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Climate Variability and Socioeconomic Vulnerability of Aquaculture Farmers in Malaysia

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Abstract. The aquaculture sector has undergone significant transformation in increasing food security for the nation as well as enhancing Malaysian Economic growth. This sector is put under the consideration of the Third National Agricultural Policy (1998-2010) in order to become the major area of concentration in fisheries production to improve the competitiveness of agriculture sector in Malaysia. At the national level, the development of aquaculture sector serves to resolve the insufficient fish supply as the main protein source of the household and reduces the social problems such as poverty, malnutrition and income inequality of the aquaculture farmers. Although the physical and financial drivers play their roles well in enhancing this sector, the climate variability provides major challenges in sustaining future outlook of aquaculture sector. Furthermore, the climate fluctuation raises the socio-economic vulnerability to aquaculture farmers due to the high production cost and production loss. The major concern of this study is to identify the association between climate variability and socio-economic vulnerability of the aquaculture farmers. Primary data was obtained from 120 aquaculture farmers in Sarawak, Malaysia. The findings revealed that there is significant association between climate variability and production loss especially when the water temperature changes and there is pandemic disease outbreaks. However, all factors have small effect on the aquaculture production loss. From the farmers' view, other factor such as less dissolved oxygen, drought season, raining season and flood event were also factors that contributing to production loss. The results suggest that an effective and accurate adaptation strategy is needed to help aquaculture farmers cope with the climate variability impacts in their production.

Keywords: climate variability, socio-economic vulnerability, aquaculture sector, production loss.

1. Introduction

Malaysia's aquaculture sector development and growth since 1920's had helped to overcome the decreasing of fish stock due to over exploitation fishing activities in coastal area by the commercial fishery (Tan, 1998; CICS, 2000). The aquaculture industry promotes technological transformation and drove to the high market contribution by fulfilling the domestic demand for high protein resources and export demand of fish products. The performances help to sustain the national economic development as targeted by the government that is to achieve the growth of food production by 33.4% or 1.8 million metric tonnes for fisheries sector (Malaysia, 2008). With respect to socio-economic development, aquaculture sector is involved in improving food supply, create employment and increasing the farmers' income (Safa, 2004). Aquaculture activities help to reduce the poverty problem especially in rural areas although they are still practicing traditional aquaculture techniques (Edwards, 2000). The development of aquaculture activities in the rural area has benefited the farmers and the nearby community due to the increase allocation of infrastructure such as electricity, communication system and road access which improve their quality of life (Mohd. Fariduddin, 2006).

Climate variability is an environmental factor that is strongly associated to aquaculture productivity. Environmental and social aspects are important keys in ensuring sustainable and safe aquaculture production (Anon, 2003). In Malaysia, variance in temperature and precipitation, flood and drought seasons and water deterioration and stratification are events that indicate climate variability. The extreme patterns of climate

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events affect the rivers and ponds water quality and diseases outbreak bring to unconducive environment and threat to the fish survival. This leads to production risk which happened due to the vulnerable and volatile features of weather that affect the physical yield of crops and animals (Harwood, et. al., 1999; Westlund, et. al., 2007). The production risk contributes to the production loss and the vulnerability to the socio-economic aspects of farmers who majorly depend on the aquaculture resources. The climate change risk increases production cost in managing the farm efficiently (Sulit, et.al., 2005) and to minimize the production loss from the aquaculture farm. The rising cost of production and lack of support system in coping with production risk leads to financial and physical capital loss and poverty mostly for the small scale farmers (Heltberg, et. al., 2009). Moreover, the response of market to climate and production changes and the implications for prices, economic returns and sector investment will have major impacts on aquaculture sector performance, employment, food security and longer term development impact (Tol, et. al., 2004). The climate variability harms the community with the incidence of poverty, income risk, thrashing in common property rights and inefficiency in joint action and investment affects (Kelly and Adger, 1999).

The motivation of this study is to examine the effects of climate variability on aquaculture production and farmers' livelihood since only a few studies has been carried out in Malaysia. Much more studies need to be done to provide understanding of aquaculture vulnerability to climate change that able to recommend for prioritizing adaptive strategies (FAO, 2008). Moreover, the social dimension in climate change research help to improve the policy and practice in coping with the climate shocks (Adger and Kelly, 2000).

