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Modelling the sustainable agriculture management adaptation practices: Using adaptive capacity as a mediator

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The purpose of this research is to investigate the mediating role of farmers' adaptive capacity between adaptation practices and economic, social, natural, technological, and institutional limitations. A survey questionnaire was employed to collect data, which was subsequently analysed using PLS-Structural Equation Modelling Structural equation modelling. The entire population was stratified into 27 *Pertubuhan Peladang Kawasan* out of which 500 targeted respondents were randomly selected from seven strata for data collection. The findings revealed that only 67% of farmers are aware of adaptation practices, while 33% are uninformed. The study also revealed that economic, social, natural, technological, and institutional barriers affect farmers' adaptive capacity levels and ultimately hamper their adaptation practices. This result further affirms the influence of farmers' adaptive capacity level on their adaptation behaviour. Adaptation strategies are essential to mitigate the negative effects of climate change. However, the success of these strategies is contingent upon the farmers' adaptive capacity level, which is strained by several barriers. The findings contribute to the development of a national adaptation plan in a bid to aid the implementation of the 2011–2020 National Agri-Food Policy (NAP) to increase the competitiveness and production capacity of the entire agri-food industry value chain and ensure food security in Malaysia. This study will help policymakers come up with a good policy framework to get rid of the problems that get in the way of adapting to climate change.

KEYWORDS

adaptation practices, adaptive capacity, adoption barriers, sustainable agriculture management, PLS-structural equation modelling

Introduction

Livelihoods and agricultural sectors are under intense pressure due to their poor adaptive capacity (AC) amid exposure to extreme climatic conditions such as oods, droughts, cyclones and storms, which further increase the rate of plant pests and diseases (Abid et al., 2019; Parker et al., 2019). As a result, agricultural production has already begun to decline (IPCC, 2014; Kumasi et al., 2019), which could lead to food insecurity (Parker et al., 2019). Schroth et al. (2017) and Bunn et al. (2014) remarked that losses in "cacao and coffee" production could endanger national economies as well as the regional and global supply chains of these respective industries. Wang et al. (2018) discovered that the global production of the four major crops (maize, rice, wheat and soybeans) is affected by climate change. On average, climate change is expected to fuel the reduction in maize production from 3.3% to 5.2% to 6.4% to 12.2% by 2030 and 2050 respectively and decrease irrigated yield by 3%–8% in 2030 and 5%–14% in 2050, if the current varieties are still being cultivated (Tesfaye et al., 2017).

These developments threaten the progress towards the achievement of Sustainable Development Goal-2 (SDG-2): "End hunger, achieve food security and improve nutrition and promote sustainable agriculture." This sustainable development goal acknowledges the interrelationships between support for sustainable agriculture and the empowerment of small-scale farmers. Moreover, the demand for agricultural products is increasing with the rise of the global population, which may lead to food insecurity. In order to prevent such occurrence, sustainable agricultural development is essential, especially for developing nations like Malaysia. The impacts of climate change on agriculture have received a lot of attention in Malaysia due to its significant contribution of 8.1% to the GDP, with paddy being registered as the country's second largest agricultural product after oil palm (Department of Statistics Malaysia, 2018).

In Malaysia, agriculture, forestry, biodiversity, water resources, coastal and marine resources, public health and energy are vulnerable to the impacts of climate change (Tang, 2019). Hence, the farmers' adaptive capacity level should be strengthened to tackle the climate variability. Nevertheless, numerous barriers such as economic, social, natural, technological and institutional adversely hamper farmers' adaptive capacity and practices (Jones and Boyd, 2011; Islam et al., 2014). Despite the several studies on adaptation behaviour, barriers and strategies as well as the estimation of adaptive capacity (Masud et al., 2017), there is a lack of empirical evidence on how these barriers impede farmers' adaptive capacity as well as adaptation practices in the regional context. The design of appropriate adaptation strategies necessitates having a clearer picture of climate change, current adaptation model and its determinants (Abid et al., 2019). Thus, for policy improvement to combat the effect of climate change, which poses great challenges to farmers in Malaysia, it is paramount to empirically assess the farmers' choice of proper adaptation measures and identify hindrances impeding their adaptive capacity and adaptation behaviour towards sustainable agricultural management amid climate changes. Those most vulnerable to climate change have little adaptability. Therefore, it's important to determine which of these talents will provide a basis for investigating effective strategies to help Malaysian farmers' livelihoods and agricultural productivity. Juhola and Kruse (2015) and Adger et al. (2009) hypothesised that assessing adaptable capacity improves climate change adaptation tactics. To guard against socio-ecological vulnerability, adaptation must be greatly increased (Yazdanpanah et al., 2022). Institutions, education, knowledge, equity, economic growth, social capital, infrastructure, and technology predict adaptive capabilities (Adger et al., 2009; Jones and Boyd, 2011). Therefore, this study aims to examine the impact of various types of barriers namely economic, social, natural, technological, and institutional on farmers' adaptive capacity with its mediating effects.

