, leading to better access to agricultural inputs, which positively impacted paddy production. This positive shock contributed to an improvement in the agricultural sector's performance during this time. These dummy variables demonstrate that paddy production is not solely driven by internal agricultural factors but is highly susceptible to macro-economic shocks and government policy responses. The positive effect of the 2009 policies shows that well-timed interventions can indeed mitigate negative trends and boost production. This implies that policymakers must be agile and responsive to external economic shocks and global market dynamics, implementing targeted support measures to stabilize the agricultural sector.

The overall fit and reliability of the model are strong. The R-squared value of 0.96 indicates that 96% of the variation in paddy production is explained by the independent variables included in the model. This is a robust indicator that the model captures most of the factors affecting paddy production. The adjusted R-squared of 0.94 further reinforces this, showing that even after accounting for the number of predictors used, the model still explains a substantial portion of the variation. The F-statistics of 61.46 with a p-value less than 0.01 indicates that the overall model is highly significant. This suggests that the independent variables as a group have a strong relationship with the dependent variable (paddy production) and that the model is unlikely to be a result of random chance. The Durbin-Watson statistic of 1.94 suggests minimal autocorrelation in the residuals, meaning that the errors are largely independent of each other. This is important for the reliability of the model, as autocorrelation could indicate problems with the model's assumptions or data structure. A Durbin-Watson value close to 2 typically indicates little to no autocorrelation, supporting the model's reliability and validity. Overall, these statistics demonstrate that the model is highly effective in explaining paddy production and that its results are statistically significant and reliable.

4.3 Summary of Hypothesis Tests

The hypothesis tests provide a clear summary of the statistical decisions made regarding the proposed relationships between the independent variables and paddy production. The decisions are based on the p-values derived from the multiple regression analysis. The results are summarized in Table 3.

Table 3: Summary of Hypothesis test

Variable	Interpretation	Decision
LAH	Coefficient: 0.75; t-Statistic:3.61 (significant); Probability:0.00(< 0.05).	Reject H0. The size of the area harvested has a significant positive effect on paddy production.
LFC	Coefficient: 0.19; t-Statistic:4.92 (significant); Probability: 0.00 (< 0.05).	Reject H0. Fertilizer consumption has a significant positive effect on paddy production.

Variable	Interpretation	Decision
LTEMP	Coefficient: –0.45; t-Statistic: –2.13(significant); Probability: 0.04 (< 0.05).	Reject H0. Temperature has a significant negative effect on paddy production.
LRF	Coefficient: –0.08; t-Statistic: –1.43(not significant); Probability: 0.17 (> 0.05).	Fail to reject H0. Rainfall does not have a significant effect on paddy production.

For the area harvested (LAH), with a coefficient of 0.75 and a p-value of 0.00 (less than 0.05), the null hypothesis (H0) that it does not affect paddy production is rejected. This indicates that the size of the area harvested has a significant positive effect on paddy production. Regarding fertilizer consumption (LFC), the coefficient of 0.19 and a p-value of 0.00 (less than 0.05) lead to the rejection of the null hypothesis (H0) that has no impact. Thus, fertilizer consumption has a significant positive effect on paddy production. For temperature (LTEMP), a coefficient of −0.45 and a p-value of 0.04 (less than 0.05) result in the rejection of the null hypothesis (H0) that has no effect. This confirms that temperature has a significant negative effect on paddy production.

Finally, for rainfall (LRF), with a coefficient of −0.08 and a p-value of 0.17 (greater than 0.05), the null hypothesis (H0) that it does not affect paddy production is not rejected. This suggests that, within the scope of this model, rainfall does not have a statistically significant effect on paddy production. This table provides a concise, direct answer to each of the study's specific research questions. It translates the statistical findings into clear conclusions about the hypothesized relationships, which is crucial for summarizing the main quantitative findings before proceeding to a broader discussion.

4.4 Diagnostic Tests for Model Reliability (Normality, Heteroscedasticity, Serial Correlation)

To ensure the statistical validity and reliability of the regression model, several diagnostic tests were performed on the residuals. The results of these tests are summarized in Table 4.

Table 4: Summary of residual test

Diagnostic Tests	Results	Hypothesis	Decision
Normality test (Jarque-Bera)	Jarque-Bera: 0.83; Probability: 0.66	H0: Residuals are normally distributed	P value > 0.05; Fail to reject H_0. The residuals are normally distributed.
Heteroscedasticity test (White test)	P-value: 0.79	H0: Residuals are no heteroscedasticity	P value > 0.05; Fail to reject H_0. Residuals show no heteroscedasticity.
Serial correlation test (LM test)	Prob. Value: 0.33; Durbin Watson stat: 1.84	H0: Residuals are no autocorrelation	P value > 0.05; Fail to reject H_0. There is no strong evidence of serial correlation in the residuals.

For the normality test, the Jarque-Bera statistics were 0.83, with a corresponding p-value of 0.66. Since this p-value is greater than the conventional 0.05 significance level, the null hypothesis, which states that the residuals are normally distributed, was not rejected. This indicates that there is no significant evidence to suggest that the residuals deviate from normal distribution.

The heteroscedasticity test, using the White test, yielded a p-value of 0.79. As this value is greater than 0.05, the null hypothesis of no heteroscedasticity is not rejected. This implies that the variance of the residuals is constant across all levels of the independent variables, satisfying an important assumption of ordinary least squares (OLS) regression. For the serial correlation test, the p-value for the LM test was 0.33. Given that this value is greater than 0.05, the null hypothesis, which states that the residuals are not autocorrelated, was not rejected. This result is further supported by the Durbin-Watson statistic of 1.84, which is close to 2, indicating minimal autocorrelation in the residuals.

