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Assessing the Impacts of Climate Change in the Malaysian Agriculture Sector and its Influences in Investment Decision

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Abstract: This paper focuses on relevant policy strategies to reduce climate related vulnerability for Malaysian rice agriculture. Here an analysis of impacts on climate change and vulnerabilities is performed, based on observational records of inter-annual variability in precipitation and worming climatic factors. The assessment involved Global Circulation Models (GCMs) together with Crop Modeling such as DSSAT to represent a range of plausible climate scenarios. The approach used follows a bottom-up strategy, focusing on the vulnerability of Malaysian rice agriculture under economic conditions and given a wide range of potential climate outcomes. The study investigates the Malaysian rice agriculture sector under a climate and economic perspective, quantifying the merits of the projected simulation and presents an insight into the nature of tradeoff between climate variability and the likelihood of a decline of earnings for rice cultivation over the next 40 years from 2020 to 2060. The projections signify to the likely future changes and uncertainties on rice production; potential path for planning strategies for investment decision to reduce vulnerabilities and to unearth prioritizing requirements for Malaysian future agriculture. The experiences from this study can be used for climate related agriculture policy in Malaysia and elsewhere.

Key words: Rice Agriculture · Climate Change · Scenario Analysis · Investment decision · Policy Strategy

INTRODUCTION

General Background: alaysia is a South-eastern tropical country (2 30 N, 112 30) [1] which borders with Singapore, Brunei, Indonesia and Thailand. It is divided in three main regions, Peninsular Malaysia, Sabah and Sarawak. Malaysia is considered a middle-income country which since the 1970s has been successful in transforming its economy from a strong production of raw materials dependency into an emerging multi-sector economy characterised for an expansion in manufacturing, services and tourism [1].

Agricultural Background: Malaysian tropical climate characteristics create optimal conditions for the production of fruits and vegetables [2]. However, the major parts of Sabah and Sarawak are covered with dense jungle which does not allow sound farming conditions. Peninsular Malaysia instead, presents favourable conditions for agriculture and it is thus, the predominant agricultural region. In addition, there are barely extreme weather events like hurricanes or severe droughts in Peninsular Malaysia [3]. Malaysia had in 2003 approximately 1 Millions farmers, some of them involved in more than one crop [4]. This implies that 13% of the

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labour force is occupied in the agricultural sector. The agricultural sector contributes to the total purchase parity with a value equal to 10.1% [1] and the 6.3% of the export earnings [3]. Out of the 33 Million ha of the total Malaysian land area, 5.5% is arable land, whereas 17.5% is used as permanent crops. The irrigated land was 3.650 km^2 in 2003 [1].

Malaysia is particularly strong in tree crop agriculture (timber) and management of large scale production of industrial crops [5], which involves the processing and manufacturing of mainly rubber and palm oil. The industrial crops occupy 77% of the total agricultural land [4]. The agriculture of other crops is also important, like cocoa, rice, coconuts or pepper [1]. Nowadays, the agriculture in Malaysia is experiencing a diversification process, which includes the development of newer crops like oil palm, cocoa [3].

Palm Oil: In 2008, Malaysia is the second largest producer of Palm Oil, with a production of 83 Million Tonnes, just after Indonesia (85 Million Tonnes) [6]. Nevertheless, 40% of the world oil palm production is located in Malaysia. The earnings from exports on 2005 were 19 Billion USD [5].

Rubber Plant: In 2008, Malaysia produces approximately 1 Million tonnes of rubber plants. However, since 1990 there has been a significant decrease in the production of this crop because the large plantation companies began to turn to the more profitable palm oil production [2]. This process is still going on in spite of the government efforts to improve the production [3]. Due to this fact, rubber is no longer the country's primary source of export income, although in 2008 Malaysia accounts for the 10% of the world rubber production. The earnings from exports on 2005 were 5 Billion USD [5].

Cocoa: In 2008, Malaysia produced 30.000 tonnes of cocoa. However, a closer look in the evolution indicates that there has been a decrease since 1990. The share in the world cocoa production of Malaysia is equal to 0.7% [6].

Pepper: Pepper is grown on Sarawak. The production in 2008 was equal to 24.500 tonnes [3].

