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Agricultural Vulnerability and Adaptation to Climatic Changes in Malaysia: Review on Paddy Sector

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ABSTRACT

Climate change has mixed impacts on agriculture and the impacts are different in terms of areas, periods and crops. The changing factors of climate have been exerting strong negative impacts on Malaysian agriculture, which is apprehended to result in shortages of water and other resources for long term, worsening soil condition, disease and pest outbreaks on crops and livestock, sea-level rise, and so on. Due to climate change, agricultural productivity and profitability is declining. Despite continuous increases of government subsidy, area of paddy plantation is decreasing and the adaption practices are ineffective. As climate change is universal and its existence is indefinite, the farmers need to adapt to and find ways to mitigate the damages of climatic variation in order to sustain agricultural productivity and attain food security for them.

Key words: Climate Change, Agriculture, Food Security, Sustainability, Adaptation, Mitigation, Vulnerability, Malaysia.

INTRODUCTION

The changing patterns of climate factors adversely affect the social, economic and environmental agents all over the world. The agriculture is fully dependent on the factors of climate and consequences of climate change are of adverse impacts on agriculture and agriculture relevant stakeholders. Among all the stakeholders, farmer community is the most affected and risk group due to their full dependency on agriculture.

The climatic factors as expressed by the amount of rainfall, sunshine hours, temperature, relative humidity and length of the drought period result in year-to-year and area-to-area variability of crop production. Variability of production unit causes indirect impacts on the social and economic status of the livelihood of farming community along with several direct impacts- e.g. health hazards, frequent sickness etc.

The impacts of climate change are not limited to any geographical boundary or timeframe. Some of the aspects are long term and related to national or international security such as, soil erosion, chemical poisoning or nuclear waste (Daly and Cobb, 1990), and some issues are related to daily quality of life such as, water pollution, shortage of food or resources (Homer-Dixon, 1992; Alam *et al.,* 2011d). The combined effects of these issues are difficult to predict such as, natural and environmental catastrophes in recent times- floods, landslides, long periods of drought etc (United Nations, 1997), and these cause vulnerability in terms of yield, farm profitability, regional economy and hunger (Reilly, 1999; Schimmelpfenning *et al.,* 1996; Siwer *et al.,* 2009).

Several impacts of climate change affect various sectors, regions and factors in different ways (Klein *et al.,* 2005). Agricultural sector dominates the economies of 25% of the world's countries, where half of the world's workforce is currently employed. Due to the climate change the agricultural sector is vulnerable in terms of productivity and economic benefits. This paper provides a brief review on the global and Malaysian perspective of climate change, and its impacts on Malaysian agriculture and relevant adaptation practices, and policy recommendations for better coping with the changing nature of climatic factors.

Global scenario of climate change

Due to increasing atmospheric concentration of carbon dioxide and other trace gases, since the beginning of the 1980s, many climatologists predicted significant global warming in the coming decades. The Intergovernmental Panel on Climate Change (IPCC) was established in 1988 by the United Nations Environmental Programme (UNEP) and the World Meteorological Organization (WMO) to assess the scientific, technical and socioeconomic information relevant for the understanding of human induced climate change, its potential impacts and options for mitigation and adaptation.

National Academy of Science (2001) found trends of increasing average temperature and more volatile rainfall patterns. IPCC report 2007 shows further scientific evidence that the world's climate systems are changing faster than predicted, raising the likelihood of more rapid and damaging changes. It also motions 90-95% likelihood that changes in modern climate have been caused by human actions (Figure 1).

According to the Third Assessment Report of IPCC (2001), if the levels of emissions are not reduced, the global average temperature will increase by 1.4°C to 5.8°C between 1990 and 2100. Another projection pointed to an increase in the average global temperature of 2.4ºC between 1990 and 2100, with 95% chance that the change will be between 1.0ºC and 4.9ºC (Webster *et al.,* 2002). Other studies have estimated that the average global temperature is likely to rise by between 0.3ºC and 1.3ºC during the next 30 years (Zwiers, 2002).

The warming to a great extent, during the next 30 years, will be due to emissions that have already occurred. Over the longer term, the degree and pace of warming depends mainly on current and near future emissions. There is more than 50% chance that in the longer term the temperature rise would exceed 5°C. Due to the climate change impacts, the amount of 5% of the global GDP, which is regionally going up to even 20%, is expected to amount at annual loss in future (Stern, 2007: iv).

