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Full Length Research Paper

Policy challenges towards potential climate change impacts: In search of agro-climate stability

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This study focuses on climate-related vulnerability for Malaysian agriculture. We use an analysis of impacts based on observational records of inter-annual variability in precipitation and warming climatic factors. The assessment involved General Circulation Models (GCMs) together with the Stern Review study to represent a range of plausible climate scenarios and economic outcomes. This study investigates the major Malaysian agricultural sectors such as food crops (that is, rice) and cash or industrial crops (i.e. palm oil and rubber) under a climatic and economic perspective, quantifying the merits of the projected simulation and presenting an insight into the nature of the overall subject of suitability of adaptation options. These analyses signify the likely future changes to agriculture, potential strategies to reduce vulnerabilities and reveal adaptation requirements for agriculture. The findings of this study can be used for climate-related national policy on agriculture in Malaysia.

Key words: Climate change, agriculture, environment, impacts, policy challenges.

INTRODUCTION

Agriculture practice and climate are generally seen to be connected with each other in a circular way. Climate change most significantly affects agriculture out of all other economic sectors because of its wide distribution and the strong link with and dependence on the climate and environmental factors (Baharuddin, 2007). Thus, the effects of climate change on agricultural production impact the socioeconomic dimension at both the macro- and microscale (MDP, 2006). Under the recent Malaysian climate change scenario, the direct impacts to agriculture are classified as: (a) a decrease in agricultural productivity; (b) an increase in food insecurity; (c) a rise in the air and water temperatures, reducing plant efficiency and power output and leading to major economical costs; (d) geographic distribution limits and yield crops modified due to changes in precipitation, temperature, cloud cover and increases in CO2 concentrations (Al-Amin et al., 2010).

The Malaysian rate of change in CO_2 emissions is very fast: the difference in growth between 2003 and 2005 when compared to 1994 and 1996 is an increase of 70% (Baharuddin, 2007). The development rates of agriculture crops accelerate in response to an increase in CO_2 concentration from 400 to 800 ppm with standard temperature (<26℃). But with the increasing temperature above the tolerance limit (>26℃) and CO_2 variation, photosynthesis is reduced, respiration increases, the vegetation and grain-filling periods are shortened and ultimately overall Malaysian agriculture yields decrease (Chamhuri et al., 2009). The available policies are essentially ways of preventing these issues. Either mitigation policies or adaptation strategies can be adopted, such as building capacity to identify climate change risks, strengthening to monitor the impacts on regional climate, downscaling global climate models, developing impact scenarios and finally building adaptive capacity to reduce vulnerability.

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Climate change mitigation measures are obviously very necessary to offset the negative impacts for long-term policy. Now the question arises: how can we resolve our climate change issues following mitigation and adaptation strategy? What is the best possible option for preventing climate change issues? Effective frameworks or cost-effective choices to tackle climate change concerns are generally lacking in Malaysia. There are no specific public documents addressing potential preventive measures for agriculture. We believe that climate change issues are the most important challenges for future generations. In this study we try to figure out two specific challenges, i.e. appropriate arguments for mitigation strategies following economic analysis, and evaluate the adaptation options for agriculture with the adaptation challenges at national level. Here, an analysis of the impacts of climate change and vulnerabilities is performed, based on General Circulation Models (GCMs) together with the Stern Review (Stern, 2007), to represent a range of plausible climate scenarios and outcomes. This study investigates the major Malaysian agricultural sectors under a climatic and economic perspective, quantifying the merits of the projected simulation, and presents an insight into the nature of the overall subject of suitability of adaptation options.

MATERIALS AND METHODS

In this study we use several approaches to identify the outcomes. Firstly, our assessment involves the use of computer simulations based on General Circulation Models (GCMs) to see the virtual outcomes of climate change issues in agriculture. Our modelling and mathematical approach followed the studies by Lobell et al. (2008) and Tilman et al. (2002). The approach utilised in this study is a bottom-up approach, focusing on the vulnerability of Malaysian agriculture. We considered a wide range of potential climate change outcomes such as temperature rise, rainfall fluctuations and carbon concentrations. Our modelling framework synthesises essential components, detailed agronomic-based knowledge, and future crop production potentials.

