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The impact of climate change towards Malaysian paddy farmers

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Ricardian model was used to estimate the impact of climate change on granary level net revenue of paddy sector in Malaysia. Panel data from eight granaries was used in this study and the annual net revenue was regressed against climate variables and other controlled variables. The results indicate that climate is one of the determinants of Malaysian paddy granaries' profitability. Given future predicted climate scenario indicates that farmers are predicted to lose an average of about 67% of revenue within the period of 2020 to 2029, 88% within 2050 to 2059, and 127% within 2090 to 2099. The losses might affect the livelihood of 296,000 paddy farmers in Malaysia. Thus, immediate adaptation strategies are critical in order to deal with such predicted effects.

Key words: Climate change, Malaysia, paddy, Ricardian model.

INTRODUCTION

Paddy is mainly planted in Peninsular Malaysia (PM), contributing 85.5% of Malaysia's total paddy production. The area involves eight major granaries, which have been reserved and designated purposely for wetland paddy cultivation by the government in the National Agricultural Policy. Most of the government support programs and interventions in paddy sector are concentrated in these areas, which also makes it an important area for research and development activities. As shown in Table 1, these eight granaries are located in seven states of PM. The designation is based on their record as large producer of paddy for the country. In order to supervise and monitor this intervention programs, a dedicated government authority is mandated to help the paddy farmers to improve their productivity, output, earning and technology practices.

The agricultural sector in Malaysia can be divided into three sub-sectors comprising agro-industrial, food and the miscellaneous group sub-sector. Paddy can be considered as the most important crop under the food sub-sector simply for two reasons. Firstly, Malaysian per capita consumptions accounted for 500 to 799 of calorie intake per day, which make rice the main staple food in Malaysia (Nguyen, 2005). Secondly, the crop provides a source of income for small-scale farmers that depend solely on paddy cultivation. With approximately 296,000 paddy farmers in Malaysia, almost 40% of them cultivate on full time basis (Elenita and Ema, 2005). Nonetheless, the local supplies still lag behind to cater for local demand, as Malaysia is still dependent on imported rice. Malaysian Padiberas Nasional Bhd (BERNAS), which holds exclusive right to import rice, is importing about 30% of rice from Vietnam, Thailand and Pakistan (Department of Agriculture, 2009b). Although Malaysia continues to be a net importer of rice, yet, in the wake of the global food crisis in 2008, the government effort to boost up local rice production is indispensable, as the crisis has indicated that cheaper imported rice would not always be available to cater local demand.

For instance in the early 2008, China has introduced export restrictions in order to safeguard the stocks of rice for domestic consumption due to the abnormally cold weather that affected production. The disastrous flooding in 2010 has forced Indonesia to import a large quantity of rice, as paddy fields across the country suffered almost a year of excessive flooding due to heavy rain (Deutsch

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Table 1. Location and average planted area of the granary areas in 2008.

State	Granary areas	Average planted area (ha)	Share to total paddy area in Malaysia (%)
Kedah and Perlis	Muda Agricultural Development Authority (MADA)	96553	38.4
Kelantan	Kemubu Agricultural Development Authority (KADA)	24965	10.0
	Kemasin Semarak Integrated Agricultural Development Project	2797	1.1
Terengganu	Northern Terengganu Integrated Agricultural Development (KETARA)	4293	1.7
Pulau Pinang	Pulau Pinang Integrated Agricultural Development Project	10305	4.1
Perak	Krian Sg. Manik Integrated Agricultural Development Project	26959	10.7
	Seberang Perak Integrated Agricultural Development Project	7272	2.9
Selangor	Barat Laut Selangor Integrated Agricultural Development Project	18301	7.3

Source: Department of Agriculture (2009a).

and Hidayat, 2011). Recent massive flood that hits Thailand in October, 2011 had destroyed approximately 10% of the nation's rice crop (Thanyarat, 2011). As a consequence, international rice trade volume in 2012 could drop to 33.8 million tons from projected 34.3 million [Food and Agriculture Organization (FAO), 2011]. Prior to the projection, the Asia-Pacific region has been expected to experience the worst effect on rice and wheat yields worldwide as result of climate change and decreased yields could threaten the food security of 1.6 billion people in South Asia [International Food Policy Research Institute (IFPRI), 2009].

The future climate scenario of PM is expected to experience a worrying trend. In every decade, the temperature is predicted to signify an increasing pattern, whereas rainfall is expected to have an opposite direction. Based on figures by Malaysian Meteorological Department (MMD), both west coast and east coast of PM has shown an increasing annual mean temperature trend (Figure 1) from 1968 to 2007 and a reduction in rainfall (Figure 2) from 1975 to 2005 (line A) as compared to those of 1951 to 1974 (line B). Temperature, precipitation, sea level rise, higher atmospheric carbon dioxide (CO_2) content and the incidence of extreme events are the main climate change related factors, which impact agricultural production (McCarl et al., 2001).