Rice: Rice plays an important role in the Malaysian culture and agriculture. In 2008, the production was 2.4 Million tonnes [6], which 70% is produced in Peninsular Malaysia [3]. However, the production does not satisfy completely the needs of the country and they are forced to import rice from Thailand and Vietnam [2]. This situation specially occurs in Sabah and Sarawak, areas where most of the rice is imported. Peninsular Malaysia imports a share equal to 20% out of the total consumed in the Peninsula [3].

Other Vegetables and Fruits: Malaysian farmers produce a number of fruits and vegetables mainly for the domestic market. These include: bananas, coconuts, durian, pineapples, *rambutan* and others [2].

Logging: In 2000, Malaysia sold more tropical logs and sawed timber than any other country in the World and is also one of the largest hardwood exporters (EoN, 2010). The logging process and manufacturing industry is especially important in East Malaysia and in the northern states of Peninsular Malaysia [2]. This industry has a production equal to 22 Million in 2000 of sawed logs and earned 2.5 Billion from exports in 2005 [2].

CLIMATE CHANGE AND AGRICULTURE

Agriculture practice and climate are directly related exerting mutually effects [7]. In Malaysia, "climate change and agricultural practice are generally seen to have been connected one with other in a circular way" [8]. Climate change affects most significantly in agriculture out of the others economic sector because of its worldwide distribution and the strong linkage and dependence of the climate and the environmental factors [7]. Thus, the effects of climate change on the agricultural production impact the socio-economical dimension at both the macro and micro-scales. Floods and droughts are the most common processed directly affecting the relation between agriculture and climate change [9].

Climate Change and Agriculture in Malaysia: Malaysian rate of change in CO_2 emissions is very fast, the difference of growth between 2003 and 2005 when compared to 1994 to 1996 is 70% of increase [7]. On the other hand, the agriculture is a sector which has a considerable contribution to the overall CO_2 emissions of Malaysia, with a share equal to 4.8% out of the total [7]. Malaysia could suffer temperature variations from 0.7 to 2.6°C and rainfall changes ranging from -30% to 30% [9]. Sea level is foreseen to rise in the range of 15cm to 95cm over a hundred year period [10]. According to Mad Nasir and Ahmad Makmom [7], under a climate change scenario, the direct impacts to the agriculture can be classified in:

- Decreasing of the agricultural productivity
- Increasing of the food insecurity
- Affection of the supply chain caused by the sea level rise

General Effects of Climate Change in the Agriculture in Malaysia:

- Climate change could reduce crop yield [10].
- Areas vulnerable to drought can become marginal for the cultivation of some crops such as rubber, oil palm, cocoa or rice, thus posing a threat to national food security and exports earnings [10].
- As much as 100.000 ha of land planted with oil palm and 80.00 ha of land under rubber could be flooded and abandoned as result of sea level rise [10].
- Increasing temperatures will result in enhanced evapotranspiration, this fact leading to a reduction of the water availability, which can be further exacerbated during dry months [10].
- An increase in the magnitudes of the storms will result in an increase in the frequency of floods and flood damage [10].
- It will be increased salt intrusion causing less amount of water available to use in the agriculture [10].
- A rise in the air and water temperatures will reduce plant efficiency and power output leading to major economical costs [10].
- Geographic distribution limits and yield crop could be modified due to changes in precipitation, temperature, cloud cover and soil moisture as well as increases in CO_2 concentrations.
- Regional variations in productivity gains and losses will probably result in a slight overall decrease in world cereal grain productivity [8].
- High temperatures and diminished rainfall reduce soil moisture, reducing the water available for irrigation and impairing crop growth in non-irrigated regions [8].
- According to Chamhuri *et al.* [8], climate change could influence food production adversely due to resulting:
- Geographical shifts and yield changes in agriculture,
- Reduction in the quantity of water available for irrigation and
- Loss of land through sea level rise and associated salinization.
- The risk of losses due to weeds, insects and diseases could increase. "The range of many insects will expand or change and new combinations of pests and diseases may emerge as natural ecosystems respond to shifts in temperature and precipitation profiles". In addition, this effect of climate on pests will contribute to the overuse of pesticides and the loss of biodiversity [8].
- Physical damage, lost of crop harvest, drop in productivity, vigour and others related to crop potentials are examples of direct and indirect effect of the extreme climate change [9].

