Farmers' livelihood and adaptive capacity in the face of climate vulnerability

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Abstract

Purpose – The purpose of this study is to analyze the economic, social and environmental impacts of climate change on farmers' livelihoods and adaptive capacity while highlighting specific adaptation strategies in the local climate context.

Design/methodology/approach – Data were collected using a survey questionnaire and analyzed using partial least square structural equation modeling (PLS-SEM). Respondents were selected from seven farmer organizations (Pertubuhan Peladang Kawasan) located in Kedah, Malaysia.

Findings – The study revealed that farmers perceive the economic, social and environmental impacts of climate change. These adverse effects of climate change have an impact on their livelihoods as well as their adaptive capacity. The findings also demonstrated that farmers' livelihoods mediate the relationship between economic and environmental impacts of climate change as well as the adaptive capacity of farmers.

Originality/value – Climate change severely affects the agricultural sector as well as farmers' livelihoods. To minimize its effect, scientists and policymakers emphasize the improvement of farmers' adaptive capacity as well as appropriate adaptation methods. However, there is little research on how climate change affects the livelihoods of farmers in the context of Malaysia. Therefore, the results of the study will provide a new perspective for policymakers to formulate a better adaptation policy framework as well as select appropriate adaptation strategies for sustainable agricultural development.

Keywords Adaptation strategies, Adaptive capacity, Climate change impact, Farmers' livelihoods

Paper type Research paper

1. Introduction

The focus on economic growth at the expense of the agricultural sector in some countries may be attributed to their naivety about food shortage (Lee and Baharuddin, 2018). In countries like Malaysia where there is shortage of food production, food importation had been a major source of succor. The studies of Zainal *et al.* (2014) and Abdul-Razak and Kruse (2017) revealed that the climatic variation accelerated the growth of fungi and diseases, thus influencing the Malaysia's agricultural yield. It is estimated that the temperature in Malaysia may increase by 2.6° over the next three to four decades (IPCC, 1995); therefore, climate

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change presents a major challenge for the country in its effort to sustain agricultural productivity. For instance, Toriman *et al.* (2013) indicated that despite having the production capacity of 7.2 metric tons, Malaysia produces about 3–5 metric tons of rice per hectare, which has a detrimental effect on the livelihoods of farmers. To ensure food security in the country and protect the means of livelihood of the farmers, the agricultural sector should be accorded adaptation priorities, given its inherent vulnerability to climate change (Hossain and Paul, 2019). The earlier studies (Zizinga *et al.*, 2017; Assan *et al.*, 2018) attributed the success of these adaptation policies to several factors which include provision of farmers' support services, knowledge-base of farmers, social support systems, technology, access to capital and the physical environment that make such changes conceivable. However, only minimal efforts have been made to provide empirical shreds of evidence capable of improving farmers' adaptive capacity and consequently minimizing the economic, social and ecological impacts of climate change on their livelihood and adaptive capacity. Therefore, this study attempts to evaluate the impact of climate change on the livelihood and adaptive capacity of farmers, based on specific adaptation strategies in the local climate context.

2. Literature review

Climate change has become a global focus due to its adverse impact on various physical and biological processes, including agriculture (Berg and Lidskog, 2018; Bendell, 2018). Such climate change is a threat to life on the planet due to its degradation of the ecological system, and interruption of the natural equilibrium of water, food and temperature (Farzaneh *et al.*, 2019). Agriculture is considered the most vulnerable sector in human society owing to the varying patterns of climate change. This is because the productivity of this sector is heavily influenced by natural factors such as water supply, soil quality, humidity and so on. These natural determinants of agriculture are very sensitive to changes in climate elements – temperature, precipitation, sunshine hours, etc. The studies by Hasegawa *et al.* (2018), Van Meijl *et al.* (2018), Ray *et al.* (2019), Fujimori *et al.* (2019) and Zainal *et al.* (2014) confirmed that the agricultural sector has already been affected by climate change, given the remarkable decrease in food production and increase in food insecurity. In the long run, this may destroy the supply chain of the agricultural sector, consequently reducing agricultural income, eliminating farmers' means of livelihood and retarding economic growth. It is further worsening that projections indicate a future rise in such negative impacts (IPCC, 2014). Invariably, most developing countries operate an agriculture-based economy, with the farmers depending on it as their primary source of income, consequently exposing them to the adverse effects of climate variability (Di Falco *et al.*, 2012). The agricultural sector had always been susceptible to climate change, which ultimately affected farmers' means of livelihood and national food security (Huq *et al.*, 2015). Chronic climate change in Malaysia poses significant challenges for small-scale farmers whose livelihoods are primarily dependent on agricultural resources (Nabara *et al.*, 2021). Climate variability shocks, according to Solaymani (2018), reduce consumption and welfare across all household groups, particularly in rural areas. This is also a threat to people whose livelihood directly rely on agriculture, such as merchants (Badolo and Kinda, 2014; Barnett and Adger, 2007). The climatic variability also contributes to the hiking food prices, which results in child malnutrition (Ringler *et al.*, 2010; Christian, 2010) and leads to a decrease in the level of agricultural production and growth capacity of the economy via a drop in exports and investment in R&D (Jones and Olken, 2010). Therefore, farmers' adaptive capacity should be improved to minimize the possible adverse effects of climate change on the agro-food system (Fadina and Barjolle, 2018). High temperature represents a major constraint to rice production in tropical climate countries like Malaysia (Firdaus *et al.*, 2020). For example, a study using the Decision Support System for Agrotechnology Transfer (DSSAT) crop simulation model projected that rice yields in Malaysia will decline by 12% during the main season and 31.3%