Several studies in South East Asia have confirmed that climate change can produce detrimental effects on rice production. Among the earliest studies that probe the impact of climate change towards paddy production in South East Asia was carried out by Amien et al. (1996). The study predicts the impacts of climate change in the decades of 2010, 2030, and 2050 and found that an increase in maximum and minimum temperatures, rainfall, and solar radiation leads to reduction of about 1% of rice production annually in East Java. In Malaysia, study to assess the economic impact of climate change on paddy sector has only started in recent years. Chamhuri et al. (2009) asserted that paddy production could be affected by climate change as changes may cause shortage in water and other resources, which eventually would affect soil fertility and lead to pest and disease outbreaks. They imply that this climate crisis is highly expected to hit states of Malaysia where the poverty level is high especially in Kelantan, Terengganu, Perlis, Kedah and Perak. Recent study by Al-Amin et al. (2010) forecast that rice yields are expected to decline between 4.6 and 6.1% as a result of 1°C increase in temperature at the current CO_2 concentration level which could reduce rice productivity by 34.8% per hectare in 2060. They indicate that rise in temperature above 26°C will increase plant respiration and shorten the grain-filling periods. The periods become shorter as the plant growth rate increase and the growth duration decrease.

None of the above discussed studies especially those in Malaysia apply the Ricardian method in assessing the impact of climate change on agriculture. Actually, the application of Ricardian method has been primarily used

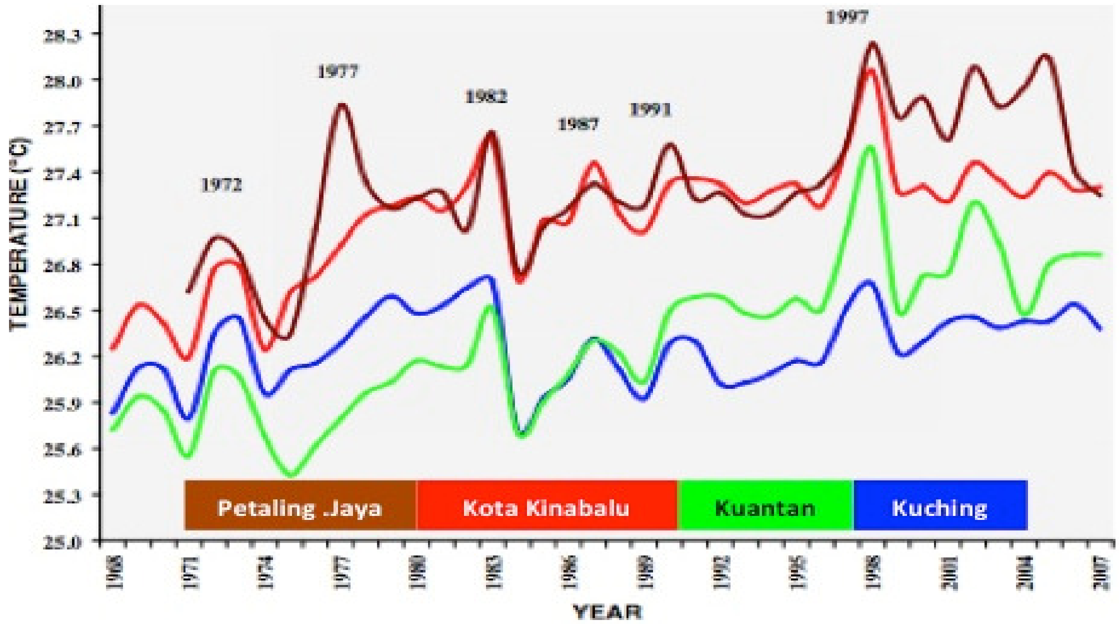

Figure 1. Annual mean temperature in Malaysia from 1968 to 2007.

