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WHICH REGION IS TECHNICALLY EFFICIENT IN PADDY PRODUCTIVITY AT MUDA AGRICULTURAL DEVELOPMENT AUTHORITY (MADA)?

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ABSTRACT

Malaysia relies on rice imports to meet domestic needs despite its multiple rice-producing regions, including the Muda Agricultural Development Authority (MADA), which contributes nearly 40% of national rice production. However, MADA regions face varying levels of productivity. This study examined the factors affecting paddy productivity at MADA regions and identified the most efficient region in the MADA area. These variables include the sociodemographic characteristics of paddy farmers, input factors, management practices, and the adoption of machinery technology by paddy farmers. Data from 673 rice farmers across four MADA regions were analysed using descriptive statistics and stochastic frontier analysis. The analysis of technical efficiency scores for MADA paddy regions shows variations and identifies the most efficient region. Furthermore, an analysis of input utilisation across regions helps identify best practices and techniques that enhance paddy productivity. The average technical efficiency in MADA paddy regions is 0.92 (Region I), 0.90 (Region II), 0.88 (Region III), and 0.91 (Region IV). Seed utilisation, machinery utilisation, the involvement of young paddy farmers, and improved levels of education are factors that contribute to increased regional efficiency. As a recommendation, MADA regions can improve paddy productivity by focusing on the factors mentioned.

Introduction

Importance of the Rice Sector in Malaysia

Rice is a staple food consumed daily across Malaysia (KRI, 2019). It holds significant cultural and dietary importance due to two main reasons: It is a primary food source and 40% of Malaysian farmers depend on rice cultivation for their income (Firdaus *et al*., 2020). Additionally, rice contributes to 70% of Malaysia's food security and stability. The self-sufficiency project in Malaysia has prioritised paddy production (Dorairaj & Govender, 2023). The increasing demand for rice in Malaysia underscores the importance of the rice industry.

Figure 1 illustrates this growing demand for rice. In 1990, rice consumption was 1.6 million metric tonnes, rising to 2.90 million metric tonnes by 2023, an increase of approximately 1.30 million metric tonnes (OECD-FAOSTAT, 2024). Furthermore, the per capita rice consumption in Malaysia exceeds the global average of 54.6 kg per individual. While Malaysia's per capita rice consumption (80.0 kg) is higher than in countries like India (69.0 kg) and Japan (54.8 kg), but it remains lower than in Indonesia (135.0 kg), the Philippines (116.7 kg), and Thailand (103.5 kg)

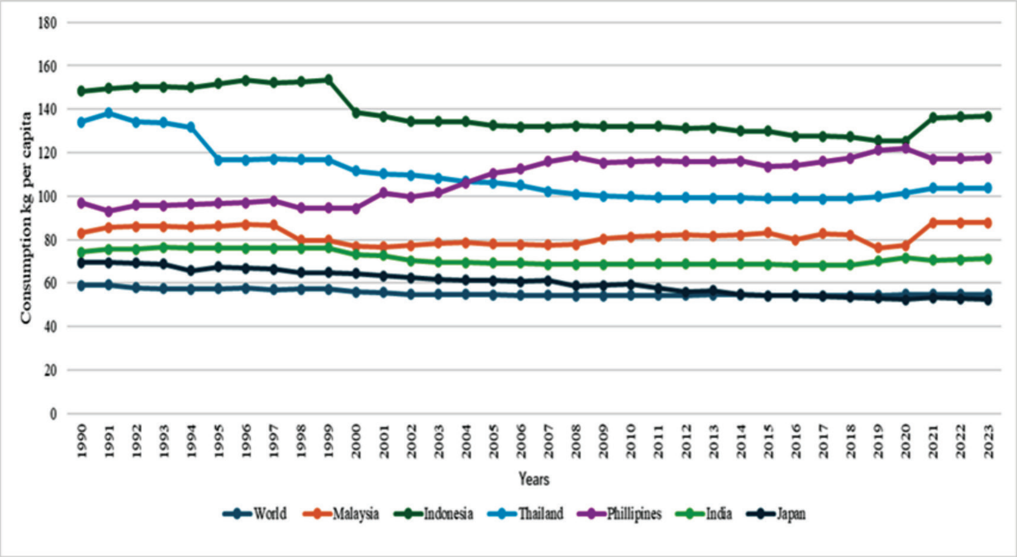


Figure 1: Rice consumption per capita (1990-2023)

Source: OECD-FAOSTAT (2024)

(OECD-FAOSTAT, 2024). This data highlights the substantial role of rice in the Malaysian diet and its critical contribution to the nation's food security.

Challenges in National Rice Production

In Figure 2, the self-sufficiency ratio in 2019 indicated that domestic production could meet only about 62.4% of Malaysian rice consumption. The trend decreased to 56.2% in 2023, highlighting the domestic rice production's ability to meet local consumption, which declined over the year. At the same time, it increases the dependency on imported rice (Figure 2). Thus, enhancing paddy productivity is a critical issue to meet domestic consumption in Malaysia.

Paddy Productivity in MADA

There are 12 granary areas in Malaysia namely, Muda Agricultural Development Authority (MADA), Barat Laut Selangor Integrated Agricultural Development Area (IADA BLS), Northern Terengganu Integrated Agricultural Development Area (IADA KETARA), Rompin Integrated Agricultural Development Area (IADA Rompin), Kemubu Agricultural Development Authority (KADA), Pulau Pinang Integrated Agricultural Development Area (IADA Pulau Pinang), Kemasin Semerak Integrated Agricultural Development Area (IADA Kemasin Semerak), Kota Belud Integrated Agricultural Development Area (IADA Kota Belud), Kerian Integrated Agricultural Development Area (KSM), Seberang Perak Integrated Agricultural Development Area (IADA Seb. Perak), Pekan Integrated Agricultural Development Pekan Integrated Agricultural Development Area (IADA Pekan), and Batang Lupar Integrated Agricultural Development Area (IADA Batang Lupar).