Although the GCMs simulate large-scale circulation relatively well, except for some constraints on regional exercises, we utilised empirical downscaling models (EDMs) and temperature coefficients between 20 and 40℃ that map the observed large-scale vulnerability on Malaysia for the year 2060. Temperature and rainfall variations derived from the historical records of annual mean temperature and rainfall fluctuations relative to 1990-1999 are superimposed on the annual cycle of precipitation, and then we apply EDMs to projected changes in the large-scale variation forces by following different concentrations of greenhouse gases (CO2/parts particulate matters; 400 - 800 ppm) to produce an 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, temperature and variability of climatic factors on Malaysia. A more detailed modelling and mathematical approach can be found in supplementary materials (Lobell et al., 2008; Tilman et al., 2002; Gunther et al., 2005).

Secondly, we considered climate change mitigation options (that is, greenhouse gas (GHG) impacts) to identify the potential outcomes following the formula: $\delta = \rho + \eta g$, which is discussed by Sir Nicolas Stern in his study of the economics of climate change (Stern, 2007), where ρ is the social rate (percentage change) of time preference, g is the projected growth rate (percentage change) of average consumption for any time periods and η is elasticity of social weight for any economy followed by damage function. The values of ρ is the social rate of time preference, can take positive numbers following on the value of η such as η ~1, 2, 3…so on. Here we utilized discount rate based on Malaysian capital accumulation based on net present value which is discussed details by Sir Nicolas Stern (Stern 2007). The discount rate can take any positive/negative numbers such as ±1, 2,.….so on. However based on the degree and relative magnitudes of each variables (that is, ~1, 2, 3…) and values surrounds for the time preferences (that is, from 2010 to 2099) and discount values generate mostly similar potential outcome on δ. The damage function we used exactly followed Stern, (2007). Finally, we used a simple regression approach, that is, $\Delta Yield = m + y_m \Delta CChange + \varepsilon$, to see the adaptation option in agriculture, where $\Delta Yield$ indicates the agricultural impact of climate change, $\Delta CChange$ is a climate change scenario, y_m is the climate change adaptation option, m is the average yield change with current management option and ε is the statistical error terms.

RESULTS

The results specifically indicate that temperature fluctuations between 0.3 and 1.4℃ (Table 1), a variation of CO2 between 400 and 800 ppm and rainfall fluctuations between -32% and +14% reduce Malaysian rice, palm oil and rubber production and the earnings resulting from them. CO2 (ppm) concentrations play a far more significant role in rice yields compared to palm oil and rubber. For example, we find that with 0% rainfall fluctuation, the rise in CO2 from 400 to 800 ppm causes a positive effect on rice production from 7.202 – 10.962 kg/ha/yr over the next 40 - 45 years; with 0% rainfall fluctuation and a rise in CO_2 from 400 to 800 ppm, the effect on palm oil production is steady overall, but rainfall fluctuations cause production to decline from 26.00 tonnes/ha/yr to 14.30 tonnes/ha/yr. Similarly, with 0% rainfall fluctuation and a rise in CO2 from 400 to 800 ppm, rubber production is steady overall, but rainfall fluctuations cause production to decline from 2000.00 to 1520.00 kg/h/yr. Our simulations find that rice production is very sensitive both to rainfall and temperature fluctuations.

The mixed effects of climate change (rainfall, temperature, and carbon concentration) on palm oil and rubber mostly indicate declining trends (Table 2) over the 40 - 45-year periods, but significant impacts are made on rice cultivation. Our simulations find mostly negative trends of the mixed effects of climate change on rice. Rice yields may decline between 4.6 and 6.1% per 1℃ temperature increase (from the mean level: >26℃) under the present CO_2 concentration level, but a doubling in CO_2 concentration from 400 to 800 ppm offsets the detrimental effect of a temperature increase on rice

Table 1. Projected agricultural yields in 2060 (Rice: kg/ha/yr; Palm oil: tonnes/ha/yr; Rubber: kg/ha/yr) within climate variations.