during the off-season until 2030 owing to rise in temperature and change in precipitation pattern (Vaghefi *et al.*, 2016). Similarly, Indonesia, Philippines, Thailand and Vietnam are also expected to experience a decline of about 50% by 2,100 (Sekhar, 2018). A number of the previous studies (Armah *et al.*, 2011; Abdul-Razak and Kruse, 2017) supported the farm-based adaptation techniques and procedures in fighting against the adverse effects of climate change.

In Malaysia, farm-level adaptation is critical, particularly during the off-season, as climate change may expand rice output differences between cropping seasons and granary locations (Tan *et al.*, 2021). However, declining rice yield could be partially offset by yield improvements and adaptation.

Farmers can improve their adaptive capacity to climate risk by increasing their revenue from diverse livelihood sources (Jha *et al.*, 2018; Tripathi, 2017; Patnaik and Das, 2017). Nguyen *et al.* (2021) identified a number of elements that influence and hinder farmers' ability to adapt. Lack of access to information, lack of access to extension services, limited awareness and expertise, and restricted financial choices were cited as barriers impeding their adaptive capacity. Farmers in Malaysia, Bangladesh and Ghana were observed to have a moderate adaptive ability (Akhtar *et al.*, 2019). Choden *et al.* (2020) highlighted that for an informed decision-making, adaptive capacity must be addressed. Gupta *et al.* (2020) discovered that adaptive capability, exposure, sensitivity and vulnerability differed regionally across India's Garhwal Himalaya region. They also proposed that the geographic variation in socio-environmental vulnerability should lead to targeted investments in adaptation measures in the most susceptible areas.

Thus, Juhola and Kruse (2015) postulated that the evaluation of adaptive capability provides necessary data for the improvement of climate change adjustment strategies. Fundamentally, to defend the vulnerability arising from different socio-ecological schemes, there is a need to enhance the capacity of adaptability substantially (Žurovec and Vedeld, 2019). Few scholars (Nakuja *et al.*, 2012) also evaluated the farmer's adaptive capabilities at the local level by including their attributes – accessibility, knowledge, use, consultation and availability. Based on the framework of sustainable livelihood, Defiesta and Rapera (2014) applied five dimensions related to asset types (social, physical, human, natural and financial capital) upon which Serrat (2017) postulated that the means of livelihood of an individual were built.

Aniah *et al.* (2019) remarked that before the effects of adaptation on the means of livelihood of individuals are established, it is critical to investigate the influence of climate change on means of livelihood. Barnett (2001) postulated that vulnerability may result from over-exploitation of the environment, natural disasters, and careless use of natural resources. Tierney *et al.* (2001) stated that social vulnerability may include socioeconomic factors and demographic characteristics, which mitigate the effects of the harmful phenomenon in local populations. In the context of climate change, people may be at risk due to the fluctuation in climate condition. According to Hobley (2002) and DFID (1999), marginalized people are severely affected by varying factors beyond their control, which could subsequently affect their means of livelihood. Pandey (2009) found that the impact of climate change is intensified in the provincial Sahelian communities which are now devoid of expected rains. Thornton *et al.* (2014) argued that climate change had been profound in recent years, and had consequently altered people's sustainable livelihood, socioculture and ecological system. Nevertheless, IPCC (2014) reported that most poor countries around the world have been severely affected by natural disasters owing to their poor adaptability to climate change. Watson *et al.* (2016) indicated that adjustments in means of livelihood due to climate change will evoke various vulnerabilities and questions; as an instance, people are unable to determine how the climate change and its various consequences will affect other unique procedures over different scales.