Specific Effects of Climate Change in the Agriculture

Floods: Floods have already happened in the southern states of Malaysia, involving *Negeri Sembilan, Melaka, Johor* and *Pahang*. *Johor* was the worst affected amongst them. Such floods displaced 110,000 people, damaging an estimate of RM 0.35 billion worth of infrastructures and RM 2.4 billion of economics losses. An estimate of RM 84 million worth of agriculture produce were damaged or losses affecting 7000 farmers [9]. About 9% of the land area in Malaysia is vulnerable to flooding affecting 3.5 million people. The estimation of the costs is difficult to carry out. However, it was used the conservative Figure of RM 100 Million to estimate the average flood damage per year [9]. The loss of agricultural production due to inundation of erosion during the floods in *Johor* signified RM 46 million for Western Johor Agricultural Development Project area [11].

Droughts: Droughts have also happened in Malaysia already. In 1991, *Malacca* caused the drying up of the Durian Tunggal Dam and resulted in prolonged water rationing in most parts of the state [9]. This produced that during a time period from 4 to 9 months, more than 170.000 people was affected comprising an area of 2.797 km^2. In addition, 1580 km^2 suffered a wild fire, 100 km^2 of which were agricultural lands. The total sum of farmers affected was 7.200 farmers. The estimated costs caused economical looses of RM 7 million. A part from these facts, several districts were forced to suffer water rationing and rice crops were totally wipe out, forcing the public authorities to send food supplies to alleviate the situation. This was also experienced in the North Eastern part of *Sarawak* near *Miri* region [9].

Effects to the Malaysian Crops:

Rubber: A rainfall increasing is prejudicial for rubber plantations which suffer due to loss of tapping days and crop washouts [9].

Oil Palm: Even though theoretically they will have higher growth as rainfall increases, an excessive amount negatively affects the crop yield [9]. In southern Malaysia, the production of crude palm oil has reduced to 1.1 million metric ton or 26.3% in December 2006 [9].

Rice: A decreasing in the rainfall will affect crops that need wet conditions such as rice, vegetables and others. In addition, rice grain yields might decline by 9 to 10% for each 1 degree Celsius rise [9]. Drought periods make not feasible to maintain the rice ecosystem affecting the food security. However and at least at short and medium term, the increase of CO_2 can have a positive in the yield of rice. Rising in the sea level can cause that crops which are planted in low-lying like rice, corn, coconut and others abandoned [9].

An Assessment of Climate Change and Vulnerabilities: As climate is continuously changing and affecting Malaysian agriculture in diversified ways; its impacts and awareness of policy resources for implementation are frequently voiced in mainstreaming climate policy and within development activity. However, specific operational guidance on how to take it into account is still lacking. Proper policy relevant adaptive framework to climate change, networking and communication among stakeholders or policy makers is extremely obvious to contribute to shaping the nationally appropriate policies which are apparently absent in Malaysia. Sustainable long term agricultural policy requires a workable framework for climate change and vulnerabilities that is employed in our study. Our projections and risk of climate change and vulnerabilities signify possible future changes and uncertainties on rice production, potential path for planning strategies to reduce vulnerabilities and promoting sustainable development but the following questions remain in doubt: (i) ISSUE: Are proposed planning strategies for agricultural resources fully supported by the climate record? (ii) IMPACTS: What additional pressures will be placed on these resources as a result of projected climatic variability and change? And (iii) POLICY: What practical (not theoretical) strategies may be engaged to reduce vulnerability and enhance social, economic resilience? The focus of the paper is to unearth prioritizing requirements to copping with doubts on the climate uncertainty and vulnerability.

MATERIALS AND METHODS

The study has been on analyzing the future availability using of regional resources, based on the context of technological and environmental changes, including climate variability. Because of the complex interaction between climate change and climate variability to the regional agriculture level, our assessment study has involved the use of computer simulations based on Global Circulation Models (GCMs) together with Crop Modeling such as DSSAT [12] to represent a range of plausible climate scenarios from the year 2020 to 2060. Our approach follows the bottom-up approach, focusing on the vulnerability of Malaysian rice agriculture given a wide range of potential climate outcomes, rather than on a specific climate forecast.