Different behaviors of climate factors were found by different studies based on place and time differences. Average precipitation is expected to increase globally (IPCC, 2001), but the magnitude of regional precipitation changes as well as varies among models: with the range 0-50% where the direction of change is strongly indicated, and around -30 to +30% where it is not. For some areas, it shows a positive trend in the daily intensity and a tendency toward higher frequencies of extreme rainfall in the last few decades (Houghton *et al.,* 1996). Among them, the main areas where significant positive trends have been observed are USA (Karl *et al.,* 1995; Trenberth, 1998; Kunkel *et al.,* 1999), eastern and north-eastern Australia (Suppiah and Hennessey, 1998; Plummer *et al.,* 1999), South Africa (Mason *et al.,* 1999), UK (Osborn *et al.,* 2000), and northern and central Italy (Brunetti *et al.,* 2000, 2001).

Fuhrer *et al.,* (2006) reviewed on Europe that both rain-day frequency and intensity during winter increases to the north (about 45°N), while the rain-day frequency decreases to the south. This is also consistent with increases of mean winter precipitation by 10 to 30% over most of the central and northern Europe, and decreases over the Mediterranean. In summer, the most notable change is strong decreases in the frequency of wet days, for instance to about half in the Mediterranean, along with a 20 to 50% decrease of mean summer precipitation. In the tropics, models show an increase in Africa, a small increase in South America, but no change in Southeast Asia. Summer precipitation is expected to decrease in the Mediterranean-basin and in regions of Central America and north-western Europe. Bonaccorso *et al.,* (2005) analyzed the trends of annual maximum rainfall series of Mediterranean areas and found different behavior patterns based on the different time scales, particularly shorter duration series shows increasing trends and longer duration series shows decreasing trends. In most cases when there is a positive trend in rainfall intensity, an increase in total precipitation has also been observed (Groisman *et al.,* 1999). However this relationship is not universal. Observation shows that there is an increase in heavy precipitation in some areas (i. e. Italy) with a tendency toward a decrease in total precipitation (Brunetti *et al.,* 2001).

The costs costs due to impacts of climate change have already been tried to point out by different institutions (WBGU 2003: 17; Stern 2007: iv). The joint research centre PESETA of the EC has calculated the costs in 1995 arising from sea level rise with and without adaptation measures by 2020 and 2080 (Commission of the European Communities, 2007: 10). Oxfam estimates that adaptation in developing countries will cost at least USD $50–$80 billion each year, based on the estimation from the World Bank, Stern and IPCC (Raworth, 2007). The costs of adapting existing urban water infrastructure in Africa alone have been estimated at USD $1.05–$2.65 billion annually, excluding the cost of rehabilitating deficient infrastructure. In Africa, the costs of climate-proofing new development are also likely to rise by USD $1–$2.55 billion a year (Muller, 2007).

The IPCC mentioned Africa as one of the most continents vulnerable to climate change (Boko *et al.,* 2007). Very few parts of Africa will be benefited from a rising temperature, unlike some parts of the northern hemisphere (Canada, Japan, Russia). The UN Framework Convention on Climate Change (UNFCCC) identifies a list of 49 Least Developed Countries (LDCs), which are at high risk from climate change, and out of these countries at stake, 33 are located in Africa. A study analyzed that due to climate change, Southern Africa will lose more than 30% of its main crop, maize, by 2030, and Asia, especially South Asia and South East Asia will lose top 10% of many regional staples, such as rice, millet and maize (Lobell *et al.,* 2008)

All of the projections of the future climate change are based on the extrapolation of current trends with logical assumptions about future emissions of greenhouse gases, prospective economic and industrial growth, population growth, technological progress etc., which are not phenomenon for any particular country , rather they are global concern.

Climate change in malaysia

According to the United Nations Development Report, carbon dioxide emissions in Malaysia increased by 221% during the period of 1990 to 2004, and the country is included in the list of 30 biggest greenhouse gas emitters. Curb Global Warming (2007) quoted from the Associated Press (AP) that rapid growth in emissions has occurred even though Malaysia ratified the Kyoto Protocol and has taken several initiatives to use renewable energy as well as ways to cut emissions. Currently Malaysia ranks as the 26th largest greenhouse gas emitter in the world with a population of about 27 million, and it appears likely to move up the list quickly due to the growth rate of emissions.