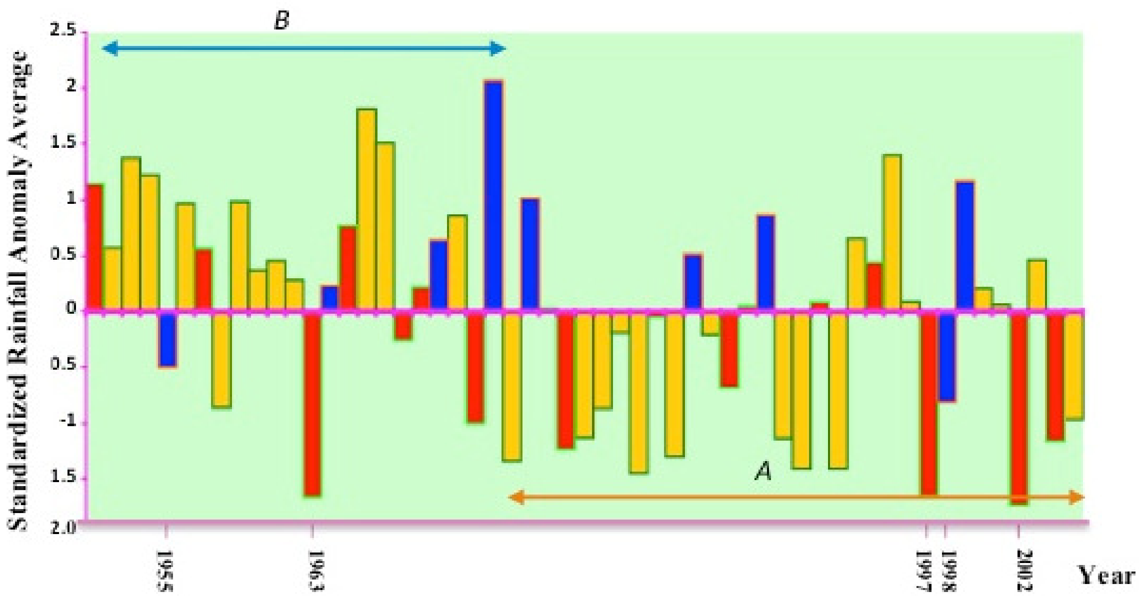

Figure 2. Standardized annual rainfall anomaly in Malaysia from 1951 to 2005. Source: MMD (2009).

in the US to predict the damages from climate change (Mendelsohn et al., 1994; Mendelsohn, 1996; Schelenker et al., 2004). There have also been a number of studies in India (Dinar et al., 1998; Kumar and Parikh, 2001), India and Brazil (Sanghi and Mendelsohn, 2008), Canada (Reinsborough, 2003), China (Liu et al., 2004), Sri Lanka (Seo et al., 2005; Kurukulasuriya and Ajwad, 2007), South African (Gbetibouo and Hassan, 2005; Behnin, 2008), Israel (Fleischer et al., 2008), Cameroon (Molua, 2008) and Nigeria (Ajetomobi et al., 2011). By and large, the literatures suggest that the impacts of climate change would be favourable to some cropping areas in America, eastern Mediterranean and some regions in China, but the impacts will be deleterious in tropical and semi-tropical countries, where most of them fall under the group of developing and low-income countries. Inevitably,

Table 2. Descriptive Statistics: Variables for net revenue regression model (Main Season and Off Season from 1999 - 2008).

Parameter	Paddy seasons in PM			
	Main season		Off season	
	Mean	SD	Mean	SD
Net revenue per ha (RM)	1218.21	681.10	1500.39	713.12
Rain (mm)	1682.94	649.52	1411.26	450.92
Temperature (℃)	27.14	0.3954	27.58	0.4539
Planted Area (ha)	24059.30	28631.46	24023.14	29007.84

Source: Author's simulation.

relevant adaptation strategies need to be taken as the negative impact could lead to insufficient food supplies in the country, especially in the case of 'staple' food crops such as paddy.

The main advantage offered by the Ricardian method is that, it allows a number of controlled variables to be included so that a measure of adaptation and adjustment strategy to mitigate the effects of climate change on farmers' productivity level can be taken into account. In this study, two different adaptation strategies were taken into account. In spite of its popularity, nevertheless the model has its own limitations. Mendelsohn (2007) revealed that the Ricardian approach could not measure CO_2 fertilization because they are relatively uniform across the world. He pinpoints this failure as one of the weaknesses in this analysis. However, in the case of Malaysian paddy, al-Amin et al. (2010) has confirmed that increase in CO_2 could not offset the negative impact brought by the temperature increase. Another shortcoming of Ricardian method is the use cross-sectional analysis. Since changes in climate are related to dynamic impacts, Kurukulasuriya and Ajwad (2007) suggest that panel data would be more reliable to measure inter temporal effects. In this study, panel data was used to overcome this problem.

Undeniably, the government has allocated a vast amount of budget in the form of subsidies and incentives to encourage production, but this may not be enough to retain the farmer's interest, if changes in future climate could substantially affect production and income. Furthermore, with competition by other agriculture crops such as palm oil and rubber that perhaps could offer better income, this may force farmers to leave the paddy cultivation and shift to the other lucrative agriculture crops. In fact, the grave long-term challenges spear-headed by changes in climate may dampen the effort of government in boosting rice production in Malaysia since climate is one of the primary determinants of paddy productivity. Consequently, the nation's food security will be under threat. Thus, this study attempts to estimate a relationship between climate variables and granary-level net revenue and project the impacts in a predicted future climate scenario with a view to find potential strategy of adapting.