Although the GCMs simulate the large-scale atmospheric circulation relatively well, the regional cycle often poorly produced. As a result of some constraints of GCMs, we developed empirical downscaling model (EDMs) and genotype coefficient (between the 20 and 40°C) that map the observed large-scale vulnerability for Malaysia up to the year 2060. EDMs give out regional projections by using output from GCMs where large-scale precipitation and large-scale atmospheric climatic variables that are simulated reliably by GCMs. Precipitation variations derived from the historical record are superimposed on the annual cycle of precipitation and the we apply EDMs to projected changes in the large-scale variation forces by following different concentrations of greenhouse (CO_2/ppm400-800) (ppm-parts per million) gases to produce approximation of Malaysian vulnerability to climate change. This approach enables us to build a possible distribution of possible future outcomes for the annual cycle of precipitation and variability of climatic factors over east and peninsular Malaysia. This modelling helps us to quantify the likelihood of exceeding thresholds for agriculture.

Our modelling framework synthesizes essential components and potentiality of crop production and socioeconomic impact for climate change and uses the detailed agronomic-based knowledge, options and future crop production potentials. We have chosen three different scenarios to quantify the full range of future climate related vulnerability. Our EDMs receive the same weights as GCMs in the assessment results for projected scenarios and quantify the regional-scale impacts for Malaysia over the next 40 years from 2020 to 2060. More detailed modeling and mathematical approach and explanations can be found on the supplementary materials on Lobell *et al.* [13]; Tilman *et al.* [14] and Gunther *et al.* [15].

PROJECTED

The EDMs map on the large-scale patterns (based on GCMs) and produce large-scale regional distributions and projections by increasing the temperature change and CO_2 (ppm) concentration. We here applied participations variations derived from the projected records by NRS [16]. Following the empirical downscaling model (EDMs) and superimposed variability on the annual rainfall and temperature fluctuations, the likelihood distribution of significant scenarios are Figured out in Table 3 and Table 4. The Figures of Tables 3 and 4 show the climate change effects on east and peninsular Malaysia over future 40 years. The simulations revealed mixed relationship between simulated results and climate change and the uncertainty of Table 4 caused by climate forcing is relatively found insignificant by NAHRIM [17]. The Figures of Table 1 indicate that the projected rice yields depend on temperature change, rainfall fluctuations and CO_2 (ppm) related photosynthesis. The combination of GCMs and EDMs used in our analysis presents a clear picture: rice yields significantly fluctuate between 0.3 and 0.8°C of temperature and under the 400-800 CO_2 (ppm) concentration with certain level of rainfall fluctuations. Table 4 divulged a significant relationship between climate change and rice yields (kg/ha/yr): changes in earnings (RM) for rice cultivation with climate change over the next 2020 to 2060 years of time periods. We studied the relation between climate variation and crop production by synthesizing data on temperature fluctuation, precipitation and CO2 concentration/radiation between 1970 and 2000 and used those data sets for forecasting yields throughout the Malaysia for the period 2020-2060. We applied a simple model for rice yields for the year 2020-2060:

Malaysian Geographical and Socio-Economic indicators		
Parameter	**Value**	**Unit**
Total Land Area	329.847	Km^2
Population	25.7	Million
Total Fresh Water Withdrawal (2000)	9.02	Km^3/year
Fresh Water Withdrawal per capita (2000)	356	m^3/year
GDP (2009 est.)	378.9	Billion USD
GDP per capita (2009 est.)	14.7	USD
Labour force (2009 est.)	11.29	Million
Exports (2009 est.)	156.4	Billion
Imports (2009 est.)	119.5	Billion

Fig. 1: Malaysian map with geographical and socioeconomic indicators. Sources: [1-3]