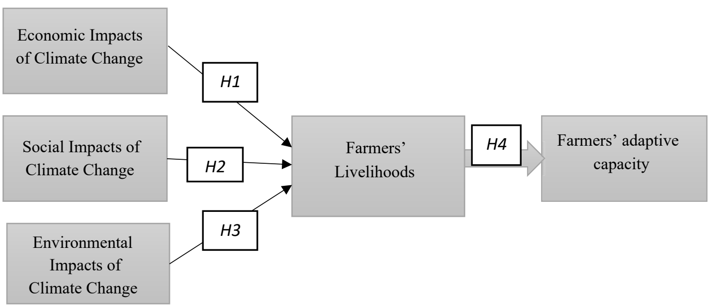
Adaptation to climate change involves the functional activities and perception of people (Jeffers, 2020), the situational conditions (since climate change affect people through social structures) of decision-makers and the features of innovation in deliberation, which occur due to changing ecological conditions, social, economic and political circumstances (Lioubimtseva and Henebry, 2009). The diffusion of the innovation theory pinpoints four basic dimensions (time, communication channels, the environment of social systems and innovation itself), which positively impact the theory (Aniah *et al.*, 2019). The social structure involves people, communal groups, the relationship among others, and social networks. An individual's values, role, and opinion about the social systems also reflect the extent to which innovations are readily adopted. Accordingly, adaptation to environmental change assumes the same points of view shared by small householders. According to Aniah *et al.* (2019), farmers must recognize the first important step required in the implementation of adaptation measures in order to mitigate the effects of ecological and climate change on their means of livelihood. The second crucial phenomenon is that farmers should be able to recognize which adaptation measures are required, and why they should be implemented. Osumanu *et al.* (2017) and Bawakyillenuo *et al.* (2016) noted that farming experiences, education, age, institutions, information and financial resources influence the adaptive capability of households. Bawakyillenuo *et al.* (2016) also noted that the decision to execute adaptative measures relies on institutional support, economic vulnerability, education and the accessibility of available information.

3. Proposed research model

This study presents the following research paradigm based on the preceding literature review. As shown in Figure 1, the suggested framework depicts the perceived economic, social, and environmental impact of climate change on farmers' means of livelihood, which in turn affects their adaptation capacity.

4. Methodology and measurement

The MADA region of Kedah in Malaysia was considered a case study in this research. This region, often regarded as the "rice bowl of Malaysia," was selected owing to its contribution to Malaysia's rice production, which amounts to a total of 75%. MADA is home to the Muda irrigation system comprising 27 peasant organizations, referred to as the Bahasa Malaysia Pertubuhan Peladang Kawasan (PPK), and 55,000 farmers. An attempt to cover the entire population in this study would prove to be tedious owing to time and budget constraints; therefore, the G-Power version 3.1 was utilized in the selection of an appropriate sample size.



Note(s): *H = Hypothesis

Figure 1. Proposed hypothesized Model

The G-Power software recommended a sample size of 160 to test the proposed research model comprising six constructs with an effect size of 0.15. The PLS-SEM, on the other hand, required a minimum sample size of 100 (Reinartz *et al.*, 2009). Using a stratified random sampling technique, this study collected data from 397 participants, which exceeded the minimum recommended sample size. Specifically, we used stratified proportionate sampling to divide the entire study area, which is made up of a homogenous group of approximately 55,100 farmers, into 27 PPK strata. As it is difficult to cover all strata due to time and budget constraints, we chose seven strata (7 PPK) and subsequently made a proportionate random selection of respondents from each stratum. Survey questionnaires were used to collect data from the study area. The questionnaires were distributed by hand to the respondents who were then informed about the main goals of the data collection. There were three sections to the questionnaire. The first section collected respondents' socioeconomic characteristics; the second assessed the perceived impact of climate change on economic, social, environmental and agricultural factors; and the third examined the effects of climate change on farmers' means of livelihood and adaptive capacity.

The measurable items of this study, particularly for the exogenous constructs, were evaluated using a five-point Likert scale, ranging from 1 (strongly disagree) to 5 (strongly agree). As for the mediating and endogenous variable, a seven-point Likert scale was employed in the evaluation of items, which ranges from 1 (strongly disagree) to 7 (strongly agree).