METHODOLOGY

Data and variable specifications

The granary and climate data were obtained from the Department of Agriculture and MMD (Table 2). Granary level data on net revenue requires data on paddy production in metric tons per hectare, total area planted per season, total farmers cost from planting to harvesting and the selling floor price of paddy (RM per ton) including the price subsidy. These data are seasonal data, which involves period of 1999 to 2008. The price subsidy from 1999 to 2008 is at a rate of RM248.10 per metric ton, which is actually given as an incentive by the government to encourage farmers to produce more. The data are in the form of seasonal granary level data (main season and off season), which covers farmers' activities starting from land preparation to harvesting.

Seasonal data on temperature and precipitation are based on the location of the weather station, not on granary. This climate data was taken from six stations namely Alor Star, Bayan Lepas, Ipoh, Kuala Terengganu Airport, Kota Bharu and Petaling Jaya. Alor Star station will represents climate for MADA; Bayan Lepas station for IADP Pulau Pinang; Ipoh station for Krian Sg Manik and Seberang Perak; Petaling Jaya station for Barat Laut Selangor; Kota Bharu station for KADA and Kemasin Semarak; and Kuala Terengganu Airport station for KETARA.

As shown in Table 2, the statistics indicate that the off-season period is generally warmer than main season due to lower level of rainfall and slightly higher temperature. Although more planted areas are devoted during the main season, however, the net revenue per hectare is slightly better during the off-season period. This suggests that the planted area or the size of the granary may hold a non-linear relationship (a u-shaped or inverted u-shaped) with farmers' profitability.

Net revenue

Based on the Ricardian model, theoretically the net revenue per hectare (NR/ha) for this study, which is the dependent variable in Equation 1 is defined as:

$$NR/ha_{it} = [P_{it} * Q_{it}(X_{it}, E_t) + S_{it} * Q_{it}(X_{it}, E_t)] - \Sigma C_{it}(Q_{it}, X_{it}, E_t)] / \Sigma L_{it} \quad (1)$$

where, S_{it}, P_{it} and Q_{it} are, respectively the price subsidy, selling price and total paddy production for granary *i* in period *t*. The symbol of *t* indicated the series of time for each variable, since this

Table 3. Average forecasted annual mean rain and temperature changes in the all granary areas for period 2020 to 2029, 2050 to 2059 and 2090 to 2099.

Annual mean rain	Temperature
2020 to 2029	
-13.4	+1.3
2050 to 2059	
+2.7	+1.9
2090 to 2099	
+10.3	+3.1

Rain is in % changes; temperature is in °C changes. Source: Malaysian Meteorological Department (2009).

study applies pooled time series cross-section regression analysis instead of individual cross-sectional analysis. C( ) is the function of all purchased inputs (X) other than land, E is a vector of climate variables and L represents the planted area. Cost of fertilizers, which is subsidized by the government, is assumed to be borne by the farmers. Most of the paddy land in the granary areas is privately owned by the farmers. Some of them leased the land on a short-term basis to other farmer or private enterprise but the data pertaining on the number of land tenants are not available. Thus, cost of renting the land will not be included in this analysis. It is assumed that all farmers are landowners.

Temperature and rainfall

In this study, temperature and rainfall was used as a proxy to measure the variations in climate towards net revenue. The average temperature and total rainfall will be computed based on two cultivation seasons in Malaysia, namely the 'Main season' and 'Off-season' from 1999 to 2008. The main or off-season's period in one granary is not the same between other granaries. The main or off-season's period in one granary also varies from 1 year to the next. For example, the period for main or off-season in MADA is not the same as in other seven granary areas. MADA's main or off-season period varies from 1998 to 1999, 2000 and the subsequent years. However, normally paddy is planted in main season between the month of August and February of the following calendar year, while for off-season starts from the end of March until July in a year.

Most of the Ricardian method uses an average of 30 years climate data, while Kumar and Parikh (2001) computed 20 years average climate data. Instead of climate, this study however relies on seasonal average temperature and total rainfall computed from annual weather of 1999 to 2008. Same approach was applied by Kurukulasuriya and Ajwad (2007). In fact, year 1998 to 2007 was considered as a long-term average climatic in terms of temperature and precipitation in Malaysia (MMD, 2009). It is worth to note that decreasing seasonal rainfall trend for PM can be observed in 1998 to 2007 as compared to those in 1961 to 1990 and there is also no significant difference in temperature between period 1961 to 1990 and 1998 to 2007.

