# Climate Change, Socio-economic and Production Linkages in East Malaysia Aquaculture Sector

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Abstract. Aquaculture sub-sector is the largest contributor to the development of the fisheries sector in Malaysia. Due to its potential and ability to enhance the national food production and resolve social problems in Malaysia, the government allocated substantial funds and planned many programmes related to aquaculture development. Climate change impact on aquaculture production is however uncontrollable and damaging to the aquaculture growth. This study is carried out with the objective of identifying the relationship between production, socio-economic and climate change risks in the aquaculture sector in Sarawak, East Malaysia. This research was conducted on 249 aquaculture ponds and cages farmers in Sarawak. To determine the relationship between all factors, cross-sectional multiple linear regression was employed by using socioeconomic and climate risks data. Socio-economic factors such as number of family members, variable cost and technology usage was found to significantly influence the aquaculture production. Hence, bivariate analysis was employed to indicate the relationship between volumes of annual aquaculture production with all climate change risks factors. The results revealed that increase of climate change risks events have low and significant relationship with decrease in aquaculture productivity. In addition, the qualitative information from the interviews did verify that decrease of dissolved oxygen in water, flood and drought events were common production risks to aquaculture in Sarawak. This study suggests adaptation and mitigation strategies need to be taken immediately to overcome the problem of climate change risks that may be increasing in the future.

**Keywords:** climate change, risk, socio-economic, production, aquaculture growth.

#### 1. Aquaculture Sector Growth in Malaysia

Aquaculture sector is one of the important sub-sectors in agricultural development in Malaysia. The sector is still developing compared to such sector in neighboring countries like Thailand and China. Aquaculture sector had been developed since 1920's in Peninsular Malaysia. It started off with the freshwater aquaculture and then brackish water aquaculture in the late 1930. While in Sabah and Sarawak (East Malaysia), the aquaculture sector had only started to grow in the early 1990's. Currently, there are three practices of Malaysia's aquaculture; the fresh water, brackish water and marine aquaculture.

The physical and financial drivers are two important aspects that have enhanced the competitiveness of aquaculture sector development in Malaysia. From 1998 to 2010, the aquaculture production in Malaysia has increased from 133,062 tonnes (3.9% of growth) to 500,000 tonnes (36.6% of growth). Starting from the year 2003, a lot of programmes have been announced and commenced by the government to enhance the potential of this sub-sector. The government invested and allocated a huge fund in order to improve and built good facilities especially in aquaculture industrial zone area. The underlying reasons are due to the important contribution of aquaculture sector in increasing national food production and to resolve the insufficient marine fisheries landings and optimal exploitation of marine fish (Malaysia, 2003; Malaysia, 2011). The contribution of aquaculture sector to Malaysia's GDP shows a positive improvement within the years. Aquaculture sector has contributed 0.283 in production value as percent of GDP in 2003 (Lungren et. al.,

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2006) and increased to 0.3666 in 2004 (Sugiyama, et. al., 2004) and 0.3 in 2006 (2008). Thus, this sector has been targeted by the government in the Third National Agriculture Policy (1998-2010) to become the major area of concentration to enhance the competitiveness of agriculture sector in Malaysia.

Aquaculture sector has a great potential to be developed and could play a significant role in overcoming the decreasing fish stock due to over exploitation fishing activities in coastal area by the commercial fishery (Tan, 1998; CICS, 2000). In 2002, the aquaculture output increased 5.8% due to 2.7% reduction of marine fishing output (Malaysia, 2002). Aquaculture sector also has been greatly modernized and transformed to a more technological based activities and was driven to high market contribution (Shariff et. al., 1997). The change in the sector was endorsed by the private sector technical and research capability for the economic development (CICS, 2000). Aquaculture has been identified as the strategic industry to fulfill the domestic demand of high protein resources and export demand of fish products and among the major contributor to food production growth in order to achieve self-sufficient target by 2010 (Malaysia, 2008).