4.1 Assessment of the measurement model

The result of the measurement model test revealed the lower factor loading value as 0.657 and higher factor loading as 0.926 (Table 1), indicating the satisfactory level of internal consistency. As recommended by Gudergan *et al.* (2008), a factor loading greater than 0.70 is best for reliability assessment, but on the occasion that the AVE does not attain a satisfactory level, the value between 0.40 and 0.70 may be dropped. Hence, no item will be dropped, as our AVE result attains the suggested cut-off point of 0.50 (Hair *et al.*, 2016).

The measurement model also reveals the convergent and discriminant validity following the Fornell-Larcker's criterion and Heterotrait–Monotrait Ratio (HTMT). The convergent validity is "the degree to which indicators of a specific construct converge or share a high proportion of variance in common" (Hair *et al.*, 2016). The findings indicated that the composite reliability (CR) ranged between 0.843 and 0.924, while AVE ranged between 0.575 and 0.752, both of which exceeds the cut-off point of 0.70 and 0.50, respectively (Hair *et al.*, 2010), and satisfies the convergent validity of this study. To determine the construct reliability and internal consistency, the cut-off point above 0.70 was considered for evaluating rhoA and Cronbach's alpha (Dijkstra and Henseler, 2015). In our discovery, the rhoA threshold ranged from 0.768 to 0.922, indicating a satisfactory level of the construct reliability. The Cronbach's alpha for this study exceeded the threshold of 0.70, indicating internal consistency of the data. Table 2 expresses the summarized result of the construct reliability and validity of the existing study.

The discriminant validity was assessed by differentiating the square root of the AVE and correlation coefficients of factor. In this study, three methods were used to check the discriminant validity. First, Table 3 illustrates the result of the discriminant validity of the Fornell-Larcker criterion. Fornell and Larcker (1981) stated that "the average variance shared between each construct and its measurements should exceed the variance shared between the construct and other constructs." The findings revealed that each variable conforms to the satisfactory level of discriminant validity. This is because there is no correlation (shown at off-diagonal) exceeding the square root of AVE (shown at diagonal), subsequently indicating the validity of all constructs according to the discriminant validity test Fornell and Larcker (1981).

No.	Items of the construct	Outer loadings
Economic impact of climate change		
EICC 1	Rice production is decreasing due to livestock pests and diseases etc.	0.754
EICC2	Decreasing income level	0.876
EICC3	Price hike for essential goods	0.812
EICC4	Reduced self-sufficiency level	0.870
EICC5	Declining food quality	0.889
Social impact of climate change		
SICC1	Increase lack of food security	0.880
SICC2	Increased rural–urban migration	0.848
SICC3	Climate change is hazardous to human health	0.873
Environmental impact of climate change		
ENICC1	Increased land degradation	0.657
ENICC2	Contributes to extensive water, air and soil contamination	0.724
ENICC3	Reduce water availability	0.814
ENICC4	Increasing temperatures, changing precipitation patterns and changing in extreme weather events	0.826
Farmers' livelihoods		
FL1	Climate change affects economic assets	0.817
FL2	Climate change affects social assets	0.917
FL3	Climate change affects financial assets	0.892
FL4	Climate change affects environmental assets	0.759
Farmers' adaptive capacity		
FAC1	I have knowledge about adaptation strategies	0.926
FAC2	I have several years of experience on climate change adaptation	0.912
FAC3	I know how to use technology for adaptation	0.811
FAC4	All services are accessible	0.763

Table 1.
Outer loadings of the measurement model

Variables	Cronbach's alpha	rho_A	Composite reliability	AVE*
Economic impact of climate change	0.896	0.899	0.924	0.708
Social impact of climate change	0.835	0.836	0.901	0.752
Environmental impact of climate change	0.752	0.768	0.843	0.575
Farmers' livelihoods	0.869	0.875	0.911	0.720
Farmers' adaptive capacity	0.880	0.922	0.916	0.732

Note(s): *AVE = Average Variance Extracted

Table 2.
Construct reliability and validity

Second, the cross-factor loadings were examined to determine the discriminant validity of the measurement model. Table 4 displays the results of the cross-factor loadings. Hair *et al.* (2016) suggested that all indicators must have higher loadings to their respective variable. The result showed that all indicators have the highest value on their respective constructs, ensuring the attainment of discriminant validity of the existing study.