These 12 granary areas in Malaysia play a critical role in boosting paddy production, advancing agricultural practices, and achieving rice self-sufficiency. According to Table 1, Malaysia's overall rice productivity stands at 4.2 tonnes per hectare. However, specific granary areas, such as IADA Pulau Pinang and IADA Ketara, have the potential to surpass the national average, achieving yields of more than 5 tonnes per hectare. Table 1 also reveals that the majority of paddy production is managed by MADA,

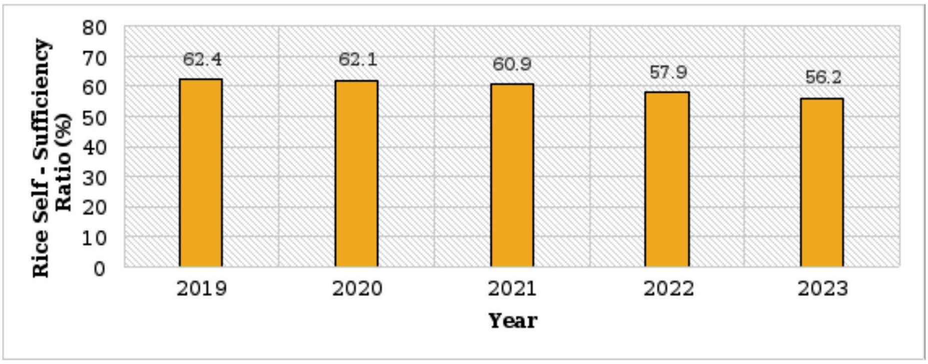


Figure 2: Self-dependency ratio on rice in Malaysia (2019-2023)
Source: Department of Statistics, Malaysia (2024)

Table 1: Land area, production, and productivity of paddy granary areas in Malaysia (2021)

No.	Granary Areas	Land Area (ha)	Production (tonne)	Productivity (tonne/ha)
1	MADA	201,347.00	843,947.00	4.19
2	KADA	52,589.00	256,295.00	4.87
3	KSM	36,994.00	141,687.00	3.83
4	IADA BLS	35,885.00	155,631.00	4.34
5	IADA Pulau Pinang	24,210.00	136,919.00	5.66
6	IADA Seb. Perak	26,296.00	68,724.00	2.61
7	IADA KETARA	9,752.00	50,886.00	5.22
8	IADA Kemasin Semerak	8,401.00	30,716.00	3.66
9	IADA Pekan	7,446.00	13,853.00	1.86
10	IADA Rompin	5,272.00	24,306.00	4.61
11	IADA Kota Belud	7,092.00	25,105.00	3.54
12	IADA Batang Lupar	1,131.00	3,220.00	2.85
	Total	**416,415.00**	**1,751,289.00**	**4.21**

Source: Department of Agriculture, Malaysia (2022)

amounting to 843,947 tonnes in 2022. Despite this significant production volume, MADA does not enhance paddy productivity within the granary areas (Kalimuthu & Applanaidu, 2024). This underscores the need to intensify efforts to enhance paddy productivity, especially in regions that fall below the global average of 4.2 MT/ha (Abidin *et al*., 2023).

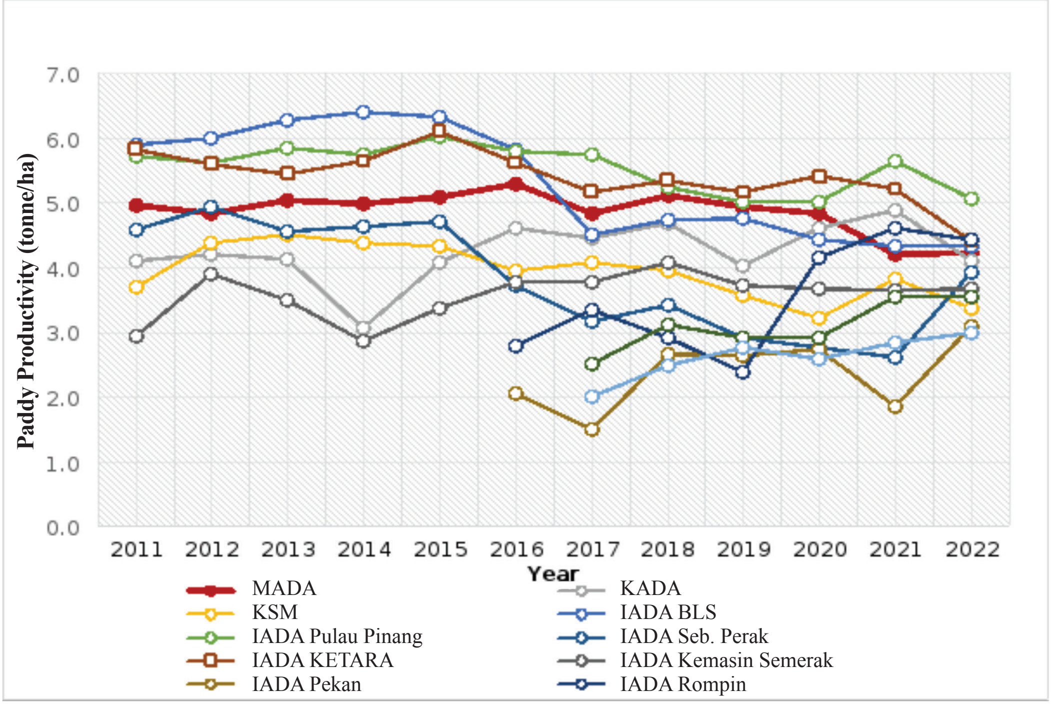
Malaysia's low rice productivity poses a significant threat to its food self-sufficiency, especially in the MADA region, the country's largest rice producer, where yields lag behind those of other granary areas. This stagnation has contributed to long-term challenges in the rice sector. As a result, boosting national rice productivity has become a critical focus for the Malaysian agricultural sector (Dorairaj & Govender, 2023).

To maintain efficient functioning and effective management, MADA has been divided into four distinct regions: Perlis, Jitra, Pendang, and Kota Sarang Semut. According to MADA (2024), paddy productivity in the MADA regions has been inconsistent from 2018 to the present.

Productivity improvements have remained unstable, lacking consistency across the different regions. As highlighted in the MADA annual report (2023), there has been no uniform progress in increasing paddy productivity among the regions. These findings indicate a declining capacity within the MADA region to enhance paddy productivity, underscoring significant challenges in achieving sustained agricultural growth and efficiency.

Figure 3 shows a decreasing trend in paddy productivity in some granary areas since 2011, including MADA. The decrease in productivity in MADA poses a significant threat to food security, as this area accounts for the most significant paddy production in Malaysia. This decreasing trend in productivity underscores the need to identify technical efficiency differences within the MADA region, with respect to farmers' characteristics and input use.