Aquaculture activities have helped to reduce poverty problem especially in the rural areas through both the traditional and modern aquaculture practices such as in China and Indonesia. From the socio-economic aspect, aquaculture activities had benefitted the poor livelihoods by improving food supply (to more nutritional foods), employment and generate income (Edwards, 2000; Safa, 2004). In 1990, out of 18,143 people are employed under this sector and occupied with the various level of operation activities including harvesting, processing and marketing (Tan, 1998). The number of labor force in aquaculture sector has rapidly increased to 23,986 people in 2009 (Department of Fisheries, 2011). Besides, the development of aquaculture activities in the rural area benefitted the farmers and nearby community due to the allocation of infrastructure such as electricity, communication and road access that help to improve the quality of life (Mohd. Fariduddin, 2006).

Environmental factors have major influence on the sustainability of aquaculture production in Malaysia. The environmental pollution was identified in many studies as a threat to aquaculture development (Hambal, et. al, 1994; Shariff, et. al., 1997; Roslina, et. al., 2008). However, the worldwide problem of climate change is becoming the most risky and peril to aquaculture development in the long run. The physical impacts of climate change are different from one place to another and its effect on human and environment varies (World Bank, 2010). The motivation for this study is the concern about this issue. This study attempts to identify the relationship between climate change risks from the aquaculture operators' experience, their socio-economic background and the aquaculture production in East Malaysia aquaculture area. This study is important in order to assess the aquaculture and socioeconomic vulnerability to climate change and to come up with recommendation for potential and prioritizing strategies in reducing the risk.

### 2. Climate variability, socio-economics and production

The environmental and social aspects are important keys in ensuring sustainable and safe aquaculture production (Anon, 2003; Kelly and Adger, 2000). Biophysical factors such as climatic change and extreme weather affect the sustainable growth of aquaculture sector (Tisdell, 1999; Akegbejo-Samsons, 2009; and Schmidt, 2007). Climate change is a natural climatic event (production risk) that influences the quality and quantity of aquaculture production (Beach and Viator, 2008).

Increasing temperature and changes in rainfall caused vulnerable especially to the northern peninsular Malaysia and also the coastal of Sarawak and Sabah (Mustafa, 2007). The climate change causes the modification to evaporation and precipitation cycle and caused harm mostly to the water salinity. The rising temperature caused the problem of oxygen depletion that promotes the growth of algae blooms which affect toxins in the water and causes fish death. The problem of water stress emerges due to the 2°C increase in temperature above preindustrial level (World Bank, 2010). High temperatures in higher inland water temperature surpass the finest temperature level apt to cultivated species (World Bank, 2010) and increased stratification of water and reduce the production. The growth of fish also reduced due to insufficient feeding (rising metabolisms) in line with temperature (Akegbejo-Samsons, 2009) and the spread of disease to the cultured species (World Bank, 2010).

The physical factors that influenced inland aquaculture and coastal aquaculture in Malaysia are affected by the flooding events, variability in accessible water and siltation problems occurred in the aquaculture area. Flooding causes low water quality and cause water to contained the amount of poised solid, silt and threatens the high stream of the water which threatens mainly the cages system. Drought events however, lead to the water stress to the aquaculture activities (Hambal et. al., 1994). The most dangerous effects for aquaculture production and other coastal activities are the occurrence of storm surges, waves, and coastal erosion. Severe storm will results to high losses to the farmers due to the serious and high damage of farm resulting in cost high for recovering the destroyed (CICS, 2000).

The extreme climate change conditions will diminish the potential for growth and development as well as destroying lives and livelihood. Climate change risk increase production cost in managing the farm efficiently (Schjolden, 2004; Sulit, et. al., 2005) and maximize the production loss from the aquaculture farm. Thus, the small farmers are unable to survive in this sector due to rising cost of production and lack of support system to cover the cultured fish and shrimp from the impacts of production risk. The farmers failure in production and decline in food production will lead to problem of famine (Sen, 1981) and is responsible for creating the poverty trap because of the permanent losses of human and physical capital (Heltberg, et. al., 2009).