2. Socio-economic vulnerability to climate variability.

There are plenty of vulnerability definitions that are being emphasized by scholars in climate change studies. The Intergovernmental Panel on Climate Change (IPCC) Second Assessment Report defined vulnerability as the extent to which climate change may damage or harm a system due to the system's sensitivity (climate shocks and adaptive capability) to the new climatic conditions. Adger (2006) introduced the general concept of vulnerability as the interaction between few components known as exposure and sensitivity to shocks and the capacity to adapt. Exposure is a system occurrence to environmental stress; sensitivity is where system is customized or distress by anxieties towards the vulnerability; and adaptive capacity is the capability of system to go forward, to hold and cope with environmental problem and policy adjustment and to diversify the changes. The social vulnerability present the human dimension where focus on the capacity to anticipate, cope with, resist and recover from the impact of natural hazards where always together with exposure (Kelly and Adger, 2000; Burton et. al., 2002).

Liverman (1994) emphasizes that the vulnerability can be defined by understanding the biophysical conditions. The biophysical assessment shows the situation of environmental risk and exposure to production and people that vulnerable to the hazard. Smit et. al. (1999) verified that vulnerability in agriculture is influenced by the farm system, species of crops or animals, farm size, farmers' capability in investment, production practices and location. These are known as the exposure units that affect to the different vulnerability scales (Jones, 2001). In impact assessment, economic and social vulnerability are relevant in the process of performing the sensitivity analysis in physical systems where vulnerability level is formed by connection of core economic and social condition and energetic adjustment in both factors and physical environment. Social vulnerability can be individual vulnerability (focus to resources and income sources) or collective vulnerability (group contribution of institutional and market structure by allocating infrastructure and income) (Kelly and Adger, 1999). In assessing the impacts of climate variability to socioeconomics vulnerability, expected utility approach is useful in modelling behaviour under risk. Utility theory explains the acceptance of individual towards risk and measuring values by taking advantage of an individual's perception of risk. The farmers are allowed to use their subjective perception of probabilities to make decision (Ngathou, et. al., 2005).

Climate variability modifies the biophysical aspect and interacts with the social aspect in two conditions. The changes in price and quantity of the production raise the market damages. On the other side, it leads to welfare loss or the loss of biodiversity and ecosystem service known as non-market damages (Goulder and Pizer, 2006). The climate risk affects stress to groups and individuals as a results of social and environmental change that is vulnerable to food security, resource dependency and economic factors (Maciver and Dallmeier, 2000).

3. Methodology

The data was gathered from 120 aquaculture farmers in Sarawak, Malaysia. The respondents were farmers who practiced ponds and cages systems. This criterion is chosen based on their production linkage to the natural environment. The data was obtained through questionnaire with the assistance of face-to-face interview at their farm. The climate variability data was presented by decrease of water temperature (tempdec), increase of water temperature (tempinc), less dissolved oxygen (lessO2), drought season (drought), raining season (raining), flood event, pandemic disease (pandc) and non-pandemic disease (nonpandc). These climate and environmental indicators were based on the handbook of aquaculture practice prepared by the Department of Fisheries, Malaysia. The socioeconomic vulnerability was presented by production loss (prodloss). The Pearson's chi-square test was used to investigate the existence of relationship between climate variability with the production loss (Green and Salkind, 2008; Field, 2005) or whether the difference between the observed and expected frequencies is bigger than the expected by chance (Wheater and Cook, 2000). This technique is used to identify the adaptation option of farmers to climate change risk. The Chi-square can be calculated as;

$$X^2 = \frac{(O-E)^2}{E} \quad (1)$$

where, O is the observed (measured) value and E the expected (calculated) value.

4. Results and discussion

The significant result from table 1 indicated that there was an association between the production loss and the decrease of water temperature. The findings reflected the fact that when temperature of water decrease, about 8.2% of farmers (6 farmers) experience production loss and 91.8% (67 farmers) did not, whereas 100% or 47 farmers do not faced the decreasing water temperature problem and faced no loss in their production. The chi-square analyses revealed a significant association between the production losses of aquaculture to the decrease of water temperature, χ^2(1, N=120) = 4.066, p<.10. The similar significant result was shown by the association between production loss and the increase of water temperature. The result also showed that about 8.2% of farmers' experience loss in their production due to the increasing of water temperature. The remaining 91.8% of farmers experience loss due to other factor (not due to the increasing water temperature). The chi-squares result for the relationship between production loss and increase of water temperature is χ^2 (1, N=120) = 4.066, p<.10. The water temperature whether increase or decrease had small effect (V=.184) on production loss in aquaculture production.