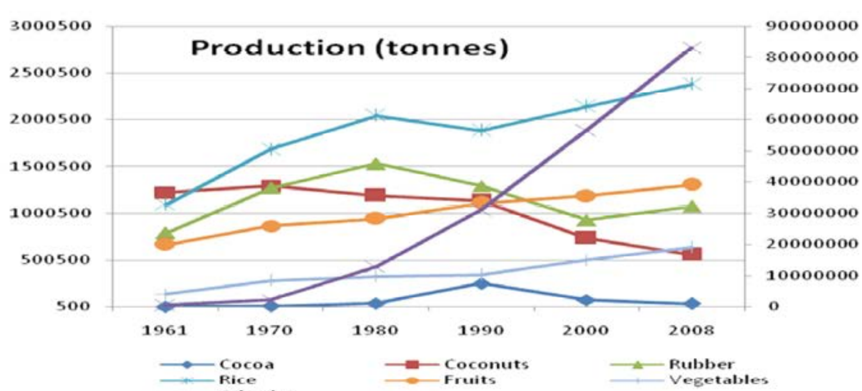

Fig. 2: Evolution of the Crop Production in Malaysia: Oil palm is in the secondary axis. Source: [6]

Table 1: Evolution of the crop production in Malaysia and South-Eastern Asia and World

Production (Thousands of tonnes)	1961	1970	1980	1990	2000	2008	SE-Asia (%)	World (%)
Cocoa beans	0.6	3.2	35.4	247.0	70.2	30.0	3.6	0.7
Coconuts	1220.0	1291.0	1188.0	1134.0	734.4	555.1	1.4	0.9
Natural rubber	789.7	1269.3	1530.0	1291.5	928.0	1072.4	12.9	10.1
Oil palm fruit	500.0	2155.0	12800.0	31000.0	56600.0	83000.0	47.1	40.4
Pepper	15.0	31.6	31.6	31.2	25.1	24.5	11.4	5.7
Rice, paddy	1089.0	1681.4	2044.6	1885.0	2141.0	2384.0	1.3	0.3
Tobacco	1.8	2.6	9.5	10.1	7.1	14.0	3.4	0.2
Fruit excl. Melons	662.5	865.3	938.1	1109.5	1182.0	1305.1	2.7	0.2
Vegetables and Melons	133.8	279.5	322.8	344.2	498.3	636.7	2.0	0.1

Source: adapted from FAOSTAT [6]

Table 2: Predicted effects of climate change on agriculture over the next 50 years

Climate element	Expected Changes by 2050	Confidence in prediction	Effects on agriculture
CO2	Increase from 360 to 450-600 ppm	Very high	Good for crops; increased photosynthesis; reduced water use
Seal level rise	Rise by 10-15cm, increased in south and offset in north by natural subsistence	Very high	Loss of land, coastal erosion, flooding, salt intrusion
Temperature	Rise of 1-2°C. Increase in the recurrence of hot waves	High	Change in seasons
Precipitation	Seasonal changes by -10%	Low	Lodging, soil erosion

Source: [7]

Table 3: Projected Rice Yields (kg/ha/yr) within climate variations

Year 2020				Year 2040				Year 2060			
CO_2(ppm)	400	400	400	CO_2(ppm)	600	600	600	CO_2(ppm)	800	800	800
V_{temp}(°C)	0.30	0.80	1.40	V_{temp}(°C)	0.40	1.40	2.40	V_{temp}(°C)	0.60	2.00	3.40
$V_{rainfall}$				$V_{rainfall}$				$V_{rainfall}$			
0%	7,202	6,860	6,642	0%	9,042	8,642	8,242	0%	10,962	10,402	9,642
14%	6,156	5,801	5,586	23%	7,342	6,942	6,542	32%	8,619	8,059	7,499
7%	6,646	6,301	6,086	11%	8,200	7,800	7,400	15%	9,834	9,274	8,714
-7%	6,698	6,380	6,177	-11%	8,047	7,691	7,335	-15%	9,318	8,842	8,366
-14%	6,194	5,900	5,712	-23%	6,962	6,654	6,346	-32%	7,454	7,073	6,693

Source: Authors estimation based on NRS [16]

Table 4: Earning impacts (RM/yr) of rice cultivation for projected climate change

Year 2020				Year 2040				Year 2060			
CO2(ppm)	400	400	400	CO2(ppm)	600	600	600	CO2(ppm)	800	800	800
V_{temp}(°C)	0.30	0.80	1.40	V_{temp}(°C)	0.40	1.40	2.40	V_{temp}(°C)	0.60	2.00	3.40
$V_{rainfall}$				$V_{rainfall}$				$V_{rainfall}$			
0%	0	0	0	0%	0	0	0	0%	0	0	0
14%	-415.7	-414.2	-415.7	23%	-669.1	-669.1	-669.1	32%	-922.1	-922.1	-922.1
7%	-218.9	-218.1	-218.9	11%	-331.4	-331.4	-331.4	15%	-443.9	-443.9	-443.9
-7%	-198.4	-188.2	-168.0	-11%	-391.6	-374.3	-357.0	-15%	-647.0	-614.0	-580.9
-14%	-396.8	-376.7	-366.0	-23%	-818.6	-782.4	-746.2	-32%	-1380.6	-1323.7	-1239.3