Due to high greenhouse gas emissions, the temperature is projected to rise by 0.3°C to 4.5°C. Warmer temperature will cause a rise in sea level about 95cm over hundred periods. The changes in rainfall may fluctuate from about -30% to +30%. This change will reduce crop yield and and will cause drought in many areas with a consequence that cultivation of some crops such as rubber, oil palm and cocoa will not be possible (MOSTE, 2001). Table 1 shows the projection of positive rainfall changes by 2050 in few areas of Malaysia. The projection shows maximum monthly precipitation will increase up to 51% in Pahang, Kelantan and Terengganu, while minimum precipitation decreases between 32% to 61% for all over Peninsular Malaysia. Consequently, annual rainfall will increase up to 10% in Kelantan, Terengganu, Pahang and North West Coast, and decrease up to 5% in Selangor and Johor (NAHRIM, 2006). This variation of climate factors will make the agricultural system vulnerable in Malaysia.

Climate change and malaysian agriculture

The global effect of climate change on agricultural production is minimum to moderate, where regional impacts are significant for many areas. Regional variations in gains and losses result in a slight overall changes in world cereal grain productivity.

Some studies addressed climate change impacts on rice yields, which vary greatly, in South and Southeast Asia (Matthews *et al.,* 1994a, 1994b). Climatic impacts on agriculture span a wide range depending on the climate scenario, geographical scope, and study. While large changes were predicted for China, to a certain extent warming would be beneficial with yield increasing due to diversification of cropping systems. In case of Japan, the positive effects of CO_2 on rice yields would be generally more than offset any negative climatic effects (MOSTE, 2001).

Under current climate change scenario, temperature above 25°C may decline grain mass of 4.4% per 1°C rise (Tashiro and Wardlaw, 1989), and grain yield may decline as much as 9.6%-10.0% per 1°C rise (Baker and Allen, 1993), where average temperature in rice growing areas in Malaysia is about 26°C. Singh *et al.,* (1996) mentioned that the actual farm yields of rice in Malaysia vary from 3-5 tons per hectare, where potential yield is 7.2 tons. It also mentioned that a decline of rice yield between 4.6%-6.1% per 1°C temperature increases under the present CO_2 level, but a doubling of CO_2 concentration (from present level 340ppm to 680ppm) may offset the detrimental effect of 4°C temperature increase on rice production in Malaysia. In a recent study it is found that a 1% increase in temperature leads to a 3.44% decrease in current paddy yield and 0.03% decrease in paddy yield in next season; and a 1% increase in rainfall leads to 0.12% decrease in current paddy yield and 0.21% decrease of paddy yield in next season (Alam *et al.,* 2010a).

Tisdell (1996) mentioned that rainfall variability increases the level of environmental stress that affects the capability of the system to maintain productivity. The projection of paddy yield in the country shows that any positive or negative variation of above 0.4% in both rainfall and temperature will decrease the yield of paddy production by 2020 (Table 2). When considering a positive or negative variation of above 0.7% in both rainfall and temperature by 2040, paddy yield tends to decline further and this negative trend of paddy yield is expected to continue by the year 2060, considering the variation (±) of above 1%. These clearly indicate a very high level of vulnerability of paddy productivity due to the climatic variation in the next couple of decades. This indicates that climate change has an adverse impact on agriculture in Malaysia.

Alam *et al.,* (2011a) indicate that the yearly total rainfall is increasing and its monthly variation is too high. The adverse effects of lower rainfall can be reduced or averted by introducing proper irrigation system. But the effect of the opposite phenomenon of over rainfall especially at the end of the crop cycle or at the maturity period is absolutely uncontrollable.

The climatic change causes change in several agriculture relevant factors that determine the sustainability of agricultural production. Farmers believe that vulnerability of some of the factors like injurious insects (supported by 42.9% of the farmers), temperature (supports by 58.6% of the farmers), soil fertility loss (supports by 49.5% of the farmers), cost of inputs (supports by 61.1% of the farmers), shortage of rainfall (supports by 45.5% of the farmers), excessive rainfall (supports by 35.9% farmers) increased over the last 5 years (Alam *et al.,* 2011b). Due to the climate change impacts on agriculture, the projections of NAHRIM of paddy yield in terms of climate change, in a given level of temperature and CO_2 level, shows more than 0.4% variation of rainfall by 2020 and will cause a fall in paddy yield in Malaysia (NAHRIM 2006). Therefore the agricultural sustainability in the future in Malaysia is projected to be vulnerable due to climatic changes.