Literature review and hypothesised development

Economic barrier and farmers' perceived adaptive capacity

The adverse effects of climate change could be subdued by undertaking the proposed numerous short and long-term adaptation approaches for sustainable agriculture (Chenani et al., 2021). The effects of economic barriers (EB) to the adaptation practices for sustainable agricultural management are pronounced, especially for the small-scale farmers and low-income communities (Adger et al., 2009). Each type of adaptation involves direct or indirect financial costs to farmers (Antwi-Agyei et al., 2015), such as the adoption of enhanced crop varieties and divergence of livelihoods (Smit and Skinner, 2002). Monnereau et al. (2015) reported that financial implications to farmers include the cost of hull insurance, replacement of equipment, repairs, performance, safety standards and increased investment. Muller and Shackleton (2014) also argued that the lack of funding and government support is a leading obstacle to climate change adaptation.

H1. EB positively influences AC.

Social barrier and farmers' perceived adaptive capacity

Several circumstances or hindrances cause adaptation strategies to be less effective (Antwi-Agyei et al., 2015).

Impediments have been recognised as limiting climatic adaptations that are endogenous, outright, and thus incomparable (Reckien et al., 2015; Dow et al., 2013). Various agendas and methods have been considered to actualize the elimination of limitations and barriers to climate adaptation (Kolikow et al., 2012; Lehmann et al., 2015; Dow et al., 2013). However, the following have been highlighted as main impediments to the implementation of climate adaptation: First, the incapacity of ecological system to adjust to the speed and degree of climate variability; second, the hindrances of technology, economy, psychology, behaviour, society, institution, culture and nature (IPCC, 2007; Jones and Boyd, 2011); and third, natural boundaries, ranging from thresholds of ecosystems to geographic and geological boundaries (Jones and Boyd, 2011). These impediments might cause inconsistency between the proposed need for adaptation and a general failure to take appropriate steps towards climate conditions (Chenani et al., 2021).

H2. SB positively influences AC.

Natural barrier and farmers' perceived adaptive capacity

Restrictions and hindrances to local adaptation may arise at various time-space levels (Adger et al., 2005) and may be affected by several factors. As an instance, the dynamic nature of climate change can retrofit the physical environment to restrict the possibilities for adaptation (Nicholls and Tol, 2006). In addition, the sensitive nature of certain ecosystems, habitations and species could influence the restrictions of adaptation (Adger et al., 2009). Therefore, sectors such as agriculture and fisheries, which are directly affected by the ecological system, will have more limited adaptation possibilities.

H3. NB positively influences AC.

Technological barrier and farmers' perceived adaptive capacity

The fourth type of barriers to adaptation is associated with technology (Antwi-Agyei et al., 2013). Lack of heavy equipment, instruments, techniques, and engineering structures may impede adaptation practices (Reeder et al., 2009), especially in Asia, where there is a lack of precise weather projections. The absence of evidence, information and data regarding the shocks of climate variability may stall the adaptation process (Islam et al., 2014). Besides, other technological barriers (TB) include limited availability of drought-tolerant crop varieties and specific localisation technologies (Niranjan et al., 2013; Suddhiyam et al., 2013); lack of adequate fund and institutional capacity to support research and development activities on climate change adaptation (Mahat et al., 2019; Moser et al., 2019); poor management of "irrigation and water infrastructure" in rainfed zones (Panda, 2016); and lack of initial investment in water and wastewater machineries, and water conservation systems, such as micro-irrigation and water reservoir (Palanisami et al., 2015).