Source: Authors estimation; Assumption on standard grade = RM 110.00/100kg, normal grade=RM 100/100kg

$$\Delta yield = m + y_m \Delta CChange + \varepsilon$$

Where *ΔYield is* the observed trend in yield; *m* is the average yield change with current management option and other non-climatic factors; *ΔCChange* is the observed trend in temperature, precipitation and CO2 concentration; y_m proper management options and ε is the statistical errors. The rice yield trends are significantly correlated with observed temperature trends for the period between 2020 and 2060. Our rice yield trends can be explained by temperature and rainfall variations (P <0.01) over the 40-year period.

The results specifically indicate that the temperature fluctuations between 0.3°C to 0.6°C (Table 3: row V_{temp}°C) and variation of CO_2 between 400 and 800 (ppm) (Table 3 and 4: row $V_{rainfall\ 0\%}$) with rainfall fluctuations (between -32% to +14%) dampen the Malaysian rice production and earnings from rice cultivations. The CO_2 (ppm) concentrations is definitely playing a significant role on rice yields both east and peninsular regions. For example, we find that with the 0% rainfall fluctuation, the raise in CO_2 (ppm) from 400 to 800 causes positive effect on rice production from 7,202 (kg/ha/yr) to 10,962 (kg/ha/yr) over the next 40 years. Rice yields may decline between 4.6%-6.1% per 1°C temperature (from the mean level: >26°C) increase under the present CO_2 concentration level, but a doubling of CO_2 concentration from 400ppm to 800ppm offset the detrimental effect of temperature increase on rice production. The findings are not paradoxical; these impacts are the offset of the detrimental effects of doubling the CO_2 concentrations.

The development rates of agriculture crop (rice) accelerate in response to an increase in CO_2 concentration from 400 ppm to 800 ppm with standard temperature (<26°C). But the increasing temperature above the tolerance limit (>26°C) and CO_2 variation reduces the photosynthesis increase the respiration and shorten the vegetation and grain-filling periods and ultimately decreases the overall Malaysian agriculture yields and farmers earnings which is well evident from both in Table 3 and Table 4. A study by HY Kim *et al.* [18] found that current climate change scenario under different future temperature above 25°C, declines food grain yield as much as 10% per 1°C rises in temperature (above the tolerance limit; >26°C). The combination of GCMs and EDMs used in the analysis represents also a similar scenarios based on the tolerance limit (>26°C) for large-scale projections. Our results estimate that the average response to an increase of potential rice yields is about 10kg/ha/400(CO_2)ppm or about 15kg/ha/800(CO_2) ppm and outcomes of our study specify the insight into the nature of tradeoff between climate change impacts and economic burden.

Projection (Table 4) shows more than 0.4% changes of rainfall by 2020 and 1% by 2060 would cause to decline the earning of farmers under a certain level of temperature. More specifically, the temperature variation of 0.3°C and the ±14 % rainfall variations cause a negative change of earnings (up to RM415.7/yr; $US1=RM3.5) only for rice cultivation. The findings indicate that the variation of climate factors may cause the agricultural system more vulnerable in Malaysia. The gradual climate changes have had a measurable on Malaysian rice yields that decreasing the rice productivity 34.8 %/ha^{-1} by and pushing Malaysia as a future food insecure economy by the year 2060. For example, we find that within ±14% rainfall fluctuations and the 400-800 CO_2 (ppm) concentrations cause negative effect of farmers yearly earning which could vary between RM168.00-1,380.06 overall Malaysia (east and west Malaysia). That a decline of rice yield between 4.6%-6.1% per 1°C temperature increase under the different CO_2 (ppm) level; however here doubling of CO_2 (ppm) concentrations (from present level 400ppm to 800ppm) do not offset the detrimental effect of temperature increase on farmers earnings. The core reason is that total yearly rainfall in Malaysia is overall constant but its monthly variation is too high or too low [17].