Agricultural adaptation

Farmers' adaptation practices to cope with the agricultural vulnerability due to climatic change are not found adequate and satisfactory (Alam *et al.,* 2011c, 2012a,c). Their adaptation methods are based only on their ideas or reactions. As a result, only 30.3% farmers believe that they have been able to properly cope with climatic vulnerabilities (Alam *et al.,* 2012d).

On the issue of availability of external supports, most of the farmers were not found aware

Table 1: Future Rainfall and Temperature Change Projections in Peninsular Malaysia by 2050

Area	**Projected Change* in Maximum Monthly Value**	
Regions/Sub-regions/states	**Temperature (^{0}C)**	**Rainfall (%)**
North East Region -Terengganu, Kelantan, Northeast- coast	+1.88	+ 32.8
North West Region-Perlis (west coast), Perak, Kedah	+1.80	+ 6.2
Central Region-Klang, Selangor, Pahang	+1.38	+ 8.0
Southern Region-Johor, Southern Peninsula	+1.74	+ 2.9

* Difference = Average 2025-2034 & 2041-2050 minus Average 1984-1993

Source: NAHRIM, 2006

Table 2: Projection of Paddy Yield (Kg/Ha) with Different Variations of Temperature and Rainfall at Certain Level of CO_2

	Year 2020*				**Year 2040^**				**Year 2060~**		
Variation in Rainfall	**Variation in Temperature (^{0}C)**			**Variation in Rainfall**	**Variation in Temperature (^{0}C)**			**Variation in Rainfall**	**Variation in Temperature (^{0}C)**		
	0.3	**0.85**	**1.4**		**0.4**	**1.4**	**2.4**		**0.6**	**2**	**3.4**
14%	6,156	5,806	5,586	23%	7,342	6,942	6,542	32%	8,619	8,059	7,499
7%	6,646	6,306	6,086	11%	8,200	7,800	7,400	15%	9,834	9,274	8,714
0.4%	7,202	6,862	6,642	0.7%	9,042	8,642	8,242	1%	10,962	10,402	9,842
0%	7,202	6,862	6,642	0%	9,042	8,642	8,242	0%	10,962	10,402	9,642
0.4%	7,202	6,862	6,642	-0.7%	9,042	8,642	8,242	-1%	10,962	10,402	9,642
-7%	6,698	6,382	6,177	-11%	8,047	7,691	7,335	-15%	9,318	8,842	8,366
-14%	6,194	5,901	5,712	-23%	6,962	6,654	6,346	-32%	7,454	7,073	6,693

*, ^, ~ indicates CO_2(ppm) level at 400, 600, and 800 respectively

Table 3: Government Subsidy (in MYR) for Paddy Sector in Malaysia

Items	**2004**	**2005**	**2006**	**2007**
Subsidy For Paddy Price	476,628,303	443,218,042	445,749,898	444,000,000
Paddy Fertilizers	186,744,867	178,072,073	396,393,001	261,677,743
Paddy Production Incentive	NA	NA	NA	67,563,904
Yield Increase Incentive	NA	NA	NA	85,434,620
Paddy Seed Help	NA	NA	NA	17,000,000
Diesel Subsidy Scheme	NA	NA	989,727,418	1,099,000,723
Petrol	NA	NA	45,413,959	69,461,384
Total Subsidy and Incentive	663,373,170	621,290,115	1,877,284,276	2,044,138,374

Note: NA means data were not found available.

of the current supports provided by external parties to adapt to climate change. But, in order to support the farmers to increase productivity and increase income, government's subsidy for agricultural sector is increasing each year (Table 3). Worth noting to mention that government of Malaysia currently provides huge amount of subsidy to the paddy producers to encourage paddy cultivation and to ensure more production for increasing the country's self-sufficiency level. The types and contents of these subsidies have been summarized below:

Input subsidy

12 beg (20 kg each) compound fertilizer and 4 beg (20kg each) urea fertilizer per hectare – worth MYR 400 and pesticide incentive MYR 200 per hectare.

Price Subsidy

Provided at the selling price – MYR 248.1 per ton.

Rice Production Incentive

Land preparation/plowing incentive – MYR 100 per hectare and organic fertilizer 100kg per hectare – worth MYR 140.

Yield Increase Incentive

Provided if producers (farmers) are able to produce 10 tons or more per hectare – MYR 650 per ton.