In order to examine a wide range of climate outcomes, the approach relies on the 'Scientific Report on Climate Change' published by MMD. As shown in Table 3, the average forecasted annual mean rain and temperature changes reflects climate scenario that might happen in north-west, north-east and central region in Malaysia within 2020 to 2029, 2050 to 2059 and 2090 to 2099. The north-west PM covers granary areas in MADA, Pulau Pinang, Seberang Perak and Krian-Sungai Manik; Central PM represents Barat Laut Selangor and north-east PM represents Kemasin Semarak, Ketara and KADA. The simulation of annual temperature and rainfall in this report is based on ProvidingRegional Climates for Impacts Studies (PRECIS) simulation driven by HadCM3. PRECIS is the regional climate model (RCM), while HadCM3 is part of the Atmosphere-Ocean General Circulation Model (AOCGM). In practice, the AOCGM simulation model has been widely exerted by most of Ricardian method studies as in the paper by Reinsborough (2003), Liu et al. (2004), Seo et al. (2005), Kurukulasuriya and Ajwad (2007), Sanghi and Mendelsohn (2008), Fleischer et al. (2008), Kurukulasuriya and Mendelsohn (2008), and Ajetomobi et al. (2011).

Non-climatic variables

Total planted area was used as a controlled variable as number of studies have used farm's size or size of cropping area as a factor to measure net revenue gained through the concept of economy of scale (Kurukulasuriya and Ajwad, 2007; Kurukulasuriya and Mendelsohn, 2008; Molua, 2008; Fleischer et al., 2008; Ajetomobi et al., 2011). In addition, a dummy variable was used to represent the season cultivation period on farmers' profitability. It is worth to note that currently more planted areas are devoted to the main season due to the fact that the off-season period requires more water supplies for irrigation. However, farmers in some areas were unable to cultivate paddy during the off-season period due to lack of irrigation infrastructures. For instance, in Kemasin Semarak, the irrigation infrastructures only cover about 50%* of its area. However, in major granary areas such as MADA in Kedah, the size of planted area during the main season and off-season is about the same. The development of the irrigation infrastructure in some areas being implemented and in some is expected to complete in the Tenth Malaysia Plan period. These include the construction of flood mitigation, drainage and irrigation. The season's dummy variable on the other hand seeks to explain whether profitability could be explained by cultivation season.

Methods

To attain the above objectives, this study applies the Ricardian method (Mendelsohn et al., 1994). The Ricardian method is a cross-sectional approach to study agricultural production. Cross-sectional observations across different farm can reveal the climate sensitivity for each farm. The method assesses economic impacts of climatic changes as well as capturing farmers' adaptation response to climate changes. Derived from David Ricardo's (1772 - 1823), original observation made was that land value would reflect its net productivity;the principle is shown in Equation 2a:

$$LV = \Sigma P_i, Q_i (X , F , H , Z , G) - \Sigma P_x X \qquad (2a)$$

where LV is the value of land, P_i is the market price of crop *i*, X is a vector of purchased inputs (except land), F is a vector of climate variables, H is water flow, Z is a vector of soil variables, G is a vector of socio-economic variables and P_x is a vector of input prices. The original Ricardian studies [for example, in US by Mendelsohn et al. (1994) and Canada by Reinsborough (2003)] estimate the impact of climate change on land value. However, in Malaysia, data pertaining land value is unavailable due to the absence of well functioning land markets. In this study, the granary level net revenue was used to estimate the climate response

* From personal interview with Mr. Mohd Suhaimi Mohd Rashid, Ministry of Agriculture's Officer.

Table 4. Determinants of net granary revenue per hectare.

Net revenue per hectare	
Variable	**Coefficient**
Rain	-0.6809**
Squared rain	0.000132*
Temperature	11759.30*
Squared temperature	-221.2114*
Planted area	-0.023389
Squared planted area	1.59E-06
Dummy cultivation season	-368.9814**
Constant	-155182.5*
N	160
R^2	0.61

**, *, Significant at 5 and 10%, respectively.

function and reflect the impact of climate change on the eight granary areas namely MADA, KADA, KETARA, IADP Pulau Pinang, Krian Sg. Manik, Barat Laut Selangor, Seberang Perak and Kemasin Semarak. Theoretically, the Ricardian model relies on a quadratic formulation of climate:

$$NR/ha_i = \beta_0 + \Sigma\,(\beta_1 T_{it} + \beta_2 T_{it}^2 + \beta_3 R_{it} + \beta_4 R_{it}^2) + \Sigma\,\beta_s L_{it}\,\mu_{it} \qquad (2b)$$

where, NR/ha_{it}, Net revenue per hectare in period *t* for granary *I*; β_0 is intercept term; $\beta_1,\ldots\ \beta_s$, regression coefficients that measure the responsiveness of the net revenue per hectare in period *t* to a particular variable; T_{it} and R_{it}, vector of climate variables including temperature and rainfall in period *t* for granary *i*; T_{it}^2&R_{it}^2, vector of climate variables squared including temperature and rainfall in period *t* for granary *I*; L_{it}, other relevant explanatory (*non-climatic*) variables in period *t* for granary *I*; μ_{it}, error term.