Policy Framework for Prioritization: Influences in Investment Decision: How may Malaysia off-set the climate change negative impact on rice yields? There is one best possible way that can be considered that is management adaptation option. We tried to investigate that option on the section of influence in investment decision. The effects of management options, y_m in the regression model such as climate change variations needs to synthesize through suitable irrigation scheme, post-harvesting technology, integrated pest management (IPM), weather and climate information systems, diversification of cropping production and other forms of mechanizations to offset negative impacts.

Our current assessment provides expected sight of climate change impacts on rice agriculture and farmers earning variations up to 2060. Climate change direct mitigation measures are obviously necessary indeed to offset the negative impacts but adapting to future risk is more important for long-term policy as climate change is global problem. Mitigation measures required global integration by multilateral agreements and that is long intellectual process. Now the question arise that if within ±14% rainfall fluctuations and the 400-800 CO_2 (ppm) concentrations cause negative effect of farmers yearly earning between RM168.00-1,380.06 and rice yields decline 4.6 to 6.1% per 1°C temperature increase under the different CO_2 (ppm) level then what will be prioritizing investment decision for Malaysian agriculture? Malaysian current rice consumptions 2.4 million tonnes/yr and currently imports by 30% (i.e. 800,000 tonnes/yr). Under the current agriculture policy Malaysian government is looking for self-sufficiency level (SSL) by 90% from 70% (i.e. year 2010-2050).

Supporting on current population growth rate and self-sufficiency level; Malaysia required additional rice production by 1,320,000 tonnes per year to fulfill the 90% self-sufficiency level in rice agriculture for year 2060. As our simulations find that under the expected future climatic conditions rice productions may decline by 6% instead of increasing by 20% up to the year 2060. Thus aggressive agricultural productivity investments alterations are required to raise production enough to offset the negative impacts (negative decline by 6%) on rice sector. The increasing productivity of rice by 20% up to the year 2060 can be possible, if Malaysia efficiently invest on (y_m) proper management options following simple model as we applied before:

$$\Delta yield = constant + y_m \ \Delta CChange \ (improved\ management\ options) + statistical\ error$$

To maintain the self-sufficiency level (SSL) by 90% from 70%; our main intention is to improve y_m (by offset leveling position) under there broad categories with sub-instruments as follows:

1. Management Related Instruments

a. Irrigation scheduling
b. Integrated pest management (IPM)
c. Weather and climate information systems
d. Higher cropping intensity
e. Diversification of cropping production on irrigated area
f. Protected cultivation
g. Post-harvesting technology
h. Income stabilization programs due to farmers income loss

2. Infrastructure Related Instruments

a. Irrigation facilities
b. Storage and milling facilities
c. Other forms of mechanization

3. Community (CBOs and NGOs) Initiated Instruments:

a. Small scale capacity building
b. Credit facilities
c. Marketing support

Following our priotizing investment decision options such as management related instruments, infrastructure related instruments and community initiated instruments can be improved by 10-11% easily by each broad instrument accordingly. Therefore, within the improvement by 10-11% of each broad instruments our simple statistical results indicate ($p<0.001$) that between 0.3 and 0.8°C of temperature and under the 400-800 CO2 (ppm) concentration with certain level of rainfall fluctuation; clime change related declined rice yield trends can be fully off-set by 20% up to the year 2060. Therefore, Malaysian government policy for self-sufficiency level (SSL) by 90% from 70% would be fulfilled until the next centaury. However, two components however need to be clear for investment prioritization approach: (i) specific evaluation of climate variability and (ii) adaptation possible options focusing on projected scenario issues. Here management related instruments refer the overall efforts by implementing proper irrigation scheduling, timing on operation, integrated pest management (IPM) for crop loss, development programs on risk management to address moisture deficiencies and effects of droughts and develop early warning systems for seasonal weather predictions and forecasts, higher production by higher cropping intensity, diversification of cropping production on irrigated area, diversification of cropping production on non-irrigated area, protected cultivation on grain agriculture and improvement of post-harvesting technology. Extra efforts and practice of management instruments would determine (y_m /Δ% ha^{-1}) substitute effects of clime change related production loss and proxy level of rice production in Table 4.