A further exploration of the effect of technical efficiency on paddy productivity is crucial for several reasons. First, farmers struggle to adopt advanced farming tools and methods, as well as innovative farming management, due to their high cost. They developed a sceptical behaviour on the effectiveness of advanced technologies (Adnan *et al*., 2017; Rusli *et al*., 2023). Second, paddy production in granary areas were attributed to the lack of knowledge, skill in operating modern machine, limited of technology adoption and the lack of infrastructures such as irrigation systems, digital connectivity, and proper machinery repair services (Baharudin & Waked, 2021). Third, farmer's characteristics such as aging factors (41 to 50 years old farmers) and education level already add to the technical inefficiency of paddy production (Zanuldin & Mohamed, 2019). Thus, a deeper investigation into the impact of input usage, sociodemographic factors and technical



Note: Paddy productivity for IADA Kota Belud, IADA Batang Lupar, IADA Rompin, and IADA Pekan is only available from 2016 onwards.

Figure 3: Paddy productivity across paddy granary areas in Malaysia (2011-2022)
Source: Department of Agriculture, Malaysia (2022)

efficiency on paddy productivity is essential to address these persistent challenges. Variation in these factors could contribute to differences in technical efficiency across MADA granary areas.

Understanding these variations is crucial for developing targeted strategies that can stabilise and boost paddy productivity across all MADA regions. By analysing the specific factors that contribute to these disparities, more effective and tailored interventions can be implemented. These strategies will address the unique challenges faced by each region, ultimately leading to more consistent and enhanced paddy productivity throughout the MADA area. Therefore, this study aims to analyse the sociodemographic characteristics of paddy farmers by region, compare input, management, and machinery use across regions, and evaluate the technical efficiency scores of MADA regions.

Literature Review

This study extends the current understanding of paddy farming efficiency by evaluating the variables affecting regional efficiency across the four MADA areas. Through the lens of production theory, it examines the sociodemographic characteristics, input utilisation, and technical efficiency of paddy farmers in these regions.

Production Theory

The Cobb-Douglas production model, proposed in 1928, plays a pivotal role in understanding production processes by establishing the relationship between the quantity of labour and capital required to produce a specific quantity of commodities (Cobb & Douglas, 1928). This model highlights the interrelationship between labour, capital, and output, providing a foundational framework for understanding production processes. The Cobb-Douglas production function has been widely used to examine the relationship between inputs and outputs in paddy farming (Aigner *et al*., 1977). A production function can help us understand how labour, land, and capital affect the production process. Production theory remains the leading theory in output analysis because it can clearly explain changes in output resulting from small changes in inputs.

Most agricultural research in Malaysia centres on land, labour, and inputs as the key components of production (Jamaludin *et al*., 2010; Rahmat *et al*., 2019; Firdaus *et al*., 2020). Ismail and Ngadiman (2017) conducted a study to explore how changes in land use affect rice production in Malaysia. Their findings indicated that expanding land use increases output. A more comprehensive understanding of paddy yield can be achieved by applying land theory to examine production in the MADA paddy regions. Similarly, Jamaludin *et al*. (2010) observed that the amount of land accessible to farmers impacts paddy yield in paddy estates. Given its significant economic and social benefits, land use serves as the cornerstone of agricultural economies. Utilising the land component in production will enhance our understanding of paddy cultivation in the MADA paddy regions.

Labour is considered the primary and active element in production, indicating its central role in the process. The production of goods is heavily reliant on labour. Rahmat *et al*. (2019), who recently analysed Malaysia's rice production support scheme, concluded that paddy farmers play a crucial role in increasing paddy yield. The study's findings emphasise the importance of labour in rice production, noting that even slight variations in the sociodemographic status of farmers can impact productivity.

Empirical Review

This section provides a comprehensive review of the literature on the variables relevant to this study. The factors considered in this study are paddy productivity, sociodemographic characteristics of farmers, farmers' adoption of technology in machinery usage, input factors, and management techniques. The review presents clear definitions for each aspect, provides an analysis of the latest data, and identifies gaps in the existing empirical literature.

Sociodemographic Characteristics

Paddy farming is a crucial agricultural activity in many countries, providing food for the nation and employment. Sociodemographic factors among paddy farmers significantly influence paddy output. Studies have identified key factors such as land ownership, education, and experience in rice farming as affecting rice production (Rosmiza *et al*., 2019; Adnan & Nordin, 2021). Challenges such as rising food prices, climate change, and resource scarcity have been noted, but farmers' characteristics also play a substantial role in determining output in Malaysia (Hussin & Mat, 2013; Ibrahim & Mook, 2014).

Research in Malaysia shows that age, education level, and land ownership affect the adoption of modern paddy farming technology (Azmi *et al*., 2019). Younger, educated farmers are more inclined to embrace advanced techniques. In India, education and income were found to influence the adoption of paddy mechanisation practices significantly (Agrawal *et al*., 2018). Comparative studies between Malaysia and Vietnam indicate that Malaysian farmers exhibit moderate technological adoption and need greater motivation and knowledge to utilise it better (Harun *et al*., 2015). Similarly, in Ghana, the readiness and acceptance of technology among farmers were associated with paddy yields, with those seeking advice showing higher efficiency (Abdulai *et al*., 2018).

Siriwardana and Jayawardena (2014) conducted a review focusing on how sociodemographic factors affect rice farming production. Their findings indicated that farmers' skills and agricultural experience significantly impact productivity. Similarly, Oyewole and Ojeleye (2015) found that 73.6% of participants in a related survey were aged from 20 to 50 years old, a group considered the most productive. The study also revealed that 80.9% of participants had over a decade of experience in agriculture. These authors concluded that paddy productivity increases as a farmer's skills and experience grow.

Klinhom *et al*. (2020) identified age, education level, and experience as key factors influencing paddy farmers' decisions to adopt organic farming practices. Using a logit model, the study found that younger farmers with higher levels of education are more likely to adopt organic paddy farming. The findings suggest that sociodemographic factors significantly influence paddy farming practices and outcomes, shaping farmers' attitudes and intentions to adopt modern paddy technologies.

Machinery Usage

With so many variables influencing rice production, technology emerges as a key element in paddy cultivation. In the modern world, technology is essential because it advances human civilisation in every aspect. The importance of technology has become unavoidable, and developing countries have already adopted developed countries' modern technologies developed in developed countries. As a rising nation, Malaysia is taking steps towards the 4.0 industrial revolution, also known as the fourth industrial revolution, which might turn the country into a wealthy nation by 2025. With a strong infrastructure, R&D initiatives, and high-speed broadband, Malaysia is embracing new technologies in all fields, including agriculture. The integration of contemporary technologies into paddy cultivation has become a significant problem for paddy producers.