The result shows that pandemic disease threat was significantly related to production loss in aquaculture where χ^2(1, N=120) = 8.671, p< .05. The result indicates that during the pandemic disease outbreak, 31.5% of the farmers' production was affected. On the other hand, the pandemic disease threat was not a reason for 68.5% of farmers who had losses in their production. While, 8.5% percent of the farmers experienced pandemic disease threat which however had not contributed to the loss of their production. Pandemic disease had small effect (V=.269) to production loss, slightly greater than temperature change. This association is in line with study done by World Bank (2010) that verifies the climate variability alludes to disease threat in aquaculture production. The fish will be more resilience in the range of temperature that fit with the species growth and help the fish become resistance to the disease (CICS, 2000).

Table 1 Chi-square Results

Characteristic		tempdec		tempinc		lessO_2		drought		raining		flood		pandc		nonpandc	
		NR	**R**	**NR**	**R**	**NR**	**R**	**NR**	**R**	**NR**	**R**	**NR**	**R**	**NR**	**R**	**NR**	**R**
Prodloss	**No Loss**	**47**	**0**	**47**	**0**	**23**	**24**	**42**	**5**	**43**	**4**	**36**	**11**	**43**	**4**	**45**	**2**
	Loss	**67**	**6**	**67**	**6**	**39**	**34**	**60**	**13**	**64**	**9**	**52**	**21**	**50**	**23**	**69**	**4**
	χ^2 value	**4.066***		**4.066***		**0.231**		**1.153**		**0.431**		**0.420**		**8.671****		**0.090**	

NR = no risk; R = risk

Note: * p<0.10
**p<0.05

The significant association between production loss and the decrease and increase of water temperature verify that climate indicators especially temperature is most influential in the aquaculture production. Water temperature affects the quantity of oxygen dissolved in the water, evaporation and aquaculture productivity directly (Kutty, 1987). The aquaculture species are growing dynamically in the minimum and maximum tolerance limit of temperature and survive in optimal temperature. However, rapid temperature variation will have a negative effect on the aquaculture species growth due to the less dissolved oxygen in the warm water. The change of temperature will change the feeding pattern, nutrient and growth of fish because it doubles the rate of metabolism, chemical reaction and oxygen consumption (Tidwell et. al., 1999). The fish will experience stress and disease threat when the temperature increases to the maximum tolerance or fluctuates suddenly. The modification of the biophysical condition due to the temperature will affect the loss of production or unproductive growth of fisheries. It will reduce the returns of aquaculture production to the farmers and increase the operation cost of the farm.

Although less dissolved oxygen, drought season, raining season, flood event and non-pandemic disease were not significantly associated to the production loss, some of these factors had been indicated by the farmers as the major influence factors to their production growth. This was supported by qualitative information given by the farmers during the interview session. Generally, from 120 aquaculture farmers, 58 farmers verified that less dissolved oxygen was identified as one of the production risks. Furthermore, 18 farmers informed that drought season affected the production and 32 farmers mentioned flood event influenced the production loss. According to the farmers, the long drought season and raining fluctuation implicated less dissolved oxygen problem to the river or pond water and the extreme raining pattern will result in massive flooding events to the farm area. Thus, farmers have to monitor the change of climate from time-to-time in order to prevent the production loss. In adapting to the raining season, the farmers who practiced brackish water cages aquaculture in Sarawak have to start their new cycle of production in the middle of the year. This strategy will help them minimize the production loss and ensure that the percentage of new fish stock rises successfully and survive in the massive raining season that occurs at year end. Besides, the ponds aquaculture farmers are adapted to the drought season by changing the ponds water frequently to avoid the water quality problems that may threaten the fish.

5. Conclusion

The study examines the association between climate variability and its impacts on socio-economic vulnerability in aquaculture sector in Sarawak Malaysia. The results verify that climate variability has a significant association with the aquaculture production loss. Water temperature and pandemic disease threat are the main significant factors that influence the aquaculture growth. However, the less oxygen dissolved, drought season, raining season, flood event and non-pandemic disease are indirect factors that have also contributed to the production loss. The aquaculture farmers' awareness towards the problems and the impacts of climate variability on their production has encouraged them to adapt to the climate risk through the minimal cost action. The findings suggest that further improvement is needed in setting up a more accurate adaptation strategy for coping with the possible effects of climate variability on the aquaculture farmers' production in Malaysia.

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