Pursuing our priotizing investment decision options such as infrastructure related instruments can be improved by 5% easily by each broad instrument accordingly. Within the improvement by 5% of each broad instruments our simple statistical results indicate ($p<0.005$) that clime change related negative impacts on rice yield can be fully off-set by 20% up to the year 2060.

Here the infrastructure related instruments refer the efforts to uphold rice production by implementing proper irrigation facilities which can be maintained federal and local government, suitable storage and milling facilities by local government or NGOs, plowing and harvesting facilities by the NGOs or by local communities, post harvesting technologies by government and ad-hoc compensation and assistance programs for the risk of farm-level income loss associated with disasters and extreme events, farm-level land and management practices in light of changing climate conditions.

And lastly, following our priotizing investment decision options such as community (CBOs and NGOs) initiated instruments can be improved by 15% easily by each broad instrument accordingly. Therefore, within the improvement by 15% of each broad instruments our simple statistical results indicate ($p<0.001$) that clime change related impacts on rice production can be off-set by 5-10% up to the year 2060. This adaptation option moderately improves Malaysian climate change related impact in the rice agriculture up to the year 2060. The community (CBOs and NGOs) initiated instruments refer the efforts to uphold rice production based on small scale capacity building by farmers, more micro-credit facilities by small NGOs and marketing supports by local group of people. However, there is also have to be accurate information provisions, proper dissemination and training as important parts of the means by which adaptation might be encouraged rather than as specific agricultural adaptations in their own right. Technological adaptations and its prospects could be developed in Malaysia through research programs (projects) undertaken by federal and provincial governments. Government programs should be considered as institutional responses to the economic risks associated with climate change and has to be the potential to influence farm-level risk management strategies. The crop insurance programs certainly would be new in Malaysia however it would influence farm-level risk management and may be applicable.

CONCLUSIONS

A first conclusion that can be drawn from this paper is the fact that the regional impacts of Climate Change on Agricultural Productivity in the 2080s according to Zhai and Zhuang [19] could be a value from -22.5 % to -10.9% and the GDP of Malaysia could be decreased by a value equal to 1%. In addition, it seems that climate change may cause a small to moderate effect on the agricultural sector in Malaysia. However, regional effects could be significant, the crop yield significantly varying across different Malaysian regions [8]. Furthermore, even though Malaysia could be considered "as a relatively free zone from climate related disaster", mild climate related disasters are likely to become frequent in the long term. These disasters refer to the occurrence of floods, droughts and landslides due to excessive rainfall and strong winds [9]. Also, import dependence on crop products could rise for Southeast Asia in the coming decades. This effect is especially significant for Malaysia and Singapore [19].

Even though there exist great uncertainties in both the scientific projections and technical, social and economic aspects of climate change, some features can be identified. Within the framework of this paper, which has assessed climate change and vulnerability on agriculture based on GCM and DSSAT modeling, some future scenario impacts could be established. For example, evidences gathered indicate that rice yield could decline between 4.6%-6.1% per 1°C temperature increase under the 400-800 CO_2 (ppm) concentrations level and this can, in turn, lead to negative changes in yearly earnings (RM) for rice cultivation by up to RM 1,380.06. However doubling of CO_2 (ppm) concentrations (from present level) do not offset farmers' earnings. Therefore, there is a need to try to find out alternative relevant policy strategy (i.e. adaptation options) to reduce climate change related vulnerability for Malaysian rice agriculture.

From the preceding analysis, it is also possible to conclude that government should follow three broad instruments such as (i) management related instruments (ii) infrastructure related instruments and (iii) community (CBOs and NGOs) initiated instruments for long-term policy strategy; but there would be provision in which policy implementation could be change in order to meet unforeseen circumstance. Now the time has come for rethinking about the environmental concern in every step of economic development. Projections of climate change impacts on rice cultivation and farmers earnings variation for the year 2060 made by this study are analytically important for rethinking policy-makers for the 10th Malaysian Development Plan (2011-2015) with environmental care and social responsibility in mind. Our intension is to show the potential path for planning strategies to reduce vulnerabilities and to unearth prioritizing requirements for Malaysian future agriculture. This study and the experiences deriving from it can be used for Malaysian long-term climate related agriculture policy.

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