In this study, the application of paddy technology refers to the mechanisation of MADA paddy farmers. Machinery is a subset of technology that emphasises explicitly physical mechanisms rather than encompassing larger systems or processes (Ito, 2010). Due to technical developments, farm machinery has increased in size, performance, and productivity, enabling more area to be farmed more effectively (Goedde *et al*., 2020). New agricultural machinery, such as intelligent crop monitoring, drone farming, and autonomous farming machinery, has substantially enhanced agricultural technology. In a large and growing body of studies, the connection between the use of modern technologies and paddy productivity has been examined (Abdulai *et al*., 2018; Ambali *et al*., 2021). Paddy cultivation in Malaysia, with the use of technology, can encourage long-term growth and help farmers increase productivity (Adnan *et al*., 2018).

In a study undertaken by Bhoi *et al*. (2021), the researchers investigated the efficiency of machinery in paddy farming in India. They found that there are both positive and negative observations regarding the relationship between mechanisation and paddy productivity in different states of India. According to this study, mechanisation had a considerable negative impact on production in West Bengal, Odisha, and Assam. This was mainly because these regions relied more on animal labour. However, in Tamil Nadu, mechanisation had a gently favourable impact on productivity, with an elasticity of 0.014. This work employed satellite imagery, spectral imaging, and soil information to identify diseases and weeds using machine learning algorithms. According to Vasanthi *et al*. (2017), the timing of machinery use has a considerable impact on paddy crop yield in canal-irrigated fields in Tamil Nadu, as evidenced by the SFA model. The study utilised tractors and power sprayers as mechanical tools.

Input Factors

Numerous issues affecting the paddy sector in Malaysia have been identified by paddy production literature. One factor affecting rice yield in rapidly declining agricultural areas is the input factors. It is necessary to evaluate the inputs used in rice production, including the connections among fertiliser use, farmland, and labour in this industry.

Bhoi *et al*. (2021) found that input characteristics, such as skilled labour, mechanical labour, fertilisers, and pesticides, have a significant impact on production in paddy agriculture across India. In their study, Kummanee *et al*. (2018) investigated factors affecting seed production in Thailand. The results of this investigation indicated that seed land and fertiliser were the two most important variables determining seed output. Siagian (2020), who examined the factors influencing rice productivity and land use in Indonesia's Banten Province, provides evidence in favour of this viewpoint. The authors examined empirical evidence to gain a better knowledge of Myanmar's recent rice output.

In the same way, Abas (2016) investigated management techniques and found that the managerial subsystem, organic fertiliser, farm labour, and self-owned seeds were the factors impacting paddy self-reliance. Mohamed *et al*. (2016) studied the sustainable farming practices employed by paddy growers in the granary areas at Sungai Petani, Kedah. They examined several practices used by 80 rice farmers in Malaysia's Sungai Petani district, including planting, fertiliser application, weed, and pest control. This result confirms earlier research on the relationship between input variables and paddy productivity.

Management Practices

This literature also explores the importance of paddy cultivation management practices and their impact on rice crop development and productivity. Studies have demonstrated the effectiveness of these practices (Nazuri & Man, 2016; Adnan *et al*., 2017; Abdullahi *et al*., 2023). Harun *et al*. (2015) compared rice producers in Malaysia and Vietnam, and found that only a small percentage of Malaysian farmers followed the recommended 10 Rice Checks. In contrast, 60% of Vietnamese farmers practised good management, compared to just 8% in Malaysia. The study recommended reducing the disparity between the best and poorest management practices among rice farmers. According to Abdullahi *et al*. (2023), an organisation's resilience capabilities enable it to manage, adapt, and navigate disruptions, uncertainties, and emerging events, ultimately promoting long-term sustainability and enhancing performance. This suggests that strengthening the resilience of organisations can improve technology adoption among paddy farmers, thereby contributing to enhanced food sustainability in our country.

Nazuri and Man (2016) analysed MADA practices on paddy seed varieties and found that excellent practices enhance farmers' knowledge and technological development. Similarly, Abas (2016) identified self-owned seeds, management subsystems, farm labour, and organic fertiliser as key factors for paddy self-reliance. Mohamed *et al*. (2016) investigated sustainability practices in Sungai Petani, Kedah, revealing that 80% of rice farmers engaged in unsustainable paddy production. The study suggested improving sustainable farming techniques to increase output. These studies confirm that most farmers in emerging nations are aware of advanced agricultural practices that optimise production while minimising environmental impact. MADA has implemented schedules to ensure compliance, which serve as management variables. Effective communication of the latest management practices to farmers is crucial for enhancing production efficiency and effectiveness.

Effective management techniques are necessary for paddy agriculture to guarantee the best possible development and output of rice crops. To maximise yields and minimise environmental impacts, paddy farming must carefully manage the following key elements: Land preparation, water management, fertiliser management, and disease and insect control.

The primary objective of this study is to analyse the sociodemographic characteristics of paddy farmers across different regions, focusing on age, gender, principal occupation, education level, and family labour involvement in paddy farming. The second objective is to compare the input factors across various MADA paddy regions. The last objective is to evaluate the technical efficiency scores of these MADA paddy regions.

Materials and Methods

Study Area and Population

Population refers to a group of components or elements with similar qualities that are being investigated at a specific location, time, and circumstance to achieve the objectives of the study. The research population chosen for this study comprises paddy farmers from various regions within the MADA area. According to the Registrar Department of MADA, there are 57,635 paddy farmers spread across four paddy-growing regions (MADA, 2020). This study focuses on paddy farmers aged 18 and above, from 27 Pertubuhan Peladang Kawasan (PPK) within these regions. To analyse the adoption of technology and the utilisation of machinery among paddy farmers, primary data were collected through surveys.

Sampling Technique and Procedure

Given the extensive number of paddy farmers in the MADA area, obtaining data from the entire population was impractical. Therefore, a sample was selected using stratified random sampling. This method was chosen due to MADA's structured organisation, divided into four distinct regions. Stratified random sampling ensures that all paddy farmers from different regions have an equal opportunity to be included in the study. According to Krejcie and Morgan's (1970) sample size determination table, a minimum sample size of 382 is required for a population of 57,635 (Table 2). However, with the support of MADA management, data were successfully collected from 673 paddy farmers across the four MADA regions, exceeding the minimum required sample size.