Thirdly, to accurately ascertain the discriminant validity, the Heterotrait–Monotrait Ratio (HTMT) was also determined. An HTMT value lower than 0.85–0.90 is considered for satisfactory discriminant validity (Hensler *et al.*, 2015; Kline, 2015; Gold *et al.*, 2001).

Variables	Economic impact	Environmental impact	Farmers' livelihoods	Framers' adaptive capacity	Social impact
Economic impact of CC	0.842				
Environmental impact of CC	0.191	0.758			
Farmers' livelihoods	0.687	0.409	0.849		
Farmers' adaptive capacity	0.312	0.599	0.447	0.856	
Social impact of CC	0.676	0.422	0.642	0.479	0.867

Note(s): CC=Climate Change
The square root of AVE is presented in diagonals and correlations, off-diagonals

Table 3.
Discriminant validity

Economic impact of climate change	Social impact of climate change	Environmental impact of climate change	Farmers' livelihood	Farmer's adaptive capacity
0.754	0.524	0.184	0.574	0.307
0.876	0.477	0.097	0.558	0.189
0.812	0.549	0.133	0.523	0.222
0.87	0.59	0.16	0.619	0.295
0.889	0.69	0.221	0.606	0.291
0.021	0.182	*0.657*	0.236	0.377
0.158	0.309	*0.724*	0.313	0.477
0.196	0.361	*0.814*	0.347	0.442
0.17	0.396	*0.826*	0.329	0.513
0.331	0.488	0.577	0.463	*0.926*
0.322	0.468	0.547	0.431	*0.912*
0.24	0.377	0.49	0.237	*0.811*
0.14	0.27	0.421	0.332	*0.763*
0.662	0.569	0.309	*0.817*	0.395
0.61	0.585	0.4	*0.917*	0.376
0.612	0.516	0.307	*0.892*	0.378
0.424	0.504	0.378	*0.759*	0.367
0.64	*0.880*	0.367	0.522	0.412
0.464	*0.848*	0.368	0.581	0.362
0.66	*0.873*	0.363	0.564	0.471

Note(s): Italic values indicate higher values for the respected items

Table 4.
Cross-loadings

The findings indicated that all HTMT values of correlations have values below 0.90, confirming satisfactory discriminant validity for all variables (Table 5).

5. Empirical results

The SmartPLS statistical tool was utilized in this study to examine the conceptual model and hypothesized relationship between the independent and dependent variables through the partial least square structural equation modelling (PLS-SEM). The independent variables include the economic, social, environmental and agricultural impact of climate change, while the farmers' means of livelihood represents the mediator between the independent variables

Table 5.
Heterotrait–Monotrait ratio (HTMT)

Variables	Economic impact	Environmental impact	Farmers' livelihoods	Farmers' adaptive capacity	Social impact
Economic impact of climate change	–				
Environmental impact of climate change	0.24	–			
Farmers' livelihoods	0.771	0.504	–		
Farmers' adaptive capacity	0.339	0.729	0.489	–	
Social impact of climate change	0.781	0.519	0.751	0.545	–

and dependent variable (farmers' adaptive capacity). Two-step procedures were applied in the analyses of the measurement and structural model.

5.1 Respondents' socio-demographic profile

The findings in Table 3 revealed that 93 and 7% of the 397 respondents were male and females, respectively. A whopping 80.1% of the respondents were in the 50–65 age range, while 17% aged between 46 and 49 years. Hence, it can be said that majority of the farmers that participated in this study were middle-aged and are well acquainted with the impact of climate change on the agriculture sector. This vast experience of the farmers may aid them in implementing suitable initiatives for climate change adaptation. A measure of the literacy level of the respondents indicated that approximately 81.7% had a formal education, out of which 33% completed primary education; 31.3%, lower secondary education; 26.7%, higher secondary education; and 0.3% obtained a diploma certificate. On the contrary, the findings revealed that 8.3% of the respondents had no formal education. An assessment of the monthly income of the farmers indicated that a majority of the respondents (60.45%) earn below RM 2000; 35%, between RM 2001 and RM 4000; 4%, between RM 4001 and RM 6000; and approximately 0.3%, between RM 6001 and RM 8000.

The results further indicated that 31.9% of the farmers had a farm size of less than 1 hc, 25.5% had between 1 and 2 hc, and only 5.5% had above 5 hc. It was also discovered that 36.5% of the farmers had over 5 years experience in the agricultural sector and that only 30% of the farmers owned a farm as shown in Table 6.