When the quadratic term is positive, the net revenue function is u-shaped and when negative, the function is inverted u-shaped. It is expected that granary level net revenue per hectare hold a u-shaped relationship with temperature. The same goes to the size of the granary, while the main season is expected to have a positive relationship with net revenue per hectare. To estimate the above model, pooled time series cross-section analysis is used based on seasonal data over the period of 1999 to 2008, which cover all the eight granary areas in Malaysia. The model attempts to discover one principal hypothesis, that is, whether paddy farmers' net revenue per hectare is sensitive to climate. To test the hypothesis, the net revenue per hectare is regressed with climate and two controlled variables, which involve planted area and planting season. To analyze the hypothesis, a non-linear (quadratic) model has been constructed for ease of interpretation. Figures from Table 2 implied that the main season might have a negative relationship with farmers' net revenue. Hence, by employing a dummy parameter for 'cultivation season' (value of 1 for the main season and 0 if otherwise), this model attempts to discover the impact of cultivation season on farmers' net revenue.

In the initial runs, different fixed effect regressions are tested. The variables that fitted the model best are the one with cross-section fixed effects. Therefore, the results presented in this paper have eliminated the variable bias arising from omitted factors that vary across granary but were constant over time within a granary. Such variables may include geographical characteristics such as soil type, elevation and many more that are different across granaries but constant over time. Since the net revenue was defined in season wise, thus, only one definition for climate can be made. This definition is based on data for planting and harvesting time period of granaries for each season in each year.

The climate variables coefficient from Equation 2b were used to assess the projected marginal impact of changes in one climate variable on granary level net revenue, which is evaluated based on following equations:

$$E\,[\Delta NR/ha\,/\Delta T_i] = \beta_{1,it} + 2 * \beta_{2,it} * E\,[T_i] \qquad (3a)$$

$$E\,[\Delta NR/ha\,/\Delta R_i] = \beta_{3,it} + 2 * \beta_{4,it} * E\,[R_i] \qquad (3b)$$

Finally, the above equations were used to simulate the impact of future climate change scenarios (Table 3) on net revenue function. The only variables that are subject to change were the climate variables, while other factors will remain unchanged. Obviously, this will not be the case over time as scale of economy, price and cost are subject to change over time which has tremendous impacts on future granary net revenue. Therefore, the purpose of this simulation is only to examine the impacts of climate in future, rather than to predict the future as such.

RESULTS AND DISCUSSION

Table 4 presents the results of the model. This model was estimated using generalized least square. Similar to Fleischer et al. (2008), the small value of R^2 is in this study as compared to the results by Mendelsohn et al. (1994) are due to three reasons: (1) land values are more stable compared to seasonal granary net revenue, which tends to fluctuate; (2) this study data comprises only eight granaries as observation, whereas Mendelsohn et al. (1994) observation are based on country averages and (3) Malaysia is small country relative to the US where the range of average daily temperature is only marginal ranging from 26 to 28°C compared to US which is from -12 to +34°C.

More planted area in the main season contributes towards a negative relationship towards farmers' net revenue. However, the positive sign for 'planted area' quadratic term implies a u-shaped relationship of granary size with net revenue, which suggests that the eight granaries are operating at increasing returns to scale. A similar relationship is observed by Kurukulasuriya and Ajwad (2007) and Kurukulasuriya and Mendelsohn (2008). Nonetheless, the 'planted area', which is considered in the regression to account for economies of scale, has an insignificant repercussion on farmer's net revenue. Hence, the other reason for the higher mean net revenue during the off-season period could be due to lesser cost of cultivation in this period. In the off-season period, some of the input cost could probably be absorbed or acquired during the main season period. For instance, cost of additional fertilizers, and costs for controlling weeds, insects and disease.