Free Supports

Free supports for irrigation, infrastructure, and water supply.

Source

Agriculture Statistical Handbook, 2008

The subsidies for urea and compound fertilizer have been continuing since 1979. The incentive for land preparation and using organic fertilizer has been continuing since 2007. Providing urea and compound fertilizer and pesticide incentive was introduced in 2008 and these supports are still continuing. Still farmers expect several types of external supports to cope properly with the changes in climatic factors. Among several types of expected new supports, farmers significantly believe moisture deficiency related innovations, crop development, cash incentive, infrastructural supports, and adjustment in wage, and leasing system are required to adapt to climate change (Alam *et al.,* 2012a).

Policy recommendation and conclusions

As climate change is a continuous and long term process, its effects and solutions are similarly time and effort consuming process. Most of the warming during the next 30 years will be due to emissions that have already occurred. Over the longer term, the degree and pace of warming mainly depend on current and near future emissions

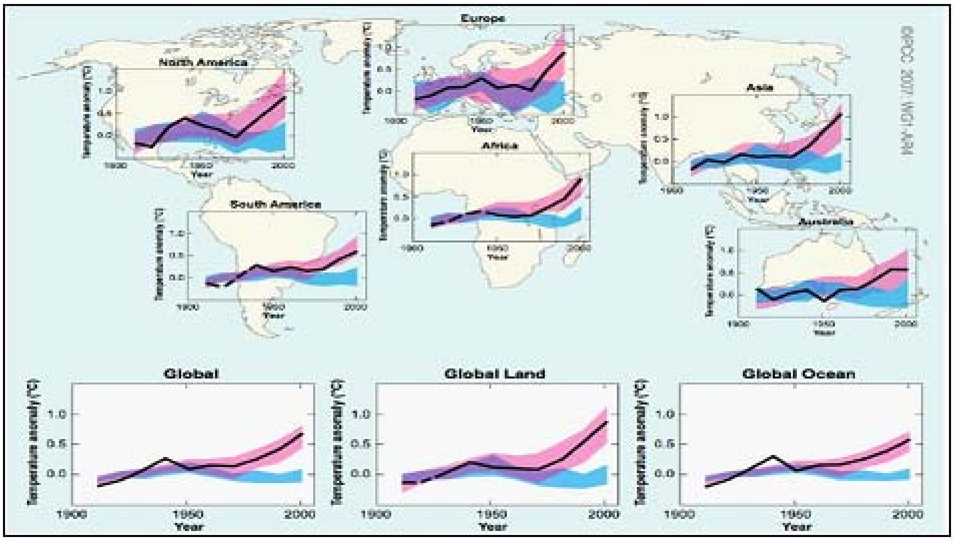

Fig. 1: Regional and Global Climate change from 1990 to 2000

(Stern, 2007). To adapt with climate change, conventionally, mitigation has received more attention than adaptation, both from a scientific and policy perspectives. Mitigation is the main way to prevent future impacts of climate change, and it will reduce the cost of adaptation. So, any delay in mitigation strategy to reduce emissions will increase the need and cost of adaptation, and increase the risk of being victim of global climate change. On the other hand, though adaptation is not a substitute of mitigation, there are arguments for adaptation to consider as a response measure. Mitigation actions never stop a certain degree of climate change due to historical emissions and the inertia of the climate system (IPCC, 2001). Moreover, mitigation effects may take several decades to manifest, where most adaptation activities take immediate effects. Adaptation reduces risks associated with current climate variability as well as addressing the risks associated with future climate changes, where mitigation only focuses on future risks. The measures of adaptation can be applied to a local scale or root level with the involvement of large number of stakeholders, where mitigation works in the decision making level. In the current world, climate factors are exogenous variables that are immitigable in a quick manner and as a consequence adaptation is the most appropriate way to cope with the system properly. It is therefore important to strike a balance between measures against the causes of climate change and measures to cope with its adverse effects (Stern, 2007; Pielke *et al.,* 2007).

In recent years, adaptation has gained prominence as an essential response measure, especially for vulnerable countries due to the fact that some impacts are now unavoidable in the short to medium term. Mitigation is necessary but adapting to future risk is more important. Immediate and long term actions are essential for various factors including government, development partners, research organizations, and community organizations. In fact, adaptation is too broad to attribute its costs clearly, because it needs to be undertaken at many levels, including at the household and community level, and many of these initiatives are self-funded (Stern, 2007). Options for agricultural adaptation can be grouped as technological developments, government programs, farm production practices, and farm financial management (Smith, 2002). So, it has been suggested to prepare a planned and proactive adaptation strategy to secure sound functioning of the economic, social and environmental system.