Climate change risk has emerged to be the social conflict to the aquaculture farmers in Malaysia due to the competition among them to grasp the natural resources for production (Roslina, et. al., 2008). The negative impacts was shown in the relation of various climate change to fish farmers' livelihood with risen socio-economic cost. The productivity and profitability level of aquaculture production depends on the direct positive or indirect negative effect of climate change to aquaculture natural resources such as land, water, seeds, feed and energy (Oguntuga, et. al., 2009). In Asian countries, it is the negative collision of aquaculture to environment and poor farmers' livelihood. The poor farmers are unable to survive in aquaculture production due to the high cost in acquiring the technologies and capital needs (Roslina and Chamhuri, 2008). Moreover, low aquaculture production affects the demand of fish protein and household price and put pressure for marine ecosystem protection (World Bank, 2010). The sensitivity of culturing procedures to the climate change variability in terms of type, scale, intensity and culture location has a bad outcome to the aquaculture farmers' livelihood and also various socioeconomic costs (Oguntuga, et. al., 2009). The pressure to access the finest water quality for aquaculture production increased the competition among farmers and other sectors' farmers. Industrial operation close to the aquaculture production has neglected the sectors' growth potential (Hambal, et.al., 1994).

#### 3. Methodology

The data was gathered from 249 out of 773 aquaculture farmers in Sarawak, East Malaysia through the random stratified sampling. The semi structured survey with the assistance of face-to-face interview with the respondents (aquaculture farmers) who practiced ponds and cages systems. These were taken because the activities were naturally influence by the environment. The cross sectional multiple linear regression analysis is used to examine the relationship between the dependent (quantitative variables) with independent or predictor variables (Berger, 2003). In lieu with the objective of study, the dependent variable is annual aquaculture production achieved by farmers  $(Y_i)$ . The independent variables consist of the combination of two categories that are socio-economic and climate risks variables. The socio-economics variables are represent by education (DX<sub>1i</sub>), gender (DX<sub>2i</sub>), number of family members (X<sub>3i</sub>), farm years production (X<sub>4i</sub>), working hours per week (X<sub>5i</sub>), non-aquaculture income (X<sub>6i</sub>), variable cost of production (X<sub>7i</sub>), number of production loss in respective year  $(X_{si})$  and buying technologies  $(DX_{9i})$ . The climate risks variables comprise of the perception of farmers to the types of climate risks that had been influence to their production. These variables are pH increase (DX<sub>10i</sub>), pH decrease(DX<sub>11i</sub>), raining (DX<sub>12i</sub>), temperature increase(DX<sub>13i</sub>), temperature decrease (DX<sub>14i</sub>), decrease of dissolved oxygen (DX<sub>15i</sub>), drought events (DX<sub>16i</sub>), flood events (DX<sub>17i</sub>), severe storm events (DX<sub>18i</sub>), pandemic disease (DX<sub>19i</sub>) and non-pandemic disease (DX<sub>20i</sub>). To identify the relationship between socio-economic factors and climate change risk factors, the qualitative variables are including in the analysis model. These qualitative variables are known as dummy or dichotomous variables. The variables such as education, gender, using technologies and all climate risks variables are dichotomous or dummy variables (with value 1 or 0) that present the qualitative explanation in the econometric model (Asteriou and Hall, 2007). This study employs the cross sectional multiple linear regression and the econometric model of this study is;