All the climate and climate squared variables are significant, thus, implying that climate has a non-linear effect on net revenues. The positive sign of squared rain and the negative sign of squared temperature indicate

Table 5. Marginal effects of temperature and precipitation on Net revenue per hectare

Marginal changes in climate variable	Net revenue per hectare
1°C Increase in temperature	RM-442.42
1% Drop in rainfall	RM -0.01

Source: Author's simulation.

that the net revenue function is u-shaped (convex) in rainfall and inverted u-shaped (concave) in temperature. This means that temperature or rainfall affects the net revenue positively or negatively up to a certain level, above or below it causes damage to the crops. This is supported by the work carried out by Ajetomobi et al. (2011) that asserts second order temperature coefficient for irrigated rice farms in Nigeria is negative. The work also reveals that most of the agronomic research found that crops are consistently exhibited by inverted u-shaped relationship with annual temperature, although the maximum point varies with the crop. Such findings also correspond to finding by Baharuddin (2007) that claims rice grain yield might decline by 9 to 10% for each 1°C rise. Kurukulasuriya and Ajwad (2007) on the other hand found that rainfall has a concave effect towards net revenue per hectare.

Drop in rainfall will affect crops that need wet conditions such as paddy. Given the small coefficient's value for rain, thus the marginal impact of rain is expected to be far smaller than temperature. The presence of irrigation water may partly affect the intense relationship of rainfall towards paddy. To some extent, irrigation water could also buffer the crop from being intensely influenced by temperature (Ajetomobi et al., 2011). Thus, the exclusion of irrigation water in this analysis could actually underrate the impact of rainfall and overrate the impact of temperature on paddy. Study by Fleischer et al. (2008) implied the relevancy to include the farm water inflow to overcome overestimation problems particularly for a crop that depends heavily on irrigation water.

Table 5 shows the marginal impact analysis result, which assesses the effect of an infinitesimal change in temperature and rainfall. As expected, the marginal effects of precipitation on farmers' net revenue were much smaller and not even close to 1% from temperature's effect. Drop in total rainfall in each season by 1% is expected to incur a loss at an average of RM 0.01% per hectare. On the other hand, 1°C increases in average temperature for each season could result in a huge loss. The net revenue could fall at an average of RM 442.42 per hectare as a result of 1°C increases in average temperature.

Forecasting

The simulation results for net revenue model are shown in Table 6. It was estimated using Equations 3a and 3b, based on the climate scenario in Table 5. The expected losses per hectare and average net revenue per hectare are estimated based on total effects of changes in temperature and rainfall. The simulation effects presented marked variation in the granaries' net revenues during the main season and off-season. Increase in temperature during the main season period is less harmful as compared to the off-season period. The average losses associated as a result of increase in temperature in the off-season period compared to main season periods are 17.37% more. A 13.4% reduction in rain during the 2020 to 2029 also affects the off-season more. However, in both seasons, increase in rain for the period of 2050 to 2059 and 2090 to 2099 are expected to lessen the losses experienced earlier in 2020 to 2029. Nevertheless, the reductions are slightly higher during the main season period. Since the mean net revenue during the off-season period is slightly higher than the main season period, thus, the average net revenue per hectare in the off-season period is expected to be greater. In the period of 2020 to 2029 and 2050 to 2059, average net revenue per hectare for off-season period are 22.16 and 67.61% more respectively, as compared to main season. In the period of 2090 to 2099, both seasons recorded negative net revenue per hectare.

In contradiction with the study by Al-Amin et al. (2010) which found that, a variation in temperature of 0.3 to 1.4°C and rainfall ±32% reduces incomes up to RM1280.60 per hectare per year, this study predicts that an increase of 1.3°C in temperature and drop in rainfall by 13.4% leads to a total loss of RM 1841.73, which is 44% higher. However, both empirical results provide conclusive evidence that the paddy sector in Malaysia is highly responsive to climate change.

Indeed the results of this study suggest that paddy farmer's net revenue per hectare is sensitive to marginal change in climate variables in both seasons and the impact could be more during the off-season period, which is more hot and dry.

CONCLUSIONS AND RECOMMENDATIONS

This study attempts to analyze the impact of climate change on Malaysian paddy sector, focusing from the eight designated granary areas in Malaysia, namely MADA, KADA, KETARA, IADP Pulau Pinang, Krian Sg.

Table 6. Forecasts of average net profits per hectare based on future climate scenario predicted by MMD.

Climate variable	Net revenue per ha			
	Main season		Off- season	
	(RM)	(%)	(RM)	(%)
2020 to 2029				
Temperature	-823.20	-67.57	-1017.87	-67.84
Rainfall	-0.30	-0.02	-0.36	-0.02
Expected loss/ha	-823.50	-67.59	-1018.23	-67.86
Expected average NR/ha	394.71	32.41	482.16	32.13
2050 to 2059				
Temperature	-1088.66	-89.37	-1283.32	85.53
Rainfall	-0.22	-0.01	-0.30	-0.02
Expected loss/ha	-1088.88	-89.38	-1283.62	-85.55
Expected average NR/ha	129.33	10.62	216.77	14.45
2090 to 2099				
Temperature	-1619.57	-132.94	-1812.23	-120.78
Rainfall	-0.19	-0.02	-0.27	-0.02
Expected loss/ha	-1619.76	-132.96	-1812.50	120.80
Expected average NR/ha	-401.56	-32.96	-312.11	-20.80

Source: Author’s simulation.