Rice				Palm oil				Rubber			
CO_2 (ppm)	400	600	800	CO_2 (ppm)	400	600	800	CO_2 (ppm)	400	600	800
V temp (℃)*	0.30	1.40	0.40	V temp (℃)	0.40	1.40	0.40	V temp (℃)	0.60	1.40	0.40
V rainfall (%)				V rainfall (%)				V rainfall %			
0	10.962	10.402	9.642	0	26.0	26.0	26.0	0	2.000.0	2.000.0	2.000.0
14	8.619	8.059	7.499	14	24.0	24.0	24.0	32	1.400.0	1.400.0	1.400.0
7	9.834	9.274	8.714	7	25.0	25.0	25.0	15	1.580.0	1.580.0	1.580.0
-7	9.318	8.842	8.366	-7	19.2	19.2	18.7	-15	1.800.0	1.800.0	1.800.0
-14	7.454	7.073	6.693	-32	14.3	14.3	14.3	-32	1.600.0	1.600.0	1.520.0

Source: Authors' estimation based on NRS (2001); *Malaysian average standard temperature 26℃.

production. The findings are not paradoxical; these impacts are the offset of the detrimental effects of doubling CO_2 concentrations. The reasons are straightforward from a biophysical perspective. However, an increase in temperature above the tolerance limit (>26℃) and CO_2 variation reduces photosynthesis, increases respiration and shortens grain-filling periods, ultimately decreasing rice yields and farmers' earnings, which is well evident in Table 2.

A variation in temperature of 0.3 - 1.4℃ and rainfall variation of ±32% causes a negative change in earnings of up to RM1280.6/yr ($US1=RM3.2) in the rice sector in 2060. Carbon concentration (800 ppm) cannot play a major role here to offset the negative earnings from other climate change-related factors. However, cash crops such as palm oil and rubber are, on average, in a better position, but earnings trends are downward with extreme rainfall and temperature fluctuations. Here, a temperature variation of 0.6 -1.4℃ and ±15% rainfall variation cause a positive change in earnings for palm oil of up to RM9153.0/yr. However with ±32% rainfall fluctuation and moderate temperature fluctuation, earnings are reduced to RM4407.0/yr. On the other hand, a temperature variation of 0.6 -1.4℃ and ±15% rainfall variation also cause a positive change in earnings for rubber of up to RM6994.8/yr, but with rainfall fluctuation of ±32%, earnings are reduced to RM5440.4/yr (Table 2). The findings for rice, palm oil and rubber indicate that the variation of climate factors may mean that the agricultural system in Malaysia is more vulnerable. Gradual climate changes have had a measurable effect on Malaysian agricultural yields, meaning that Malaysia's future food economy may be insecure. Specifically, the gradual climate changes have had a measurable impact on Malaysian rice yields, with decreased rice productivity by 34.8%/ha^{-1}, making Malaysia's future food position insecure by 2060.

We therefore plotted a straightforward alternative option to identify the potential outcomes. We found virtual impacts on agricultural production of carbon concentration of 400 - 800 ppm in Tables 1 and 2. Our findings indicate that under 400 ppm and standard temperature (<26℃), projected agricultural yields (rice, palm oil and rubber) decline with unexpected rainfall fluctuations but obviously impacts better than extreme concentrations (800 ppm) in the overall reference scenarios. Therefore, we tried to investigate how much GDP cost in Malaysia must be incurred to limit CO_2 concentration by 550 ppm. Specifically, we considered a mitigation argument to limit carbon concentration to 550 ppm using: $\delta = \rho + g\eta$ for climate change prevention, which is discussed by Sir Nicolas Stern. We consider climate change (carbon concentration and CO_2 emissions) to be a public good (inferior) par excellence and the relative magnitudes of time preferences (that is, n~1) as followed by the Stern Review (Stern, 2007).

Based on a Malaysian growth rate of 4 - 5% per annum, relevant assumptions of ρ and η, following the climate change scenarios by MMD (2009) and NAHRIM (2006), we found that the average benefit of mitigating climate change issues is justified as the increase in growth rate (GDP) from the current level to 2060 differed by more than 1.3% per year, since the present value of benefits (with an increase in the GDP growth rate of over 1.5%) exceeds the present value of the costs for mitigating GHG (from the 1% permanent reduction in the level of the GDP). There has been much criticism about the value of social rate (ρ) of time preference in the economics of climate change. However, for intervention to keep CO_2 levels within bounds (400 - 550 ppm), the Stern approach is adequately strong whether ρ can take value more than 1 as to be insensitive to the dispute about the value. A straightforward calculation shows that mitigation is better than business as usual, and Malaysia would be better off in the long-run scenario, as negative impacts can be avoided by incurring a relatively modest cost today.

