Estimation of Future Paddy Production and Sustainable Land Allocation in Malaysia: A Polynomial Approach

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ABSTRACT

This study examines the trend of paddy production and allocation of land for between 2014 and 2030 based on polynomial function. In order to gauge the time variance effect on sustainable land allocation for paddy production, short-term and long-term scenarios were used in estimating future paddy production and average yield. This study finds that with successive increases in the intensity of the long-term paddy productivity, the land required for paddy plantation in the future will be diminished. Additionally, the average yield per hectare explains the difference between long-term and short-term projection and emphasises the crucial need for improvement in research and development (R&D) and discovering alternative measures for domestic paddy production. Therefore, due to its increasing population, Malaysia has to ensure an efficient allocation of land for development and paddy plantation to cater to both current and future needs.

Keywords: Average yield per hectare, Future paddy land requirement, Food security, Paddy production, Polynomial approach, Rice demand, Sustainable paddy farming, Self-sufficiency level

INTRODUCTION

The Food and Agriculture Organization (FAO) defines food security as fulfilling the following criteria: food availability, food access, utilisation, and stability. First, food availability is defined as having sufficient quantities of food supplied through domestic production and importation. Second, food

access refers to accessibility by individuals to good quality of food. Third, utilisation means an efficient allocation of food consumption. Fourth, stability e.g. securing food for a population, households, and individuals at all times. However, the first criterion that emphasises food supply through domestic production is the main focus of this study because it directly influences the self-sufficiency level (SSL) of rice in Malaysia. This study forecasts future paddy production and land between 2014 and 2030 both short-term and long-term using the polynomial function with a high confidence level of R square compared with the traditional linear approach.

Paddy Production and Food Security

Self-sufficiency level for rice refers to the ratio of rice production to rice requirements (Bala et al., 2014). However, the government's concerns over food security for the country's self-sufficiency programme focuses on paddy production. The agriculture sector was given priority in the 3rd Malaysia Plan, during which the New Economic Policy was launched. Under this policy, more land was allocated for paddy production and this led to an increase in the self-sufficient level (SSL) from 80% to 92% (Dano & Samonte, 2005). The 4th Malaysia Plan (1981-1985) emphasised on strategies and a long-term policy to develop the agriculture sector, which caused SSL to drop in 1984. However, in the 5th and 6th Malaysia Plans, the focus was on the agricultural sector in terms of modernising, urbanising, commercialising,
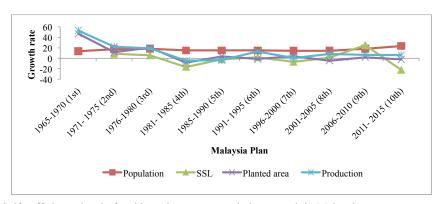
industrialising, and increasing participation of the private sector, which caused the SSL for paddy to slightly increase. In the 7th Malaysia Plan, the agriculture sector focused on competitive agriculture economy and Malaysia's accession to the World Trade Organisation (WTO), which gave importance to high value crops and this caused SSL for paddies to drop. In 2005, in conjunction with the 8th Malaysia Plan, the agricultural sector became modern, dynamic and competitive. Under this plan, the agriculture sector placed an importance on food production in order to meet increasing demand and achieve higher growth. In the 9th Malaysia plan, paddy production recorded higher SSL after the 1980s, whereby the agricultural sector was based on agro processing activities and increasing agriculture entrepreneurs. In the 10th Malaysia Plan, the SSL declined once again because the agriculture sector gave importance to commercial scale farming as well as farming new crops and livestock. Beside this, Malaysia lacks comparative advantage in paddy production compared with neighbouring countries, such as Thailand and Vietnam, which means the nation had to rely on imported rice to meet its' SSL (Arshad et al., 2011).