Government as the policy and law making authority has to play the most influential role to ensure climatic mitigation and adaptation at all levels (Alam *et al.,* 2010b, 2012b). It is the main responsibility of government to give enough supports in order to enable farmers to adapt to different climatic situations and to make them self-sufficient rather than subsidy dependent. Appropriate authorities also need to carefully define government's subsidy supports and incentive programmes to influence farm-level production, practices, and financial management. Hence, agricultural policies and investments need to be more strategic. But the government needs to define and ensure the compensation, minimum income protection, and insurance facility for the affected groups – individual farmer or farm. In the planning processes, policy makers need to account the barriers of adaptation including ecological, financial, institutional, and technological barriers, as well as information and cognitive hurdles. Other few important issues need to be focused, such as stakeholders may not sufficiently inform about the needs and possible strategies of climate change (Eisenack *et al.,* 2006, 2007), farm level faces uncertain future and hinders the development process, causes obstacle for implementation of adaptations policy (Behringer *et al.,* 2000; Brown *et al.,* 2007), and the policy deals with different conflicting interest groups. To avoid the negative impacts of climate changes on agriculture and to control pollutions and emissions in the sector, however, proper mitigation policies are urgently required for Malaysia. Further, Malaysian agriculture sector also needs to include mitigation policies due to the emission of commercial farming.

The issues of mitigation and adaptation to climate change concern all sectors as well as all levels of political, administrative, economic and everyday life. To better cope up, cooperation is necessary across countries, sectors and administrative levels. Relevant agencies need to be aware of the benefits of cooperation to gain long-term benefits instead of focusing only on short-term and individual interest. The production practices of farm and the knowledge of individual farmer also need to be updated with the changes of climate factors. The agricultural farmers should understand the crop rotation, crop portfolio, and crop substitutions. They should also take all precautions and be aware about the uncertainty of low rainfall and heavy rainfall. The financial management of agricultural farms must be efficient and the farmers must secure minimum two cropping seasons so that if crops damage in one season they will have the seeds for next season. This will help them bear the cost of another crop production and survive financially up to the time when new crops are collected. But this will make the farmers take initiative for crop sharing, forward rating, hedging, and insurance etc.

Different new groups of stakeholders also need to be engaged to ensure necessary facilities for the farmers. Financial institutions also need to be engaged more inclusively in order to provide supports of loan, insurance, saving schemes, hedging or future option, and so on to the agricultural farmers. Technological adaptation to climate change is also important to deal with the climatic problems in the long run. It is apparent that development of technology is a boundless area, but it is possible in several ways. The highest efficient method of technological advancement is expected to be able to solve the problem. Until gaining such level of technological advancement, there should be some alternative options which are expected to help the agricultural farmers in their effort to adapt to climate changes in the following ways:

To solve the problem

controlling the pattern of rainfall, sunshine, and moisture level.

To improve shielding resources

protecting crops from excessive rainfall or sunshine and solving water logging problems.

To develop defensive approach

development of varieties of crops, development of rainfall and temperature tolerant plants, and finding alternative crops and hybrids.

To find alternative approach

changing crop cycle and reducing the timing of crop cycle.

To provide information

providing weather forecast and early warning system and ensuring delivery of proper information at the farm level.

The impacts of climate change on agricultural sustainability vary from country to country, region to region and time to time. The yield and productivity of agricultural crops in Malaysia are proven to have been heavily influenced by climatic variations. Malaysia is the 26th largest greenhouse gas emitter which causes the expected rise of temperature by 0.3°C to 4.5°C, and rise in sea level is expected to be about 95cm over the time span of one hundred years. The changes in the country's rainfall fluctuate heavily from -30% to +30%. This change reduces crop yield and is prone to drought in many areas so that cultivation of some crops such as rubber, oil palm and cocoa becomes unfeasible. Current crop productivity is also affected by the climatic variations throughout the country as the actual farm yields of rice in Malaysia vary from 3-5 tons per hectare while the potential yield is 7.2 tons per hectare. The projection of climate change and its impacts on productivity and farmers' profitability are thus considered very alarming.

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