Instrument and Pretesting of the Instrument

Instrument development involves the design, validation, and implementation of data-collection tools. In this study, structured survey questionnaires were designed to evaluate

Table 2: MADA paddy farmer's population

Regions	Number of Paddy Farmers	Required Sample Size	Actual Number of Respondents
Region I: Perlis	10,180	68	125
Region II: Jitra	19,487	129	225
Region III: Pendang	13,767	91	148
Region IV: Kota Sarang Semut	14,201	94	175
Total	**57,635**	**382**	**673**

Source: MADA (2020)

the technical efficiency of paddy farmers in the MADA regions. To ensure the validity and reliability of the instrument, a pretesting phase was conducted before the full-scale data collection. This pretesting involved a small group of respondents to assess question clarity, response consistency, and the overall structure of the questionnaire. As part of the pretesting process, a pilot test was carried out with 10 respondents from each region. The participants were selected using stratified random sampling to ensure a representative sample. The questionnaire was developed in collaboration with MADA experts, incorporating their insights and expertise. Therefore, this study follows the questionnaire structure and content as designed with MADA experts' input.

The first step in this process was to examine multicollinearity among the explanatory variables. The Variance Inflation Factor (VIF) was utilised as a diagnostic measure to assess collinearity within the model. According to Gujarati (2006), a VIF value exceeding 10 indicates strong multicollinearity and suggests potential multicollinearity concerns. Similarly, Black *et al*. (2010) state that multicollinearity is present when the VIF exceeds 10 and the tolerance value drops below 0.1. The findings confirm that no multicollinearity issues exist among the predictor variables, ensuring the model's robustness for further analysis.

Data Collection

The questionnaire was standardised for use across all MADA locations and was structured into two main sections. The first section gathered information on farmers' sociodemographic characteristics, including gender, age, education level, principal occupation, and family labour. The second section explored factors related to paddy productivity, types of inputs used, management practices, and the extent of machinery and drone automation adoption in rice cultivation. Additionally, seven specific questions were included to assess the level of technology adoption among MADA farmers, particularly regarding mechanisation and drone use. The survey was designed to collect responses as continuous variables, enabling an in-depth analysis of factors influencing paddy productivity across the four MADA regions.

A stratified random sampling approach was employed to ensure representative data collection from the four MADA regions Perlis, Jitra, Pendang, and Kota Sarang Semut. The survey was carefully structured to align with the study's primary objectives and the recommendations of MADA researchers. It included a variety of structured questions covering demographic attributes, input utilisation, technology adoption, management practices, and regional paddy field conditions.

Data Analysis

The Cobb-Douglas Stochastic Frontier Production analysis was chosen to analyse paddy production in the MADA regions due to its ability to measure technical efficiency while accounting for random errors. This method effectively separates inefficiency from statistical noise, which is crucial when evaluating agricultural productivity influenced by uncontrollable environmental factors. The function of the stochastic frontier equation, which is thought to influence the level of efficiency in paddy productivity, is:

$$LY_i = \beta_0 + \beta_1\, LArea_i + \beta_2\, LSeed_i + \beta_3\, LFert_i + \beta_4\, LPest_i + \beta_5\, LMachine_i + \beta_6\, LHour_i + (v_i - u_i), \tag{1}$$

where Y_i, $Area_i$, $Seed_i$, $Fert_i$, $Pest_i$, $Machine_i$, and $Hour_i$ are natural log of paddy productivity of MADA regions in tonnes per hectare, paddy land area in hectare, paddy seed usage in kg per hectare, fertiliser usage in kilogram per hectare, pesticides usage, machinery usage, and labour hours, respectively, in region i. Meanwhile, $v_i - u_i$ represents an inefficiency model. Technical efficiency can be predicted from conditional expectations, adapted to the model's assumptions.

$$ET = \frac{Y_{it}}{Y^*_{it}} = e^{-u_{it}} = e^{(-zk_{it} - w_{it})}, \tag{2}$$

where ET is technical efficiency, Y_{it} is the performance of the output, and Y^*_{it} it is the maximum potential of the output. The technical efficiency values range from 0 to 1, and 1 is inversely proportional to the inefficiency effect (Coelli & Battese, 1996).

Furthermore, this approach allows for the estimation of individual efficiency scores, enabling policymakers and stakeholders to identify productivity gaps and develop targeted interventions to enhance the efficiency of paddy farmers in the MADA regions. This study also employed descriptive analysis to compare the sociodemographic characteristics, inputs, technology adoption, and management practices differences among the MADA regions.

This study investigates paddy productivity in the MADA region, focusing on the influence of four key independent variables: Farmers' sociodemographic characteristics, machinery use, input utilisation, and management practices. The sociodemographic factors encompass gender, age, education level, primary occupation, and the extent of family labour involvement, providing insight into the demographic profiles of paddy farmers. The analysis also examines the adoption of technology, particularly machinery and automation, in farming activities among MADA farmers. Regarding input variables, the study assesses the usage percentages of land, seeds, fertilisers, and pesticides. Management practices are evaluated by measuring farmers' adherence to crop schedules and time management in paddy farming. Collectively, these variables are analysed to understand their impact on paddy productivity in the MADA region.

Results

The primary objective of this study is to analyse the sociodemographic characteristics of paddy farmers across different regions, focusing on age, gender, principal occupation, education level, and family labour involvement in paddy farming. The second objective is to compare the input factors across various MADA paddy regions. The last objective is to evaluate the technical efficiency scores of these MADA paddy regions. These sections show the results of this study.

Sociodemographic Profiles of Farmers

The sociodemographic profiles of paddy farmers are summarised in Table 3. The majority of paddy farmers in each region are male, comprising over 75.2% of the survey respondents. In MADA, most paddy farmers are senior citizens aged 51 years old and above. Region I has the highest percentage of young farmers, with 10.4% of farmers under 40 years old. When comparing the MADA regions, Region I also has the most

Table 3: Descriptive analysis of the MADA paddy region

Characteristics	Classifications	Region I (Perlis)		Region II (Jitra)		Region III (Pendang)		Region IV (Kota Sarang Semut)	
		N	%	N	%	N	%	N	%
Gender	Male	94	75.2	181	80.4	117	79.1	148	84.6
	Female	31	24.8	44	19.6	31	20.9	27	15.4
Age (years old)	21–30	4	3.2	3	1.3	3	2.0	1	0.6
	31–40	9	7.2	10	4.4	6	4.1	8	4.6
	41–50	13	10.4	41	18.3	23	15.5	23	13.1
	51 and above	99	79.2	171	76.0	116	78.4	143	81.7
Education status	Degree/Diploma	7	5.6	5	2.2	2	1.4	4	2.3
	Middle school	64	51.2	174	77.4	130	87.7	134	76.5
	Skills institutions	0	0	1	0.4	1	0.7	1	0.6
	Primary school	54	43.2	41	18.2	14	9.5	36	20.6
	No education	0	0	4	1.8	1	0.7	0	0
Main occupation	Paddy	106	84.8	211	93.8	147	99.3	159	90.9
	Other crops	1	0.8	1	0.4	0	0	6	3.4
	Livestock	0	0	0	0	0	0	0	0
	Services	14	11.2	9	4.0	1	0.7	6	3.4
	Business	4	3.2	4	1.8	0	0	4	2.3
Land area (ha)	0–0.99	68	54.4	101	44.9	90	60.8	94	53.7
	1–1.99	44	35.2	93	41.4	50	33.7	63	36.0
	2–2.99	11	8.8	28	12.4	5	3.4	18	10.3
	3–3.99	1	0.8	2	0.9	2	1.4	0	0
	4 >	1	0.8	1	0.4	1	0.7	0	0