H4. TB positively influences AC.

Institutional barrier and farmers' perceived adaptive capacity

The institutional barriers refer to the "social cement which links stakeholders to access to capital of different kinds to the means of exercising power and so define the gateways which they pass on the route to positive or negative adaptations" (Davies, 2016). Institutions contribute significantly to the improvement of the local farmers' ability to tackle climate change and provide instrumentality for social determinants (Agrawal and Perrin, 2009). Institutional barriers (IB) arise in the context of adaptive governance in developing as well as developed countries (Agrawal, 2010; Barnett et al., 2015). These relate to the challenges of institutional coordination through gauges and segments, the dispersion of responsibilities, and the institutional receptiveness to eliminate (Adger et al., 2009) leadership-specific obstacles (Flugman et al., 2012; Burch, 2010). In addition, Azhoni et al. (2018) opined that the integration of strategies for adaptation may be influenced by the institutional barriers of individuals and organisations.

H5. IB positively influences AC.

Farmers' perceived adaptive capacity and adaptation practices for sustainable agriculture management

Farmers need to constantly adjust their agricultural behaviour to adapt to the severe problems caused by extreme climate change (Chenani et al., 2021; Pakmehr et al., 2020). How risk is perceived and the process of coping with it has been repeatedly shown to influence adaptation decisions (Yazdanpanah et al., 2022; Pakmehr et al., 2020). This study uses farmers' perceived adaptive capacity as a mediator to investigate the impact of social barriers (SB), natural barriers, economic barriers, technological barriers, and institutional barriers on adaptation practises for sustainable agriculture management (AP). To build farmers' capacities against unpredictable climatic events that threaten their livelihoods, climate adaptation strategies need to be integrated into sustainable poverty alleviation as well as rural development

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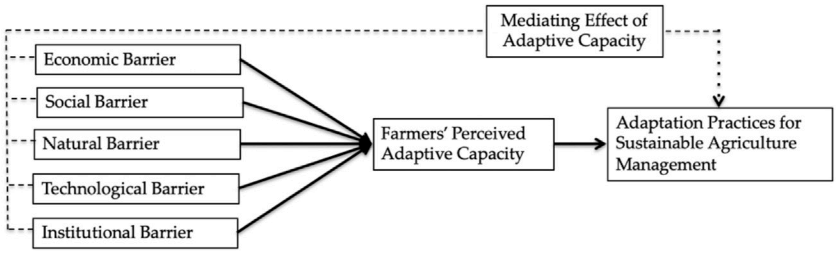

FIGURE 1
Research framework.