Manik, Barat Laut Selangor, Seberang Perak and Kemasin Semarak. It uses secondary climate, production and cost data to conduct the Ricardian cross-sectional approach to measure the relationship between the paddy farmers’ net revenue with climate variables, planted area and cultivation season. The result of the study shows that climate affects paddy farmers’ net revenue in Malaysia. The marginal impact of temperature on net revenue shows that if the temperature increases by 1°C, the net paddy farmers’ revenue falls by RM442.42 per ha, whereas if the rainfall reduces by 1%, the net revenue drops by RM0.01 per ha.

Using simulated scenarios from MMD for the period of 2020 to 2029, 2050 to 2059 and 2090 to 2099; this study forecasts the impact of changes in climate towards paddy farmers’ net revenue. The climate change scenarios’ analysis indicates that scenarios of increasing temperature with decreasing rainfall will cause more damage to paddy sector in Malaysia. However, the scenarios of increasing temperature and increasing rainfall will not be preferable because the positive impact of rainfall will not be able to compensate for the adverse effect of the warming. Warming is expected to be harmful to Malaysian paddy sector but increase in rainfall would only be slightly beneficial. Therefore, it can be concluded that rainfall gains could not outweigh temperature losses.

In general, the anticipated effects would indeed impede government’s attempt to improve rice self-sufficiency level and reduce reliance on imported rice. This study however managed to discover empirically two possible adaptation strategies. Expanding the irrigation infrastructure is vital as the off-season period is found to be more profitable as compared to main season. Currently, more planted areas are devoted to main season due to the fact that off-season period requires more water supplies from irrigation but some of the granary areas are not well equipped with irrigation infrastructure. If government decides to rely on the existing eight granaries, thus, the development of irrigation infrastructure in those areas is the best alternative available to increase total planted area. Perhaps, farmers are able to reduce cost of planting if they could plant more paddy during the off-season period, as the total cost of production will be spread over as output increases.

Finally, by expanding the eight granaries planted area, cost of planting in both seasons could be reduced due to an opportunity of enjoying an increasing return to scale. Although the result of ‘planted area’ is found insignificant, however, the u-shaped relationship provides another option that can be considered by the government. Expanding may not be in the form of adding the total acreage of the current granary areas, but perhaps could be in the form of finding a means to allow farmers to cultivate paddy three times a year rather than twice a year. Paddy farmers in Myanmar for instance, are able to cultivate paddy three times per year.

Generally, the agriculture sector in many countries is vulnerable to experience a negative impact from changes in climate in the future. However, magnitude of the impacts depends on the location, level of development, technological advancement and the institutional setting in the countries. Farmers or government could mitigate such impact through channel of adaptation strategies that could range from crops switching to farmland converting. Paddy farmers in Malaysia are also expected to experience the deleterious global effect of climate change. In this study, the adaptation strategies that can be undertaken are believed to come from an improvement in irrigation efficiency, expanding the irrigation infrastructure and area under cultivation.

LIMITATION OF THE STUDY

This study only represents the eight major granary areas in PM, excluding paddy farms outside the granary areas, as the panel data for these farms are not sufficient. The panel data observation regarding the farmers' social information is also unavailable, hence, deterring this study to observe such factor. Since the farm-level panel data is not available, thus this research is done based on the secondary data. This might cause biases in the analysis, as: (1) yield variability at the farm-level is usually bigger and (2) yield and weather relationships may not be the same from aggregated to farm level analysis. Even though, the farm-level data might be more reliable, however the collection of primary data from eight different granary areas will need huge funding and human resources. The primary data could also help future researcher to incorporate other non-climatic variables such as socio-economic factors. Future research could also further expand this research model by considering paddy fields outside the eight granary areas.

In addition to the Ricardian method, there are also other alternative approaches that can be applied such as Bio-Economic model (Finger et al., 2011) or regression model using repeated cross-sectional method (Deschenes and Greenstone, 2007). An econometric model to analyze the impacts of climate change on the mean, variance and covariance of crop yields can also be deployed especially for research that intends to focus its analysis on the implications towards allocation of multiple crops (Isik and Devadoss, 2006). Apart from changes in mean weather characteristics, the construction of climate change scenarios can also be represented by the changes in climate variability using the combination of both global climate model (GCM) and the stochastic weather generator. These tools can be used to simulate farm-specific daily weather data and have been employed in studies applying the Bio-Economic model.

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