Use of field time (hours)	< 2	76	60.8	33	14.7	0	0	39	22.3
	2–4	49	39.2	192	85.3	147	99.3	135	77.1
	5–7	0	0	0	0	1	0.7	0	0
	>7	0	0	0	0	0	0	1	0.6
Schedule compliance	Follow the schedule	14	11.2	22	9.8	0	0	6	3.4
	Late schedule	111	88.8	203	90.2	148	100	169	96.6
Family labour (person)	0	78	62.4	185	82.2	125	84.5	128	73.1
	1	47	37.6	38	16.9	22	14.8	46	26.3
	2	0	0	2	0.9	1	0.7	1	0.6
Paddy yield (kg/ha)	< 1,000	0	0	0	0	0	0	1	0.6
	1,001–3,000	0	0	2	0.9	0	0	1	0.6
	3,001–5,000	2	1.6	13	5.8	21	14.2	10	5.7
	5,001–7,000	120	96.0	197	87.5	120	81.1	149	85.1
	> 7,000	3	2.4	13	5.8	7	4.7	14	8.0

significant percentage of farmers with a degree as their highest level of education. In Region II, 77.4% of paddy farmers have a middle school education; in Region III, 87.7%; and in Region IV, 76.5%. The primary occupation in MADA regions is paddy cultivation, accounting for 99.3% in Region III, 93.8% in Region II, 90.9% in Region IV, and 84.8% in Region I. Table 3 shows that in Region I, 37.6% of paddy farmers utilise family labour, compared to 26.9% in Region IV, 17.8% in Region III, and 15.5% in Region II. Regarding paddy productivity, over 81% of farmers in each region produce more than 5,000 kg per hectare. Region IV leads with 8% of farmers cultivating more than 7,000 kg per hectare, followed by Region II with 5.8%, Region III with 4.7%, and Region I with 2.4%. The descriptive analysis of the four MADA paddy regions reveals that most characteristics of paddy farmers are similar across regions. The majority of farmers are male, older, and have a middle school education.

Comparison of Input Usage and Technology Adoption

To compare the input factors of MADA paddy regions, descriptive analysis was conducted. A descriptive analysis was conducted to assess the initial purpose of this research, which was to compare input usage across different regions. Table 4 demonstrates the comparability of variable properties across different regions.

The study on paddy productivity shows that more than 5,000 kg per hectare is the highest productivity percentage across the four regions. Region I leads with 96% of its farmers achieving this productivity, followed by Region II at 87.5%, Region IV at 85.1%, and Region III at 81.1%. Regarding yields exceeding 7,000 kg per hectare, Region IV had 14 farmers, Region II had 13, Region III had 7, and Region I had 3. Region IV and II had the highest and second-highest productivity, respectively, while Region II exceeded Region IV in the 5,000 to 7,000 kg per hectare range, indicating its commendable productivity. Region I, however, had the lowest percentage of yields exceeding 7,000 kg per hectare.

Table 4: Paddy productivity in the MADA region

Paddy Productivity (kg/ha)	Region I (Perlis)		Region II (Jitra)		Region III (Pendang)		Region IV (Kota Sarang Semut)	
	N	%	N	%	N	%	N	%
< 1,000	0	0	0	0	0	0	1	0.6
1,001–3,000	0	0	2	0.9	0	0	1	0.6
3,001–5,000	2	1.6	13	5.8	21	14.2	10	5.7
5,001–7,000	120	96.0	197	87.5	120	81.1	149	85.1
> 7,000	3	2.4	13	5.8	7	4.7	14	8.0

Table 5 shows that Region III has the highest proportion of minimal land use for paddy farming, with 60.7% of farmers using less than one hectare. Over 50% of paddy farmers in Regions I and IV also use less than one hectare. In contrast, less than 1% of farmers in each region use more than four hectares. Region II stands out for using larger land areas over two hectares on average, which contributes to its higher paddy productivity compared to other regions. Maximising land utilisation is associated with higher paddy yields.

Table 6 shows the distribution of seed usage per hectare across four regions. In Region I (Perlis), 88.8% of farmers use 0 to 149 kg/ha of seeds, while only 0.8% use more than 250 kg/ha. Region II (Jitra) has 84.4% of farmers using 0 to 149 kg/ha, and 0.9% using more than 250 kg/ha. In Region III (Pendang), 81.0% of farmers use 0 to 149 kg/ha, with 0.7% using more than 250 kg/ha. Region IV (Kota Sarang Semut) has the highest percentage of farmers (97.7%) using 0 to 149 kg/ha, with no farmers using more than 200 kg/ha. Overall, the majority of farmers in all regions use between 0 and 149 kg/ha of seeds.

Table 7 illustrates fertiliser usage (kg/ha) across four regions. Region III has the highest percentage of farmers (49.3%) using less than

Table 5: Paddy land area at MADA regions

Land Area (ha)	Region I (Perlis)		Region II (Jitra)		Region III (Pendang)		Region IV (Kota Sarang Semut)	
	N	%	N	%	N	%	N	%
0–0.99	68	54.4	101	45.0	90	60.7	94	53.7
1–1.99	44	35.2	93	41.3	50	33.8	63	36.0
2–2.99	11	8.8	28	12.4	5	3.4	18	10.3
3–3.99	1	0.8	2	0.9	2	1.4	0	0
> 4	1	0.8	1	0.4	1	0.7	0	0

Table 6: Seeds usage at MADA regions

Seed Usage (kg/ha)	Region I (Perlis)		Region II (Jitra)		Region III (Pendang)		Region IV (Kota Sarang Semut)	
	N	%	N	%	N	%	N	%
0–149	111	88.8	190	84.4	120	81.0	171	97.7
150–199	13	10.4	30	13.4	26	17.6	4	2.3
200–249	0	0	3	1.3	1	0.7	0	0
> 250	1	0.8	2	0.9	1	0.7	0	0