5.2 Structural model evaluation

To identify the collinearity problem in the model, the Variance Inflation Factor (VIF) was assessed to determine the correlation exceedance of the factors (multicollinearity), which could influence the model and p-values. Hair *et al.* (2011) postulated that collinearity issues may occur if VIF values exceed 5; Diamantopoulos and Sigouw (2006) suggested that VIF scores should be less than or equal to 3.3. The findings revealed all inner VIFs for the exogenous construct as 2.093, 2.334 and 1.178 for economic impact, social impact and environmental impact, respectively, all of which are less than 3.3, thus indicating the inexistence of collinearity issues (Hair *et al.*, 2010). It is crucial to determine the accuracy of the model's predictions (coefficient of determination R-square); therefore, the proportion of the previously explained variance was used in the existing study. The results indicated that the R-square value of farmers' means of livelihood and adaptive capacity were 0.571 and 0.200, respectively, which implied that 57.1% of the variance for farmers' livelihood was explained by the economic, social and environmental impact, while 20% of the variance for

Basic information	Group	Frequency	Percentage
Gender	Male	369	92.9
	Female	28	7.0
Age in year	25 or below	0	0
	26–30	3	0.7
	31–45	8	2.0
	46–50	68	17
	50–65	318	80.1
Education level	No formal education	33	8.3
	Primary	129	33.0
	Lower secondary	125	31.3
	Higher secondary	109	26.7
	Diploma	1	0.3
	Bachelor	0	0
	Postgraduate	0	0
Income of household (RM/monthly)	RM 2,000 and less than RM 2,000	240	60.45
	RM 2,001 – RM 4,000	140	35.0
	RM 4,001 – RM 6,000	16	4.0
	RM 6,001 – RM 8,000	1	0.3
Farm size	1 = less than 1 hc	127	31.9
	2 = 1 to 2 hc	102	25.5
	3 = 2 to 3 hc	65	16.25
	4 = 3 to 4 hc	46	11.5
	5 = 4 to 5 hc	35	8.75
	6 = above 5 hc	22	5.5
Farming experience	1 = less than 5 years	32	8.06
	2 = 6 years	52	13.0
	3 = 7 years	65	16.25
	4 = 8 years	103	25.75
	5 = more than 10 years	145	36.25
Owner of farm	1 = owner farmer	120	30
	2 = owner tenant	143	36.05
	3 = tenant farmer	134	33.5
Total		397	100

Table 6. Respondents' socio-demographic information

farmers' adaptive capacity was explained by their means of livelihood. In a bid to verify the hypothesized relationship between the constructs, the structural model was tested using bootstrapping (Wetzels *et al.*, 2009). The results indicated that economic impact ($\beta = 0.505$, $p < 0.01$), social impact ($\beta = 0.206$, $p < 0.01$) and environmental impact ($\beta = 0.226$, $p < 0.01$) have a significant and positive impact on the farmers' livelihood; thus, H1, H2 and H3 are accepted. The result also highlighted the existence of a strong and significant relationship between farmers' means of livelihood and their adaptive capability ($\beta = 0.447$, $p < 0.01$); thus, H4 is accepted (Table 7). Figure 2 illustrates the results of the structural model assessment.

The F-square (f^2) values were computed using the effect size with the R-square (R^2). An F-square value of 0.35 reflects a high effect size, while 0.15 and 0.02 are considered for medium and small effect sizes, respectively (Cohen, 1988). According to the findings in Table 7, an F-square values of the economic impact (0.317), environmental impact (0.096) and social impact (0.045) indicate high, medium and small effect sizes, respectively, for farmers' livelihood. The predictive relevance was also calculated using the Q-square (Q^2) value. The findings revealed that the Q^2 values for farmers' livelihood (0.130) and farmers' adaptive capacity (0.401) were all larger than zero (Fornell and Cha, 1994), indicating the predictive relevance of the mediating and dependent variables of this study.

5.3 Mediating effect of farmers' livelihood

The study examines the mediating effect of farmers' means of livelihood, which is summarized in Table 8. The findings revealed that farmers' livelihood mediates the relationship between economic impact and farmers' adaptive capacity (β = 0.308, t-value = 4.005, p < 0.01). The farmers' livelihoods do not mediate the relationship between social impact and farmers' adaptive capacity, but mediates the relationship between environmental impact and farmers' adaptive capacity (β = 0.148, t-value = 1.940, p < 0.05).