Figure 1 shows that Malaysia's population grew from 13% between 1965-1970 to 23% between 2011 and 2013 (Bala et al., 2014). However, SSL for the period between 1963 and 2013 appears to be lower than the population growth, especially during the negative period of 4th (-16.85%), 5th(-1.96%), 7th (-6.95%), and

10th (-22.22%) Malaysian Plans, with the exception of the 9th Malaysia Plan. Statistics show that despite the decline in the number of rice fields, production grew positively during the 6th (-1.15% vs 12.85%), 8th (-4.57 vs 8.10%), and 10th (-1.98% vs 6.13%) Malaysia Plans respectively. This was mainly due to increased subsidy in the form of fertiliser (Arshad et al., 2011). Arshad et al also highlighted that it was possible for Malaysia to achieve the desired 70% SSL by 2020. However, how much of the land that is required for future paddy production in regards to short-term and a long-term measure has not been addressed thus far. This knowledge is crucial in determining if Malaysia would be able to achieve the revised benchmark level of 100% SSL by 2020 as promised by the Ministry of Agriculture, Agro-based Industry Malaysia (Bernama, May, 2015). Because SSL is the major driving force of the paddy industry in Malaysia, it places greater pressure on discovering future knowledge on paddy production both in terms of short-term and long-term measures.

The future estimation of paddy production renders most important knowledge of the required land that shall be set aside for paddy production. Since land is a finite resource, without sustainable land allocation, the increasing modernisation and agricultural land conversions appear to pose a serious threat to future paddy production and food security (Arshad et al., 2011).
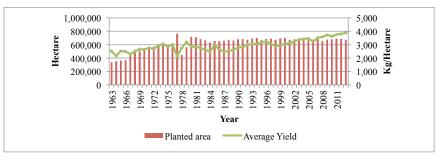

Figure 1. Self-sufficiency level of paddy and average population growth in Malaysia
Source. Adapted from Malaysia Plan and World Bank

Figure 2 indicates that although the average paddy yield per hectare of the paddy planted areas appeared to increase from 2500 kg/ha to 4000 kg/ha from 1963 to 2011, the 4th Malaysian plan indicated that due to drought conditions, yield growth rate declined drastically in 1977.

Figure 2. Paddy planted area and average yield of paddies
Source. Department of Statistics Malaysia

The average yields per hectare were negative compared with areas planted with paddy between 1977 and 2002. The positive yield growth rate was only apparent from 1963 to 1969, 1978 to 1979, and 2007 to 2011. Nevertheless, the positive yield growth rates between 2007 and 2011 (Figure 2) were still unable to accommodate the rapid need of the population during that same period (Figure 1). However, achieving self-sufficiency level is not easy due to several external factors, such as the use of fertiliser technology, labour resources, climate change, and other macroeconomic factors (Arshad et al., 2011, Ismail & Omar, 2008). Since paddy production is related to SSL, a simulation projection is essential to plan for future sustainability of rice production and food safety in Malaysia. Therefore, the main aim of this study was to estimate the future land requirement for paddy production by forecasting future production and average yield per hectare.

MATERIALS AND METHOD

The polynomial approach is generally an alternative to regression model, which is highly useful in predicting the unknown non-linear value of dependent variable in response to the known value of the independent variable. Regression models are usually used to study the relationship between variables and not specifically related to forecasting. However, the polynomial models with successive power terms are often the best flexible curve fitting technique (Ostertagova, 2012). The application of polynomial forecast was used in petroleum production to forecast oil and gas consumption in Malaysia (Rahim & Liwan, 2012).

This study also employs the same method and uses second degree polynomial as an appropriate alternative measurement tool in estimating paddy production trend between 1963 and 2013. Indeed, not many focused ons forecasting future paddy production growth, except for several studies on population growth and food security (Arshad et al., 2007; Paul, 2013). Using population growth data, Paul (2013) estimated that by 2050, the demand for rice in Malaysia would increase to 825%. In another study, the policy implication on