DISCUSSION

Together with GCM modelling, this study considers two supplementary mathematical techniques, namely $\delta = \rho + \eta g$ and $\Delta Yield = m + y_m \Delta CChange + \varepsilon$, to identify

Table 2. Earning impacts (RM/yr) for projected climate change.

Rice/Year 2060				**Palm oil/Year 2060**				**Rubber/Year 2060**			
CO_2 (ppm)	**400**	**600**	**800**	**CO_2 (ppm)**	**400**	**600**	**800**	**CO_2 (ppm)**	**400**	**600**	**800**
V temp (°C)	**0.30**	**1.40**	**0.40**	**V temp (°C)**	**0.60**	**1.40**	**0.40**	**V temp(°C)**	**0.60**	**1.40**	**0.40**
V rainfall (%)				**V rainfall (%)**				**V rainfall %**			
0%	0	0	0	0	8.814.0	8.814.0	8.814.0	0	7.772.0	7.772.0	7.772.0
32%	-922.1	-922.1	-922.1	32	8.814.0	8.814.0	8.814.0	32	5.440.4	5.440.4	5.440.4
15%	-443.9	-443.9	-443.9	15	9.153.0	9.153.0	8.814.0	15	6.139.9	6.139.9	6.139.9
-15%	-647.0	-614.0	-580.9	-15	6.102.0	6.102.0	5.198.0	-15	6.994.8	6.917.1	6.683.9
-32%	-1380.6	-1323.7	-1239.3	-32	4.847.7	4.847.7	4.407.0	-32	6.217.6	6.217.6	5.906.7

Source: Authors' estimation; assumption on standard grade = RM 110.00/100 kg, normal grade = RM 100/100 kg; Palm oil fresh fruit bunch = RM 400.00/metric tonne; Rubber = 3.90/kg.

climate change impacts on Malaysian agriculture. How much GDP will be incurred at national level for climate change issues is reflected in δ =ρ + ηg and how much crop yields (i.e. parts of GDP) will be affected in the sectoral level by climate change issues is reflected in $\Delta Yield = m + y_m \Delta CChange + \varepsilon$. We passionately assert that the obtainable policies are fundamentally ways of averting climate change issues, these are firmly correlated with δ =ρ + ηg and $\Delta Yield = m + y_m \Delta CChange + \varepsilon$. They can be espoused by mitigation or adaptation options. However, both of the two effective factors depend on a set of adaptive capacities in a region that involves the potential ability to adapt with cost-effective policy, building capacity to identify climate change risks. Adapting to future risk sometimes raises interest and is judged to be more important for long-term policy, as climate change is a global problem.

Mitigation measures require global integration by multilateral agreements and that is a long political and intellectual process. Sometimes mitigation policies are mostly disputable due to disagreement globally which is obvious in Bali or post-Kyoto agreements (Al-Amin et al., 2010). In view of strong arguments for adopting long-term climate change policy, Malaysia favours adaptation strategy in agriculture for preventing climate change magnitudes, but the choice of strategy is a subject of suitability and its factors. These fundamental factors are considered as (a) building capacity to identify climate change risks, (b) identify adaptation options based on priorities, (c) resource requirements to implement adaptation and (d) new technology. The perfect strategy must achieve not only efficiency within the market but must also be cost effective. How could Malaysia achieve the best possible adaptation options following the subject of suitability? We try to investigate that with regard to influence on decision and examining the overall subject of suitability of adaptation options, (y_m) using $\Delta Yield = m + y_m \Delta CChange + \varepsilon$ techniques. The basic climate change-related variables we consider in our investigation include building capacity to identify climate change risks, identify adaptation options based on priorities and resource requirements to implement adaptation in agriculture. These variables can easily be improved by 10 -11% with long-term capacity building. Within the additional adaptive strategy by 10 -11% of each instrument, our simple statistical results indicate ($p<0.001$) that between 0.3 and 0.8°C of temperature and below a CO_2 concentration of 400 - 800 ppm, with a certain level of rainfall fluctuation, climate change-related declines in agricultural yields trends, which can be found in Tables 1 and 2, can be fully offset by 18 - 20% by 2060. A straightforward calculation shows that adaptation strategy is better than a business-as-usual policy, and Malaysia would be better off in the long run. Although there are some doubts about the strategies on adaptation, both in terms of social and economic aspects, and even in the scenario results, simple calculations ensure that adaptation responses must be integrated into planning. The cost-effective implementation measures are particularly essential for long-term development in Malaysia.