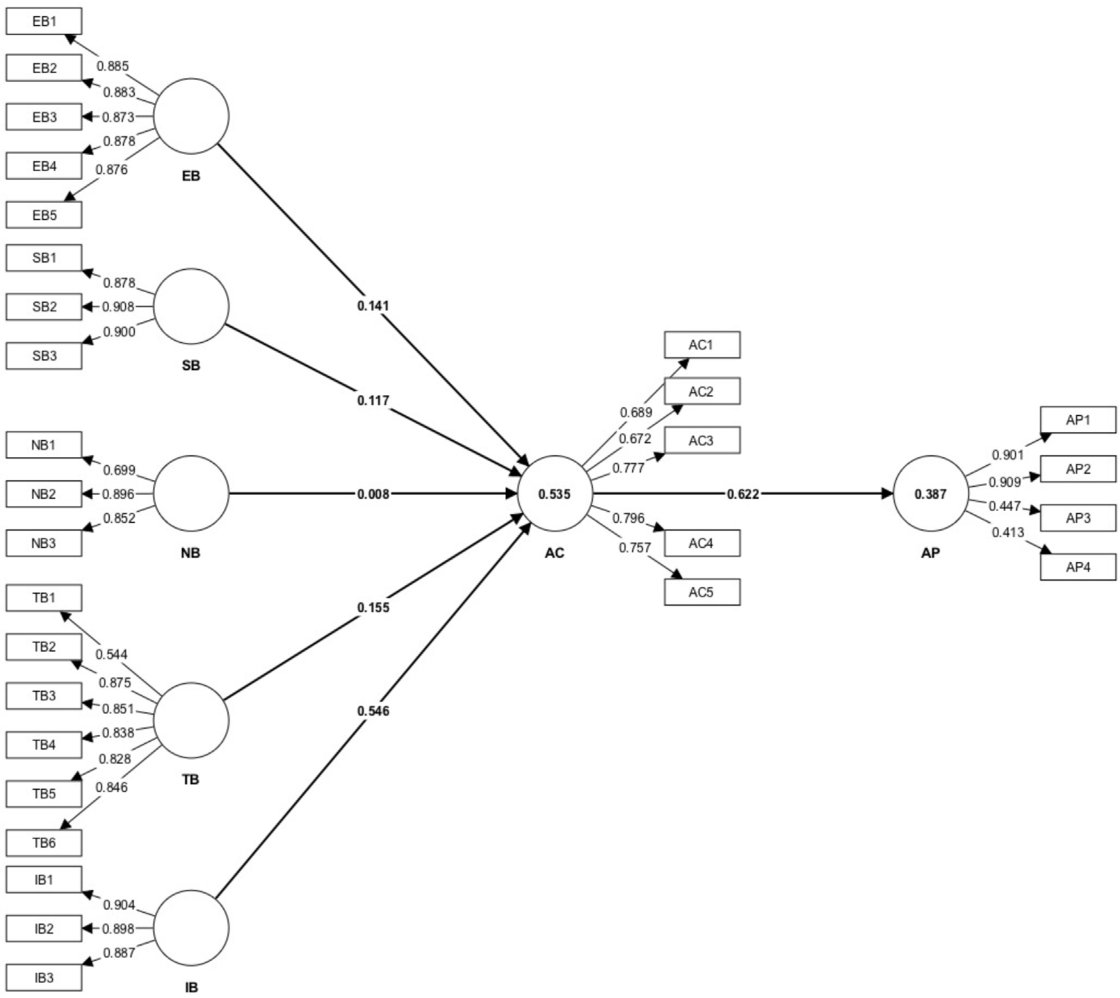

FIGURE 2
Measurement model with outer loadings.

agendas (Mashizha, 2019). Adaptation could minimise vulnerability to climate change and ameliorate its potential damage and negative impacts by engaging the agricultural populations with adaptive skills and measures (Dubois et al., 2012). Adaptation is defined by IPCC (2007) as “adjustment in natural or human systems in response to actual or expected

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climate stimuli or their effects, which moderates harm or exploits beneficial opportunities." However, adaptation practices mostly depend on farmers' adaptive capacity, which is also impeded by several barriers. Adaptive capacity is described in social systems from a variety of viewpoints, including "economic resources, technology, information, and skills, infrastructure, institutions, and equity" (Yohe and Tol, 2002). Yazdanpanah et al. (2022) stated that perceived competence as a part of cognitive process can influence individuals' intention to adopt from various aspects such as intellectual, social, environmental, and economic. Based on the above evidence, this study used Farmers' Perceived Adaptive Capacity to measure Adaptation Practices for Sustainable Agriculture Management.

TABLE 1 Social and demographic information of the farmers.

	Frequency	Percentage
Gender		
Male	360	90.00
Female	40	10.00
Age		
25 years or below	0	0.00
26–35 years	7	1.75
36–45 years	13	3.25
46–55 years	70	17.50
56–65 years	310	77.5
Education level		
No formal education	37	9.25
Primary	130	32.50
Lower secondary	120	30.00
Higher secondary	104	26.00
Diploma	9	2.25
Bachelor	0	0.00
Postgraduate	0	0.00
Household income (RM/Monthly)		
RM 2,000 and below	245	61.25
RM 2,001–RM 4,000	134	33.50
RM 4,001–RM 6,000	14	3.50
RM 6,001–RM 8,000	7	1.75

Source: Author's data analysis.

H6. AC positively influences AP.