rice production was discussed using a linear trend analysis from 1985 to 2006 (Arshad et al., 2007). A study by Sivapathasundram and Bogahawatte (2012) used Autoregressive Integrated Moving Average (ARIMA) to forecast paddy production in Sri Lanka. Although they had pointed to the importance of meeting growing demand, they did not address the fundamental requirement in sustainable land allocation for future production. Using time series data provided by the Department of Statistic, this study utilised paddy production data from 1963 to 2013 to predict future paddy production for the short-term and long-term. This study shows that the time effect plays an important role in the sustainable land allocation for paddy production as agricultural output is often time-dependant. McConnel and Dillon (1997) argued that agricultural output is often dependent on the flexibility effect and decision-making options available for a farmer in the long-term compared with the short-term. Maidin et al. (2015) note that natural disasters such as flood and droughts often affect short-term paddy yield in Malaysia. The Malaysian government support in terms of production subsidy transmits larger positive acreage effect in the long-term (Tey et al., 2010). Therefore, time effect plays an important role in addressing variation in the future estimation of paddy production.

The estimated required land for paddy production between 2014 and 2030 is based on conventional domestic production calculation, which, according to Emy et al. (2015), is the alternative approach for estimating future 'desired' productivity with 'desired paddy production'. Therefore, the physical accounting of domestic paddy production is expressed below (Emy et al., 2015):

$$PRO_p = AYIELD_h \ X \ PLANT_a \qquad (1)$$

where,

PRO_p = Production of paddy

$AYIELD_h$ = Average yield per hectare

$PLANT_a$ = Paddy planted area

Since paddy production and average yield per hectare is estimated using polynomial regression, paddy planted area is estimated by rearranging equation (1).

Therefore, paddy planted area is represented in equation (2):

$$PLANT_a = PRO_p \div AYIELD_h \qquad (2)$$

Equation (1) implies that generally, the change in the domestic production is only possible with an improvement in land allocation and/or average yield per hectare. However, since land is a finite resource with severe restrictions, required sustainable land allocation is subjected to the proportion of domestic production and average yield per hectare (equation 2). Therefore, the selection of strategy to influence domestic production depends on the alternative measures between land allocation and paddy productivity.

RESULT AND DISCUSSION

Based on the computed trend equations between 1963 and 2013, the forecasted paddy production and average yields were

generated using a polynomial function. The long-term trend was estimated using data between 1963 and 2013 with the prevalence assumption of long term effect of historical crop management, seed and fertiliser quality, seasonal factor and climate change effect. In contrast, the short-term estimation involved the period between 2000 and 2013 to gauge the prevalence effect of the most recent consistent trend in paddy production. All the estimated polynomial trends of paddy production for both long-term and short-term exhibit a very high degree of the

goodness of fit, as shown by the respective R-squares. However, the second-degree polynomial (dotted line) estimation of paddy production for both scenarios (Figures 3 and 4) seems to fit the actual data trend with R square 0.86 and 0.90 respectively. Although the long-term polynomial estimation of average yield trend (Figure 5) demonstrates a slightly lower R square compared with the short-term scenario (Figure 6), the second-degree polynomial appears to be the best fit for the actual trend with R square 0.76 and 0.90 respectively.
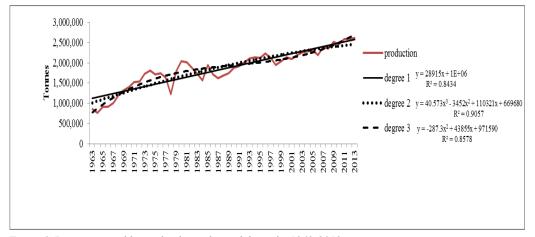

Figure 3. Long-term paddy production polynomial trends, 1963-2013
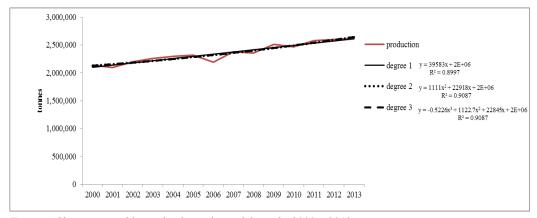

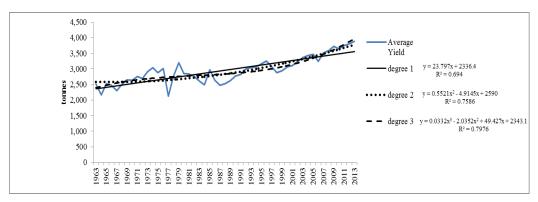*Figure 4*. Short-term paddy production polynomial trends, 2000 – 2013