 $\ln Y_{i} = \alpha + \beta_{1} D X_{1i} + \beta_{2} D X_{2i} + \beta_{3} X_{3i} + \beta_{4} X_{4i} + \beta_{5} X_{5i} + \ln \beta_{6} X_{6i} + \ln \beta_{7} X_{7i} + \beta_{8} X_{8i} + \beta_{9} D X_{9i} + \beta_{10} D X_{10i} + \beta_{11} D X_{11i} + \beta_{12} D X_{12i} + \beta_{13} D X_{13i} + \beta_{14} D X_{14i} + \beta_{15} D X_{15i} + \beta_{16} D X_{16i} + \beta_{17} D X_{17i} + \beta_{18} D X_{18i} + \beta_{19} D X_{19i} + \beta_{20} D X_{20i} + \varepsilon$ 

where  $\alpha = \text{constant}$ ,  $\beta = \text{coefficient}$  of explanatory variables, D= dichotomous variables,  $\mathcal{E} = \text{residual}$ .

Furthermore, the bivariate analysis is carried out to explain the strength and direction of linear relationship between the volumes of aquaculture production with the climate change risks factors in Sarawak's aquaculture sector (Pallant, 2010). As the variables presented categorical data, the non parametric test, Spearman's rho is used to identify the relationship between the variables (Field, 2009).

#### 4. Results and discussion

The findings from cross-sectional multiple linear regressions (table 1) show the relationship between annual aquaculture productions with all independent variables. The  $R^2$  results shows about 35 percent of the variation in total annual production is explained by the variation in the independent variables included in the models. In general, the Jarque-Bera test confirms that the estimated residual is normally distributed. There are no evidence of serial correlation from the Breusch-Godfrey LM test and no evidence of heteroscedasticity from the White test.

	Socioeconomi	ics variables		Climate risks variables				
Variable	Coefficient	t-stat	P value	Variable	Coefficient	t-stat	P value	
α	2.5837	2.6581	0.0085	DX <sub>10i</sub>	0.6580	0.5569	0.5782	
$DX_{1i}$	0.2160	0.5568	0.5783	$DX_{11i}$	-0.0008	-0.0016	0.9987	
$DX_{2i}$	-0.0238	-0.0634	0.9495	$DX_{12i}$	0.1763	0.4472	0.6552	
$X_{3i}$	-0.0695**	-2.2847	0.0234	DX <sub>13i</sub>	1.2294	0.8579	0.3919	
$X_{4i}$	-0.0128	-0.9853	0.3256	$DX_{14i}$	-0.5649	-0.4076	0.6840	
$X_{5i}$	0.0031	1.2794	0.2022	DX <sub>15i</sub>	0.1980	0.7855	0.4331	
$\ln X_{6i}$	0.0993	1.4089	0.1604	$DX_{16i}$	0.2016	0.7786	0.4371	
$\ln X_{7i}$	0.4273*	5.5578	0.0000	DX <sub>17i</sub>	0.0406	0.1733	0.8626	
$X_{8i}$	4.29E-06	0.1666	0.8679	$DX_{18i}$	0.0158	0.0361	0.9713	
$DX_{9i}$	0.7470**	2.5778	0.0106	$DX_{19i}$	0.0236	0.0684	0.9455	
				$DX_{20i}$	0.1245	0.2451	0.8066	
R-squared		0.	35	Serial Correlation		0.10		
Adjusted R-squared		0.28		Heteroscedasticity		0.47		
Standard error of regression		1.59		Normality	-	1.04		
F-statistic		5.	45	2				

Table 1: cross sectional multiple linear regression results

Note: \* significant at the 1% level; \*\* significant at the 5% level; \*\*\* significant at 10% level

(1)

The number of family members shows a significant negative relationship to annual aquaculture production. The increase of 1 person of family members will affect of 6.95 % reduces in aquaculture production. Most of the farmers (respondents) are small scale farmers. Thus, the aquaculture production is mainly for family daily consumptions (Mohd. Fariduddin, 2006). The remaining amount of production is sold to the neighbours and nearby community in small amount especially during the festive seasons.