Based on the comprehensive literature review, it was comprehended that numerous studies were conducted on adaptation barriers. However, most of them only emphasize the associated adaptation barriers in agricultural sectors, without any empirical investigation into how these barriers affect the farmers' adaptive capacity and adaptation practices. Therefore, to bridge this research gap, this study proposes the following model (Figure 1). It reveals how natural, economic, social, technological, and institutional barriers affect farmers' adaptive capacity as well as adaptation behaviour.

Research methodology

Sampling technique and size

This study considered the MADA region of Kedah in Malaysia as a case study. This area, which is frequently referred to as the "rice bowl of Malaysia," was chosen because it contributes 75% of all the rice produced in Malaysia. There are approximately 55,130 farmers involved with rice production in the study area (Kamaruddin et al., 2013). The entire population were stratified according to 27 PPK. PPK is known as the Bahasa Malaysia Pertubuhan Peladang Kawasan (PPK), is located in MADA. Out of which six were selected randomly to collect data. This study used a stratified random sampling method to get data from 500 participants, which was more than the minimum advised sample size. Due to time and money restrictions, it is challenging to cover all strata, thus we selected seven strata (7 PPK) and then randomly selected a proportionate number of respondents from each stratum.

TABLE 2 Reliability and validity.

Variables	Cronbach's alpha	Dijkstra-Henseler's rho	Composite reliability	Average variance extracted	Variance inflation factor
EB	0.926	0.928	0.944	0.772	1.356
SB	0.877	0.890	0.924	0.801	1.371
NB	0.753	0.787	0.859	0.673	1.742
TB	0.886	0.882	0.916	0.648	1.415
IB	0.878	0.878	0.925	0.803	1.219
AC	0.791	0.793	0.858	0.547	1.000
AP	0.719	0.865	0.782	0.503	0.000

Note: EB, economic barrier; SB, social barrier; NB, natural barrier; TB, technological barrier; IB, institutional barrier; AC, Farmers' Perceived Adaptive Capacity; AP, adaptation practices for sustainable agriculture management.
Source: Author's data analysis

TABLE 3 Discriminant validity.

	EB	SB	NB	TB	IB	AC	AP
Heterotrait-monotrait ratio (HTMT)							
EB	—						
SB	0.347	—					
NB	0.503	0.652	—				
TB	0.410	0.308	0.570	—			
IB	0.390	0.258	0.393	0.341	—		
AC	0.503	0.396	0.490	0.485	0.810	—	
AP	0.422	0.370	0.433	0.410	0.292	0.655	—
Fornell-Larcker criterion							
EB	0.879						
SB	0.312	0.895					
NB	0.419	0.507	0.820				
TB	0.381	0.281	0.494	0.805			
IB	0.352	0.229	0.327	0.311	0.896		
AC	0.432	0.333	0.381	0.415	0.674	0.740	
AP	0.325	0.299	0.301	0.328	0.256	0.622	0.709

Note: EB, economic barrier; SB, social barrier; NB, natural barrier; TB, technological barrier; IB, institutional barrier; AC, Farmers' Perceived Adaptive Capacity; AP, adaptation practices for sustainable agriculture management.
Source: Author's data analysis

In order to obtain appropriate sample size from the known population, the following formula by Yamane (1967) was used:

$$s = N/\left(1 + Ne^2\right) \tag{1}$$

where s = sample size, N = number of farmers in the study area, and e = margin of error (0.05). Based on the formula by Yamane (1967), the required sample size for this study is 384. 500 respondents were selected for this study in the area. Ultimately, a representative sample of 400 was selected based on factors such as the completeness of the collected questionnaires, which could represent the demographic characteristics of this target population.

Questionnaire development

In order to achieve the research objectives, a survey questionnaire was developed and analysed to identify all the barriers associated with climate change adaptation and measure farmers' adaptation capacity and practices (Jones and Boyd, 2011; Islam et al., 2014; Casey and Becker, 2019). The questionnaire consisted of three sections. The first section collects the participants' socio-demographic information, such as age, gender, and income and education level. The second section comprises questions regarding barriers to adaptation for climate change. Items were measured using a 5-point Likert scale with an anchor, ranging from 1 (strongly disagree) to 5 (strongly agree). The third section consists of items to measure farmer's adaptation capacity and practices. Using a face-to-face approach, the questionnaires were distributed and collected. The English items of the questionnaire were translated to Malay to ensure they are understood by all the respondents. All the measurement items in the questionnaire were developed and adapted from the study of (Akhtar et al., 2018; Masud et al., 2017; Jones and Boyd 2011) in light of the common adaptation practices in the region. All items used in this study presented in Appendix 1 Survey Instrument.