Table 7: Fertiliser usage at MADA regions

Fertiliser Usage (kg/ha)	**Region I (Perlis)**		**Region II (Jitra)**		**Region III (Pendang)**		**Region IV (Kota Sarang Semut)**	
	N	**%**	**N**	**%**	**N**	**%**	**N**	**%**
< 300	43	34.4	60	26.7	73	49.3	62	35.4
301–600	47	37.6	87	38.7	42	28.4	69	39.4
601–900	22	17.6	50	22.2	24	16.2	27	15.4
> 900	13	10.4	28	12.4	9	6.1	17	9.7

300 kg/ha, followed by Region IV at 35.4%. Regions I and II have lower percentages in this category. Region II leads in fertiliser usage in the 301 to 600 kg/ha range and also has the highest percentages in the 601 to 900 kg/ha and over 900 kg/ha ranges compared to other regions. Conversely, Region III's usage of over 900 kg/ha is significantly less. Overall, very few farmers in the MADA regions use more than 900 kg/ha of fertiliser for paddy farming.

According to the Table 8, the assessment of machinery used across the four MADA regions reveals minimal drone use: Only a small percentage of farmers in Regions II, III, and IV use them, and none in Region I. All farmers use machines for field preparation, seed sowing, and pesticide spraying. However, farmers in Regions I, III, and IV prefer manual labour for planting, with only a few in Region II using machinery for this task. Most farmers use machines for harvesting, except for a small percentage of farmers in Region II who harvest manually. Overall, Region II shows the most active engagement in all machinery-related activities, despite low drone and planting machine usage. Increased machinery use is linked to higher paddy productivity.

Table 9 summarises the daily time farmers in the MADA region spend in paddy fields. The majority of farmers in Regions III (99.3%) and II (85.3%) spend 2 to 4 hours per day in the fields, with Region II having the highest number of farmers (192) in this category. In Region IV, only one farmer spends more than 7 hours daily in the field. In contrast, Region I farmers spend a smaller proportion of their day, specifically 2 to 4 hours in the fields. The high paddy productivity in Region II indicates that dedicating more hours to fieldwork yields better results.

The crop timetable, organised by MADA management, aims to improve rice production by encouraging farmers to follow a set farming schedule. An analysis of schedule compliance shows that Region I has the highest percentage of farmers (11.2%) adhering strictly to the timetable. In contrast, none of the farmers in

Table 8: Machinery usage at MADA paddy regions

Machinery Usage Criteria (Yes/No)	**Region I (Perlis)**		**Region II (Jitra)**		**Region III (Pendang)**		**Region IV (Kota Sarang Semut)**	
	Y (%)	**N (%)**	**Y (%)**	**N (%)**	**Y (%)**	**N (%)**	**Y (%)**	**N (%)**
Drone	0	100	3.1	96.9	1.3	98.7	0.6	99.4
Field preparation	100	0	100	0	100	0	100	0
Sowing seed	100	0	100	0	100	0	100	0
Planting paddy	0	100	0.5	99.5	0	100	0	100
Sowing fertiliser	100	0	99.5	0.5	100	0	100	0
Spraying pesticides	100	0	100	0	100	0	100	0
Harvesting	100	0	99.5	0.5	100	0	100	0

Table 9: Total spending hours in MADA regions

Use of Time in the Field (hours)	Region I (Perlis)		Region II (Jitra)		Region III (Pendang)		Region IV (Kota Sarang Semut)	
	N	%	N	%	N	%	N	%
< 2	76	60.8	33	14.7	0	0	39	22.3
2–4	49	39.2	192	85.3	147	99.3	135	77.1
5–7	0	0	0	0	1	0.7	0	0
> 7	0	0	0	0	0	0	1	0.6

Region III follows the schedule. Most farmers across regions tend to be slow to adhere to the timetable, with only a few diligently following it. Table 10 shows that Region I has the highest percentage of farmers complying with the schedule, which may contribute to its higher paddy productivity.

Technical Efficiency of MADA Regions

Table 11 displays the technical efficiency of MADA paddy regions. The technical efficiency results for the MADA paddy regions reveal a maximum efficiency of 0.98, with minimum efficiency varying across regions. Notably, Region III recorded the lowest efficiency score of 0.88 among all the paddy regions. Table 11 shows that Region I paddy farmers have the highest efficiency percentage among the regions. Regions I and IV achieved the highest efficiency levels, with scores of 84.8% and 81.7%, respectively. In contrast, only 55.4% of paddy farmers in Region III reached the highest efficiency range. Region III had the highest

Table 10: Crop schedule compliance at MADA regions

Crop Schedule Compliance	Region I (Perlis)		Region II (Jitra)		Region III (Pendang)		Region IV (Kota Sarang Semut)	
	N	%	N	%	N	%	N	%
Follow schedule	14	11.2	22	9.8	0	0	6	3.4
Late schedule	111	88.8	203	90.2	148	100.0	169	96.6

Table 11: Distribution of technical efficiency score at the MADA region

Efficiency Score	Region I (Perlis)		Region II (Jitra)		Region III (Pendang)		Region IV (Kota Sarang Semut)	
	N	%	N	%	N	%	N	%
< 0.49	0	0	2	0.90	0	0	3	1.7
0.50–0.59	0	0	1	0.45	2	1.3	0	0
0.60–0.69	0	0	3	1.3	6	4.1	3	1.7
0.70–0.79	1	0.8	11	4.90	15	10.1	4	2.3
0.80–0.89	18	14.4	48	21.34	43	29.1	22	12.6
0.90–0.99	106	84.8	160	71.11	82	55.4	143	81.7
Total	**125**	**100**	**225**	**100**	**148**	**100**	**175**	**100**
Mean	0.92		0.90		0.88		0.91	
Maximum	0.98		0.98		0.98		0.98	
Minimum	0.79		0.29		0.51		0.17	

efficiency score, 0.80 to 0.89, on a large scale, followed by Region II, Region I, and Region IV. Region I scored the highest average efficiency at 0.92, while Region IV had a mean efficiency score of 0.91, indicating relatively high efficiency. Region III, with an average efficiency score of 0.88, had the lowest average efficiency among the regions. Region I had 19 respondents with efficiency scores below 0.90, representing 15.2% of the region's farmers, while Region III had 23 respondents with efficiency scores below the average.

Overall, most paddy farmers in the four MADA regions have efficiency scores between 0.90 and 0.99, with very few scores below 0.49. These findings suggest a close association between regions in measuring technical efficiency, with a small gap in average scores. This aligns with Rabia *et al*. (2022), who found technical efficiency levels of 0.85 in Malaysian paddy cultivation and 0.89 in organic rice farms in Punjab, Pakistan, respectively.