The annual aquaculture production in Sarawak has positive significant relationship with total variable cost expense in the production. The increase of MYR 1 of the variable cost in production will increase 0.43% in aquaculture production. In this study, the variable costs comprise of cost of buying fries, cost of labor, feeds cost, maintenance cost and management cost. The additional expenditure on buying fries and maintenance will increase the value of production of the farmers.

The results showed that the use of technology will increase the aquaculture production. The increase of 1 time of using technologies will increase the production by 74.7%. The experienced farmers believed that technology helps in increasing their production and reducing the risk of climate change. The farmers who have been operating for longer years owned technologies such as machines and equipments to manage their farms. However, technology is rarely applied by the cage aquaculture farmers where natural and traditional fish farming practices are more favored in this aquaculture system.

 Table 2: Spearman's rho correlation results summary of climate change risks drivers to aquaculture production and production loss.

Factors	pН	pН	raining	Temp.	Temp.	Dissolved	Drought	Flood	Severe	Pandemic	Non-
	increase	decrease		increase	decrease	$O_2$			storm		pandemic
Annual	141*	191**	074	143*	164**	174**	008	.076	051	116*	118*
Production	(.013)	(.001)	(.122)	(.012)	(.005)	(.003)	(.452)	(.117)	(.212)	(.033)	(.031)
Note: **. Correlation is significant at the .01 level (1-tailed); *. Correlation is significant at the .05 level (1-tailed)											

Although there is no significant relationship between climate risks with the annual production from the regression results, the relationship of climate change risks to aquaculture production and production loss are explained by the Spearmen's rho correlation result of the survey (table 2). The volume of annual aquaculture production is low significant to pH increase, r=-.141, p (.013)<.05, temperature increase, r=-.143, p(.012) < .05, pandemic disease, r=-.116, p(.033) < .05 and non pandemic disease, r=-.118, p(.031) < .05. Hence, the volume of annual aquaculture production also has low significant relationship to pH decrease, r=-.191, p(.001) < .01, temperature decrease, r=-.164, p(.005) < .01 and decrease of dissolved oxygen, r=-.174, p(.003) < .01. The relationships between all significant factors are negative which verify that the increment frequency of climate change risks factors such as pH increase and decrease, water temperature increase and decrease, dissolved oxygen decrease, pandemic and non pandemic disease increase, will result in the production loss or decreasing in the volume of annual aquaculture production. According to Swann (1997), water quality is one of the important factors influence to aquaculture growth. Fishes are sensitive to the water temperature and the change in 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 changing temperatures modify the quantity of dissolved oxygen level in water and can cause the fish death. Moreover, the increase of pH and temperature in water will affect the ammonia toxicity problem that will then decrease production.

From the interview session, it is found that the climate change risks bring moderate effects on aquaculture production in Sarawak. Decrease in dissolved oxygen in water, flood and drought events had frequently influence aquaculture failure experience by some farmers. Less of dissolved oxygen problems are common risks especially among the ponds farmers. The farmers in Kuching, Sri Aman, Sarikei and Limbang areas are those who vulnerable due to the floods events. The cages farmers in Limbang are affected by the drought seasons where it causes water quality and accessibility problem. Hence, logging and palm oil plantation activities nearby makes the problem even worse as the river water became tremendously murky and shallow and not suitable for aquaculture activities.

# 5. Conclusion and Policy Implications

The study identifies the linkages between climate change risks, socio-economic and aquaculture production in Sarawak, East Malaysia. The results verify that socioeconomic indicators such as number of family members, variable cost expenditure and the use of technologies in aquaculture farms are factors that are significant to the aquaculture production growth. Moreover, the increment of climate change risks events has significant relationship to the decreasing of aquaculture production in Sarawak. Through farmers' experience on climate change risks, they advocate that dissolved oxygen decrease problem, flood and drought events have highly affected their production loss. Although the climate change risk is not yet a severe problem to aquaculture farmers in Sarawak, it is suggested that accurate adaptation and mitigation strategies need to be plan and taken early to ensure effective usage and adaptation in the long run.

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