Data analysis

Demographic characteristics of the respondents

The descriptive statistics of the sampled respondents are presented in Table 1. According to the age distribution, 77.50% of the respondents aged between 56 and 65 years, while 17.50% are between 46 and 55 years. In other words, the majority of the farmers are middle-aged. This age group may be knowledgeable of the impact of climate change on the agricultural industry due to their extensive experience of climatic variations, which expands their farming knowledge (Abbas et al., 2019). The level of education revealed that 90.74% of respondents had formal education, ranging from primary education (32.5%) to

TABLE 4 Loading and cross-loading.

Items	EB	SB	NB	TB	IB	AC	AP
EB1	0.885	0.287	0.403	0.358	0.329	0.398	0.308
EB2	0.883	0.246	0.370	0.360	0.306	0.405	0.317
EB3	0.873	0.268	0.334	0.319	0.300	0.382	0.251
EB4	0.878	0.235	0.350	0.335	0.315	0.367	0.297
EB5	0.876	0.340	0.384	0.298	0.297	0.343	0.250
SB1	0.278	0.878	0.423	0.272	0.189	0.274	0.251
SB2	0.284	0.908	0.486	0.264	0.235	0.338	0.308
SB3	0.274	0.900	0.446	0.216	0.183	0.275	0.235
NB1	0.308	0.621	0.699	0.257	0.200	0.258	0.274
NB2	0.365	0.336	0.896	0.464	0.348	0.367	0.251
NB3	0.357	0.347	0.852	0.469	0.236	0.301	0.226
TB1	0.362	0.285	0.669	0.544	0.359	0.384	0.233
TB2	0.323	0.265	0.368	0.875	0.254	0.346	0.278
TB3	0.271	0.194	0.284	0.851	0.213	0.321	0.304
TB4	0.286	0.205	0.321	0.838	0.201	0.306	0.278
TB5	0.286	0.188	0.324	0.828	0.214	0.293	0.226
TB6	0.257	0.168	0.299	0.846	0.197	0.295	0.232
IB1	0.284	0.194	0.288	0.253	0.904	0.589	0.227
IB2	0.338	0.176	0.297	0.270	0.898	0.625	0.234
IB3	0.324	0.246	0.293	0.312	0.887	0.596	0.227
AC1	0.351	0.258	0.325	0.299	0.775	0.689	0.214
AC2	0.337	0.178	0.280	0.261	0.785	0.672	0.206
AC3	0.352	0.264	0.218	0.312	0.334	0.777	0.632
AC4	0.280	0.264	0.312	0.341	0.306	0.796	0.659
AC5	0.276	0.267	0.275	0.319	0.294	0.757	0.580
AP1	0.245	0.251	0.252	0.303	0.236	0.571	0.901
AP2	0.292	0.260	0.253	0.261	0.223	0.610	0.909
AP3	0.262	0.216	0.224	0.212	0.139	0.185	0.447
AP4	0.219	0.145	0.198	0.202	0.086	0.096	0.413

Note: EB, economic barrier; SB, social barrier; NB, natural barrier; TB, technological barrier; IB, institutional barrier; AC, Farmers' Perceived Adaptive Capacity; AP, adaptation practices for sustainable agriculture management.
Source: Author's data analysis

lower secondary education (30%), higher secondary education (26%) and diploma (2.25%); while 9.25% are formally uneducated (Table 1). In regard to the respondents' monthly income, majority (61.25%) earn below RM 2000, 33.5% earn between RM 2001 and RM 4000, 3.5% earn between RM 4001 and RM 6000, and only 1.75% of farmers earn between RM 6001 and RM 8000.