Hypo	Relationships	β	Std error	t-value	R^2	f^2	Q^2	Comment
1	EICC → FL	0.505	0.057	8.826***		0.317		Accepted
2	SICC → FL	0.206	0.062	3.311***	0.571	0.045	0.130	Accepted
3	ENIC → FL	0.226	0.066	3.408***		0.096		Accepted
4	FL → FAC	0.447	0.074	6.048***	0.200	0.249	0.401	Accepted

Note(s): Hypo = Hypothesis, β= (coefficient), Significant level at ***p < 0.01
EICC = Economic impact of climate change; SICC = Social impact of climate change; ENICC = Environmental impact of climate change; FL = Farmers' livelihoods; and FAC = Farmers' adaptive capacity

Table 7.
Hypothesis testing

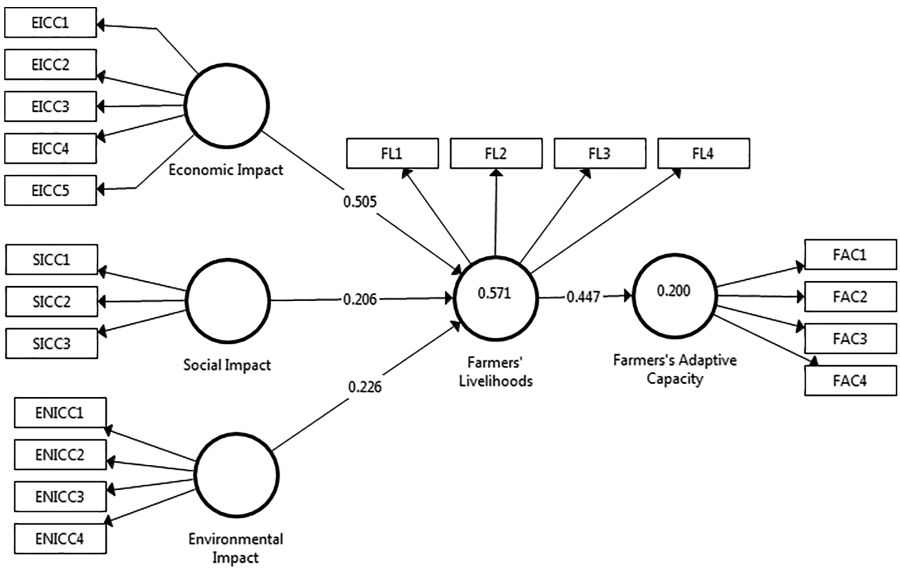


Figure 2.
The structural model of the relationship between economic impact, social impact, environmental impact, farmers' livelihoods and adaptive capacity

Relationship	Std. Beta	Std. error	t-value	p-values	Confidence interval (BC) LL	UL	Decision
EICC → FL → FAC	0.308	0.077	4.005	0.000	0.389	0.607	Partial mediation
SICC → FL → FAC	0.055	0.08	0.684	0.494	0.079	0.321	No mediating
ENICC → FL → FAC	0.148	0.079	1.940	0.050	0.108	0.370	Partial mediation

Note(s): UL= Upper level, LL = Lower level, BC= Bias-corrected

Table 8.
Hypothesis testing of the mediation

It computes 95% bias-corrected CIs and zero is non-existent between the lower and upper levels (Preacher and Hayes, 2008). As an instance, the results of indirect effect ([LL = 0.389, UL = 0.607], [LL = 0.079, UL = 0.321], and [LL = 0.108, UL = 0.370]) indicated that there is a mediating effect on the means of livelihood of farmers.

6. Discussion

This research examined the economic, social and environmental effects of climate change on farmers' livelihoods and adaptive capacity in Malaysia. The study discovered that farmers were aware of the various economic implications of climate change – decrease in income level, price hiking of essential agricultural inputs and food items, the decline in rice production, etc. These factors contribute to a reduction in the self-sufficiency level of rice production in Malaysia. It is commonly acknowledged that climate change severely affects the means of livelihood, particularly that of farmers, who appear to be more vulnerable owing to the economic losses incurred.