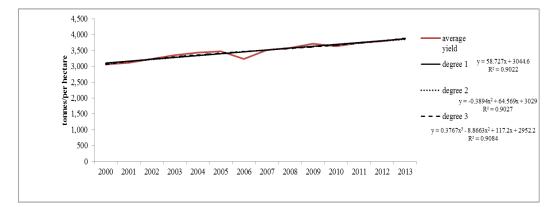*Figure 5*. Long-term average yield polynomial trends, 1963-2013

Figure 6. Short-term average yield polynomial trend, 2000-2013

Estimation fitness

The accuracy of the polynomial model was further tested using both graphical and root-mean-square error (RMSE). The RMSE is not an unbiased estimator of variance (σ) and is generally regarded as a good estimator of the size of the errors in regression (Ostertagova, 2012). The estimated paddy production closely fitted with the actual data in the both long-term and short-term (Figures 7 and 8). Similarly, the estimated average yield per hectare also seems to closely fit to the actual figures in the both scenarios (Figures 9 and 10).
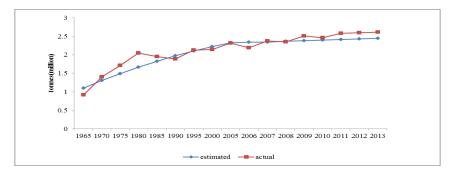
Figure 7. Long term estimated and actual paddy production trends
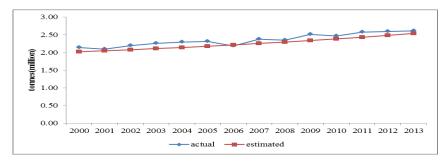

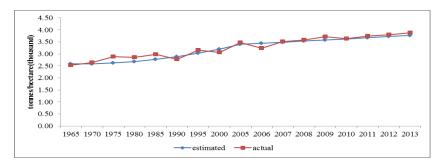*Figure 8*. Short-term estimated and actual paddy production trends

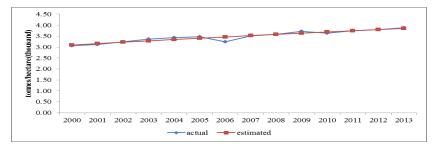*Figure 9*. Long-term estimated and actual average yields per hectare

Figure 10. Short-term estimated and actual average yields per hectare

Table 1 shows the polynomial regression result for the variable paddy production and average yield per hectare for both scenarios. The low RMSE with a high R square in the overall findings indicate the selected estimation method render greater accuracy by minimising possible uncertainty in estimation and natural variation in the projection (Ostertagova, 2012).

Table 1
Polynomial regression result

	Paddy Production		Average yield/hectare	
	Long-term estimation	Short-Term estimation	Long-term estimation	Short-Term estimation
RMSE	0.09	0.43	0.08	0.29
R^2	0.86	0.91	0.76	0.90

Forecast Result

The forecasted long-term paddy production and the average yield (Table 2) shows that paddy production would increase only by 6% from 2.48 million tonnes in 2014 to 2.62 million tonnes in 2030, while the paddy

Table 2
Forecasted paddy production, average yield and planted area for short-term and long-term, 2014-2030