Discussions

The findings of objective one indicate that Region I, characterised by a higher percentage of young and educated farmers, exhibits greater productivity levels. With higher education, farmers can optimise the use of fertilisers, irrigation, and mechanisation, reducing waste and increasing yield. Younger farmers tend to be more open to innovation, adopting advanced agricultural technologies, precision farming, and climate-smart practices that improve productivity.

Conversely, Region III, which has a larger proportion of elderly farmers, reported lower paddy productivity and efficiency. These results highlight the significant impact of education and age distribution on paddy productivity in the MADA regions. To enhance productivity across all regions, efforts should be made to improve education and modernise farming practices.

The second objective of this study is to analyse and compare the inputs, management practices, and levels of technology adoption that influence paddy productivity across different regions. Regions with greater land allocated to paddy cultivation tend to exhibit higher productivity. The findings suggest that key strategies for enhancing paddy productivity in the MADA regions include optimising land utilisation, adopting efficient farming practices, investing in modern machinery, allocating sufficient time for fieldwork, and adhering to well-structured farming schedules. The unique agricultural practices and commitment to these strategies in each region play a crucial role in determining their productivity outcomes.

The last objective involves analysing the technical efficiency levels within the MADA paddy regions. Each of the four regions was tested individually to determine its efficiency score. Region I demonstrated the highest technical efficiency, with a score of 0.92, indicating it is close to the productivity frontier and only needs to increase output by 8% with the given inputs. The technical efficiency scores across the MADA regions provide valuable insights into their productivity levels and potential for improvement. Region IV has the second-highest average technical efficiency score at 0.91, suggesting it needs a 9% increase in output to achieve optimal productivity with constant inputs.

In contrast, Region III has the lowest average score of 0.88, showing a 12% potential increase in output without additional inputs if technical inefficiency is minimised. It is evident that Region III does not adhere to the schedule. Region III, with the most significant percentage of elderly farmers, reported lower paddy productivity and poorer efficiency in paddy farming. The lack of technical efficiency in the rice supply chain significantly impacts national food security and food availability (Kurnia & Iskandar, 2020).

The average technical efficiency score across the MADA regions is 0.90, confirming previous studies that highlight the relationship between technical efficiency and paddy productivity. For instance, a study by Mailena *et al*. (2014) found that paddy farms that adhered to best practices achieved a technical efficiency score of 0.97, resulting in optimal increases in output. The technical efficiency across all regions shows minimal variation in average scores, indicating a narrow gap between them. This finding is consistent with the research by Fatimah *et al.* (2022), which estimated the technical efficiency of paddy cultivation at 0.85 using the Cobb-Douglas production function. Similarly, Rabia *et al.* (2022) reported a technical efficiency of 0.89 for organic rice farms in Punjab, Pakistan, further supporting these results.

Similar to any study, this research has limitations that may have influenced its findings. The use of a quantitative cross-sectional approach restricts the ability to analyse firms' efficiency over time. Expanding the assessment to other firms could help authorities better estimate farmers' technology adoption and efficiency relative to competitors. To overcome these limitations, future research could adopt a longitudinal design or a mixed-methods approach, providing more comprehensive insights and capturing causal relationships more effectively.

Conclusions and Policy Recommendations

The results suggest that productivity is higher among younger, educated farmers who adhere to crop schedules. Conversely, Region III, with a higher percentage of elderly farmers, reports lower paddy productivity and efficiency. This highlights the importance of education, age distribution, and adherence to schedules in enhancing productivity in the MADA regions. Efforts to improve education, modernise farming practices, and encourage adherence to schedules are recommended to boost productivity across all regions.

The results of comparing input usage, management practices, and technology adoption across MADA paddy regions reveal that maximising land use, adopting appropriate farming practices, investing in machinery, dedicating sufficient time to fieldwork, and following farming schedules enhance paddy productivity. Each region's specific practices and adherence to these factors significantly influence their productivity levels.

The analysis of technical efficiency levels in the MADA paddy regions reveals that Region I has the highest efficiency score of 0.92, indicating that only an 8% improvement in output is needed to achieve optimal productivity. Region IV follows with an efficiency score of 0.91, requiring a 9% increase in output, while Region II scores 0.90 and needs a 10% boost. Region III has the lowest efficiency at 0.88, suggesting a potential 12% increase in output. The average technical efficiency score across all MADA regions is 0.90, consistent with previous research that links technical efficiency to paddy productivity. Based on these findings, the study recommends that the government focus on supporting educated, young, and efficient farmers who are well-equipped to adopt advanced paddy technologies. Design training modules focused on modern agricultural practices, digital literacy, and agribusiness management tailored for young and educated farmers.

Enhancing food security and addressing low paddy productivity will require adopting mechanisation technology as an effective strategy to boost national paddy productivity. The findings on technical efficiency have significant implications for broader agricultural and economic outcomes such as Malaysia's national self-sufficiency goals and improvements in farmers' incomes. Higher technical efficiency in farming enhances productivity, reduces resource wastage, and increases output, contributing to greater food security and reduced dependency on imports. Additionally, improved efficiency can lead to higher profitability for farmers, encouraging investment in modern agricultural practices and technologies.

These insights align with Malaysia's long-term agricultural strategies, such as those outlined in the National Agrofood Policy (NAP), which aims to strengthen food security and promote sustainable farming practices. By identifying efficiency gaps and areas for improvement, policymakers can design targeted interventions, including technology subsidies, training programmes, and infrastructure support, to enhance farmers' productivity. Ultimately, increasing technical efficiency supports the nation's economic resilience and aligns with broader efforts to achieve self-sufficiency in key agricultural commodities.

For future studies, it would be valuable to investigate the specific factors underlying differences in technical efficiency across regions. Additionally, research could explore the long-term impact of mechanisation technology on paddy productivity and its effects on the economic stability of farming communities. Future studies could also assess the effectiveness of government policies in encouraging the adoption of modern farming technologies across diverse farmer demographics. Implementing targeted strategies such as government incentives, extension services, and public-private partnerships could enhance these efforts. However, potential challenges may arise, including limited awareness among farmers, financial constraints, and resistance to change. To mitigate these obstacles, governments could invest in education and training programmes, provide financial support through subsidies or low-interest loans, and foster collaboration between stakeholders to ensure a smooth transition to modern agricultural practices.

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Conflict of Interest Statement

The authors declare that they have no conflict of interest.

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