Abubakar *et al.* (2021) have identified several adaptation options for farmers in Malaysia, including breeding heat-tolerant hybrid varieties; promoting sustainable soil management; building a pit and tranches for better water management in plantation areas; minimizing the use of fertilizer, herbicide and pesticide; practice of zero burning; and reducing tillage. However, according to Akhtar *et al.* (2019) farmers in Malaysia face several barriers to adaptation practices, including high farm input costs, a lack of water resources, unpredictable weather patterns, insufficient agricultural extension officers, limited access to credit facilities and a lack of agricultural subsidies. To address these obstacles, policymakers should consider building an agriculture-specific adaptation policy framework. Besides, farmers are advised to conserve water, increase irrigation, improve livestock management, plant dates and practice crop diversity to adapt to the adverse effect of climate change. Farmers, especially in emerging countries like Malaysia, must adapt to climate change to avert consequentially reduced productivity of the agricultural sector. Farmers must have a better grasp of climate change adaptation and be able to apply an effective adaptation mechanism to offset climate change's negative consequences. This can be accomplished through organizing training events, establishing vocational training and enhancing the capacities of others to assist farmers in improving their adaptive capacity. These programs are critical not only for farmers, but also for government officials who offer technical assistance. The study discovered that climate change negatively impacts the livestock, promotes land degradation, triggers an increase in food costs and encourages rural-urban migration. Climate change's negative impact on ecosystem services, agricultural production, and means of subsistence may pose a challenge for Malaysia in achieving sustainable agricultural development. Kumari *et al.* (2014) stated that climate change has an adverse effect on human and animal health. In a bid to minimizing pests and agricultural diseases, some farmers adopt more sustainable agricultural practices, such as natural farming. The long-standing impacts of climate change on agriculture are soil degradation, water pollution, shortage of freshwater and loss of biodiversity. In particular, the agricultural sector is naturally sensitive to climate change, which will trigger major encounters in the future. There is a need for Malaysia to provide communal funding for adaptation, as this is commonly missing in Association of Southeast Asian Nations (ASEAN) countries. An important approach in generating communal funding for adaptation is by involving small-scale farmers in the adaptation development procedure. Ho *et al.* (2021) argued that intervention programs strengthen communication networks between farmers and local governments, as well as other organizations that provide farmers with subsidies and training courses to help them cope with climatic events, and further recommended that farmers should be given more opportunities to diversify their income sources. This study also discovered that farmers' adaptive capacity was directly affected by their means of livelihood and indirectly by the economic, social and environmental impacts of climate change. Osumanu *et al.* (2017) and Bawakyillenuo *et al.* (2016) found a number of key factors (e.g. economic resources, institutions, information, education and farming experiences) influencing the adaptive capability of farmers. Juhola and Kruse (2015), Barnett and Adger (2007), Jones and Olken (2010) highlighted social capital, economic development, education, knowledge, organizations, equity, infrastructure and technology as generic drivers of adaptive capacity.

7. Conclusions and policy implications

The study revealed the economic, social and environmental impact of climate change on farmers' means of livelihood, which ultimately affects their adaptive capacity. Adaptation practices are essential in minimizing the negative effects of climate change; in other words, adaptation programs become fruitful when farmers' adaptive capacity is improved. Consequently, it is essential to develop farmers' adaptive capacity by focusing on the development of human, economic, social, physical and environmental capital. Drawing on the experiences of other regions such as Indonesia, the government could establish a school that develops the farmer's focus on adaptation, demonstrates the relevant methods for cultivating climate-resilient crop varieties and equips farmers with a knowledge-sharing team that bolsters their confidence. As adaptation is localized and local capacities need to be built, funding opportunities must be made available to local community groups and civil society organizations. Access to information is necessary to equip the farmers with knowledge; also, an assessment team should be made available to assist the farmers through the provision of effective measures for better outcomes. Moreover, coordination between the government and policymakers is required in the development of an integrated framework for the agricultural sector. This framework will empower the farmers with the skills necessary for the selection of best adoption strategy for their further advancement.

The findings of this study have a number of implications for enhancing farmers' adaptive capacity and adaptation techniques in Malaysia. As there is little research on how climate change affects the livelihoods of farmers in the context of Malaysia, the study provides a new perspective for policymakers to formulate a better adaptation policy framework towards the development of sustainable agriculture. The coordinating authorities should engage the farmers directly in the adaptation planning and decision-making to enable them to convey their concerns and priorities effectively. Additional training, information, and knowledge exchange from local NGOs and the government, as well as other basic resources, should be provided to improve their adaptation capacity. Furthermore, the government should provide some financial assistance to farmers for proper management of climate change adaptation techniques. It is believed that with high adaptation capacities, farmers' output will increase. This capacity could be built by providing effective and extensive education and training to farmers (particularly rice growers) on adaptation practices. This will not only assist them in adapting to climate change but also in mitigating its effects on agriculture.

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