Year	Paddy production (Metric Tonnes)		Average Yield (Kg/Hec)		Planted Area (required Hec)	
	Long-term	Short-term	Long-term	Short-term	Long-term	Short-term
	$y = 971590 + 43855x - 287.3x^2$	$y = 2000000 + 22918x + 1111x^2$	$y = 2590 - 4.9145x + 0.5521x^2$	$y = 3029 + 64.569x - 0.3894x^2$	$PLANT_a = PRO_p \div AYIELD_h$	
2014	2,475,191	2,593,745	3,827	3,910	646771	663362
2015	2,488,879	2,651,104	3,880	3,962	641464	669133
2016	2,501,993	2,710,685	3,935	4,014	635830	675308
2017	2,514,533	2,772,488	3,990	4,065	630209	682039
2018	2,526,497	2,836,513	4,046	4,115	624443	689311
2019	2,537,887	2,902,760	4,104	4,165	618394	696941
2020	2,548,944	2,971,229	4,162	4,213	612432	705253
2021	2,558,944	3,041,920	4,222	4,261	606098	713898
2022	2,568,610	3,114,833	4,283	4,308	599722	723035
2023	2,577,702	3,189,968	4,345	4,354	593257	732652
2024	2,586,219	3,267,325	4,408	4,400	586710	742574
2025	2,594,161	3,346,904	4,472	4,445	580090	752959
2026	2,601,529	3,428,705	4,537	4,488	573403	763972
2027	2,608,323	3,512,728	4,603	4,532	566657	775094
2028	2,614,541	3,598,973	4,671	4,574	559739	786833
2029	2,620,185	3,687,440	4,739	4,616	552898	798839
2030	2,625,255	3,778,129	4,809	4,656	545905	811454

production growth rate tends to decrease from 0.55% to 0.19% during the same period. The short-term paddy production forecast tends to be a little higher than the long-term during the observation period, compared with short-term average yield up to 2024. Despite a consistent trend in the short-term average yield per hectare, the average long-term yield forecast tends to surpass short-term scenario after 2024. This has implication on the land requirement for paddy production in the future.

Figure 11 indicates a diverging trend between long-term and short-term land requirements for paddy production between 2014 and 2030. This finding is consistent with the underlying assumption for long-term and short-term measurements. The long-term forecast indicates that Malaysia needs less land compared with the short-term at the forecasted production level. This study found that the average yield per hectare is the main determinant for long-term and short-term projection.

The average yield or paddy productivity is dependent on several factors such as crop management, land fertility, seed quality, type of fertiliser, irrigation, climate change, natural calamity and government intervention policy (Arshad et al., 2011; Ohta & Kimura, 2007; Dano & Samonte, 2005). Thus, long-term paddy productivity estimation takes into account essential factors that influence paddy productivity with greater flexibility level. With increase in the intensity of long-term paddy productivity, the land required to produce paddy will be reduced. In contrast, short-term paddy productivity will require a larger land area to maintain the given production level in the future. Although the findings of the short-term scenario differ from Arshad (2011), they are consistent with Maidin et al. (2015), Tey et.al. (2010) and McConnel and Dillon, (1997) where short-term output was time-dependant due to inflexibility of resources and other external factors.
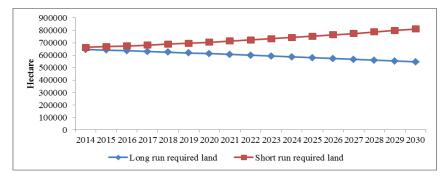

Figure 11. Long-term and short-term required land for paddy production

CONCLUSION

The objective of this study was to forecast paddy production and sustainable land requirements for future paddy production in Malaysia. Using polynomial functions, this study found a robust indication that long-term paddy production would increase by only about 6% from 2.48 million tonnes in 2014 to 2.62 million tonnes by 2030 with an increasing growth in average yield per hectare. Therefore, the required land for paddy production tends to fall from 647,000 hectares in 2014 to 546,000 hectares in 2030. In 2024, the short run production was estimated to be higher than in the long run. However, the average yield was estimated to be higher (4408 kg/hectare) in the long run than in the short run (4400 kg/hectare), with less planted area required (586710 hectares) for the long run compared with the short run (742574 hectares). This shows that the long run trend with less required land and a higher average yield is more productive compared with the short-term trend. Thus, based on increase in the intensity of long-term paddy productivity, there will be reduced demand for land required for paddy production in the future. The findings of this study point to the crucial need for improvement in the research and development (R&D) and discovering alternative measures on domestic paddy production. As a developing country and with its increasing demand for rice, Malaysia has to ensure an efficient allocation of land between development and paddy farming in order to cater to the need for both current and future consumption. Sustainability of paddy farming is essentially the key factor that will determine the nation's food security and influence economic growth.

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