Conclusion

Climate change impacts in Malaysian agriculture are well evident and the issues are now reality. Malaysia realises the consequence of climate change impacts at a national level and efforts are harmonising with those of national interests. The available policies that Malaysia is looking for to prevent climate change impacts are either those which can be adopted by mitigation policies or adaptation strategies. In this study we investigated both options using some well-known mathematical approaches. The findings are quite appealing in the scenario projections for long-term vision. Our projections indicate that climate change impacts reduce Malaysian staple agricultural production and yearly earnings (Tables 1 and 2). We realise the importance of limiting carbon concentration levels within bounds, as they are the main sources of GHG emissions and climate change issues. We draw attention to adaptation options in agriculture and included some findings and figures to support our adaptation strategies.

Specifically, in this study we fully investigated policy challenges towards potential climate change impacts for agro climate stability and we quantified potential climate change impacts on specific major agricultural sectors such as food crops (that is, rice) and cash or industrial crops (that is, palm oil and rubber) under a climatic and economic perspective. Here, for the first time we signify the likely future changes to agriculture, potential strategies to reduce vulnerabilities and unearth adaptation requirements for selected agricultural sectors in Malaysia. In this study we also investigated the importance of adaptation options. We fervently assert that the obtainable policies of averting climate change problems justified our visualisation by mitigation or adaptation options which have never been investigated simultaneously for the Malaysian economy.

This study has come up with analytical justification in the current climate changes issues and based on our analysis, arguments are quite appealing for future agriculture, especially for the year 2060.

The novelty of our study is to show policy makers the consequence of climate change impacts at the national level and possible ways of preventing climate change magnitudes, particularly focusing on major agricultural sectors such as food crops (that is, rice) and cash or industrial crops (that is, palm oil and rubber). Although there are some doubts in the strategies on both mitigation and adaptation options in terms of the technical and economic aspects, they ensure that adaptation and mitigation responses are included in long-term development planning. Adaptation, in particular, is a very favourable option in agriculture as it needs local initiatives on building capacity to identify climate change risks. The time has come to rethink future climate change issues, and effective initiatives in national policy are required in Malaysia.

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REFERENCES

Al-Amin AQ, Jaafar AH, Azam MN, Kari F, Syed OS (2010). Climate change issues and Malaysian initiatives, in Climate Change Governance, Walter Leal Filho and Jörg Knieling eds, Springer, Netherlands (2010: In Press).

Baharuddin MK (2007). Climate Change: Its effects on the agricultural sector in Malaysia, in National Seminar on Socio-Economic Impacts of Extreme Weather and Climate Change, 21–22 June, Malaysia.

Chamhuri S, Alam M, Murad W, Al-Amin AQ (2009). Climate Change, Agricultural Sustainability, Food Security and Poverty in Malaysia. IRBRP, 5(6): 309-321.

Gunther FS, Mahendra N, Francesco T, Velhuizen H (2005). Socio-economic and climate change impacts on Agriculture: an intergraded assessment, 1990–2080. Phil. Trans. R. Soc. B., 360: 2067-2083.

Lobell DB, Burke MB, Tebaldi C, Mastrandrea MD, Falcon WF, Naylor RL (2008). “Prioritizing climate change adaptation needs for food security in 2030”, Science, 319: 607-610.

MDP (2006). Ninth Malaysia Plan, 2006-2010. Economic Planning Unit, Prime Minister’s Department, Putrajaya, Malaysia.

MMD (2009). Scientific report: climate change scenarios for Malaysia 2001-2009. Malaysian Metrological Department, Malaysia.

NAHRIM (2006). Final Report: Study of the Impact of Climate Change on the hydrologic Regime and Water Resources of Peninsular Malaysia. National Hydraulic Research Institute of Malaysia (NAHRIM) and California Hydrologic Research Laboratory (CHRL), Ministry of Natural resources and Environment, Kuala Lumpur, Malaysia.

NRS (2001). National Response Strategies to Climate Change. Ministry of Science, Technology and the Environment, Putrajaya, Malaysia.

Stern N (2007). The Economics of Climate Change: The Stern Review, Cambridge University Press.

Tilman D, Cassman KG, Matson P, Naylor R, Polasky S (2002). Agricultural sustainability and intensive production practices, Nature, 418: 671–676.