Overall, these diagnostic tests confirm the model's reliability. The absence of serial correlation, heteroscedasticity, and non-normal residuals indicates that the assumptions underlying the regression model are met, thus supporting the validity and trustworthiness of the regression results. This table is vital for establishing trustworthiness of the regression results. It confirms that the underlying assumptions of the OLS model are met, meaning the estimated coefficients are unbiased and efficient. Without these tests, the reliability of the findings would be questionable. This section provides the necessary statistical assurance that the quantitative findings are robust and can be confidently interpreted for policy implications.

5. Conclusions

The study identified key factors influencing paddy production in Malaysia, including area harvested, fertilizer consumption, temperature, and historical economic and policy events. Area harvested and fertilizer consumption were found to have positive and significant effects, underscoring their fundamental importance. Conversely, high temperatures were observed to negatively impact production, highlighting the sector's vulnerability to climate change. While rainfall did not show a statistically significant effect in the aggregate model, its critical role in the broader context of water management and climate variability remains undeniable.

The findings underscore the critical need for a holistic approach to sustainable paddy production in Malaysia, one that balances productivity with long-term environmental and socio-economic viability. The path to achieving national self-sufficiency goals of 75% by 2025 and 80% by 2030 is challenging but achievable through integrated policy implementation. This requires not only addressing the direct impacts of land availability, input use, and climate variability but also strengthening farmer human capital, ensuring equitable access to resources, and accelerating the adoption of appropriate technologies. Continuous investment in research and development, the implementation of adaptive strategies, and robust farmer support mechanisms are the cornerstones for building a resilient and sustainable agricultural sector. This final statement serves as a powerful call to action for policymakers and stakeholders, reinforcing the study's practical relevance and impact, and emphasizing that the future of Malaysia's paddy sector hinges on a proactive, integrated, and adaptive strategy.

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References

Abas, M. A., Mohd Fuad, A. S., Md Nor, A. N., *et al*. (2020). Paddy farmers perceived the socio-economic impacts of climate change: A case study in Pasir Mas, Kelantan. *IOP Conference Series: Earth and Environmental Science*, 549(1). https://doi.org/10.1088/1755-1315/549/1/012075

Adekayode, F. O., & Ogunkoya, M. O. (2010). The influence of soil fertility indicators on yield of rice (Oryza sativa) in a tropical rainforest agroecosystem. *Journal of Agricultural Science*, 2(2), 69–77. https://doi.org/10.5539/jas.v2n2p69

Arifah, Salman, D., Yassi, A., & Demmallino, E. B. (2022). Climate change impacts and the rice farmers' responses at irrigated upstream and downstream in Indonesia. *Heliyon*, 8(12), [e12326] https://doi.org/10.1016/j.heliyon.2022.e11923

Arshad, F. M., Noh, K. M., & Mustapha, N. H. (1997). Industrialization and its impact on the agricultural sector in Malaysia: Policy implications. *Pertanika Journal of Social Science and Humanities*, 5(1), 23–33.

Business Today Malaysia. (2023, March 14). Malaysia's rice self-sufficiency rate drops to 62.6%. https://www.businesstoday.com.my/

Fageria, N. K. (2007). Yield physiology of rice. *Journal of Plant Nutrition*, 30(6), 843–879.

Fahmi, Z., Abu Samah, B., & Abdullah, H. (2013). Paddy industry and paddy farmers' well-being: A success recipe for agriculture industry in Malaysia. *Asian Social Science*, 9(3), 177. https://doi.org/10.5539/ass.v9n3p177

FAO. (2020). The state of food security and nutrition in the world 2020: Transforming food systems for affordable healthy diets. FAO.

Kogan, F. (2013). Drought watch and prediction in the climate change conditions. *Weather and Climate Extremes*, 1, 42–50. https://doi.org/10.1016/j.wace.2013.07.001

Kushwaha, R. L. (2016). Milling and processing of rice: Technologies and innovations. *Agricultural Mechanization in Asia, Africa, and Latin America*, 47(4), 33–40.

Malaysian Insight. (2024, April 10). Minister: Rice self-sufficiency rate recalculated under FAO standards. https://www.themalaysianinsight.com/

Ministry of Agriculture and Food Security. (2024). Annual Agrofood Statistics Report 2023. Putrajaya: Government of Malaysia.

Nasir, N. M., Ahmad, A., & Yahya, A. (2015). Effect of fertilizer application on paddy yield in Malaysia: A case study in Muda Agricultural Development Authority (MADA). *Journal of Technology*, 77(1), 75–81.

Peng, S., Huang, J., Sheehy, J. E., Laza, R. C., Visperas, R. M., Zhong, X., Centeno, G. S., Khush, G. S., & Cassman, K. G. (2004). Rice yields decline with higher night temperature from global warming. *Proceedings of the National Academy of Sciences*, 101(27), 9971–9975. https://doi.org/10.1073/pnas.0403720101

Wan, N. A., & Nor, A. (2017). The effects of land conversion on Malaysia's paddy industry and food security: Issues and policies. *Asian Journal of Agriculture and Rural Development*, 7(1), 45–60.

Zaib, M., Zubair, M., Aryan, M., Abdullah, M., Manzoor, S., Masood, F., Saeed, S.(2023). A Review on Challenges and Opportunities of Fertilizer Use Efficiency and Their Role inSustainable Agriculture with Future Prospects and Recommendations, *Curr. Rese. Agri. Far*. 4(4), 1-14.doi: http://dx.doi.org/10.18782/2582-7146.201