Reflective measurement model

This study uses Cronbach's Alpha, Composite reliability (CR) and Dijkstra - Henseler's rho to measure the internal consistency of the constructs; Fornell and Larcker Criterion and Heterotrait-Monotrait Ratio of Correlations (HTMT) to measure the discriminant validity of the model; using the outer loading and Average Variance Extracted; Finally, use Variance Inflation Factor (VIF) to check for possible collinearity issues.

Reliability and validity of reflective measurement model

Firstly, the results in Table 2 show that the Cronbach's alpha, Dijkstra - Henseler's rho and Composite reliability of all items are greater than 0.7, and the model has good internal consistency (Hair et al., 2017). Secondly, the Heterotrait-monotrait ratio (HTMT) in Table 3 are less than the recommended threshold of 0.85 and the result of Fornell and Larcker Criterion indicates that all constructs meet the satisfactory discriminant validity, with the square roots of AVE (diagonal) exceeding the correlations (off-diagonal) for all the constructs (Fornell and Larcker, 1981), the model has good discriminant validity (Hair et al., 2017). Finally, when measuring the convergent validity of the reflective model, this study uses a combination of considerations (Hair et al., 2017). Among the results, as reported in Table 4 and Figure 2 shows that the loading values of all items are greater than 0.5, which is greater than the recommended minimum threshold. Also, the loading values of all items are greater than the relevant cross-loading values. The values of Average Variance Extracted (AVE) are greater than 0.5, and the convergent validity of the model is acceptable. Finally, the values of Variance Inflation Factor (VIF) are all less than 3.3, indicating that there is no need to consider any collinearity issues in this study 3 (Diamantopoulos and Siguaw, 2006).

Test for hypothesised model

This study employed PLS-SEM to examine the relationship between barriers to adaptation practices, adaptive capacity, and adaptation behaviour for sustainable agriculture management. Before testing hypothesis, we check variance inflation factors (VIF) to avoid multi-collinearity issue. We found that VIF value range from 1.000 to 1.742 which is within threshold of >5 (Hair et al., 2017) and 3.3 (Diamantopoulos and Siguaw, 2006). Table 5; Figure 3 indicate that the R^2 for adaptive capacity (AC) is 53.5%, which suggest that all variables contributed to about 53.5% of the variance explained in AC. Moreover, the R^2 for adaptation practices (AP) was 38.7%, which indicates that all the studied variables contributed to approximately 38.7% of the variance explained in AP. The results reveal that economic barriers (β = 0.141), social barriers (β = 0.117), technological barriers (β = 0.155) and institutional barriers (β = 0.546) have positive; significant effects on adaptive capacity at 1% significance level; the confidence interval between the minimum and maximum does not contain zero, thereby supporting H1, H2, H4, H5 and

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TABLE 5 Hypothesis testing.

Hypothesis	Beta	CI (min)	CI (max)	t-Value	r^2	f^2	p	Decision
Factors affecting AC								
EB → AC	0.141	0.070	0.212	3.268		0.032	0.001	Supported
SB → AC	0.117	0.041	0.193	2.556		0.021	0.005	Supported
NB → AC	0.008	−0.064	0.082	0.178	0.535	0.000	0.429	Not supported
TB → AC	0.155	0.090	0.225	3.745		0.036	0.000	Supported
IB → AC	0.546	0.467	0.609	12.572		0.527	0.000	Supported
Factors affecting AP								
AC → AP	0.622	0.562	0.686	16.268	0.387	0.632	0.000	Supported
Mediating Effect of AC								
EB → AC → AP	0.088	0.043	0.136	3.076			0.001	Mediation
SB → AC → AP	0.073	0.025	0.123	2.478			0.007	Mediation
NB → AC → AP	0.005	−0.039	0.052	0.177			0.430	No Mediation
TB → AC → AP	0.096	0.056	0.143	3.656			0.000	Mediation
IB → AC → AP	0.340	0.287	0.389	11.100			0.000	Mediation

Note: EB, economic barrier; SB, social barrier; NB, natural barrier; TB, technological barrier; IB, institutional barrier; AC, Farmers' Perceived Adaptive Capacity; AP, adaptation practices for sustainable agriculture management.
Source: Author's data analysis

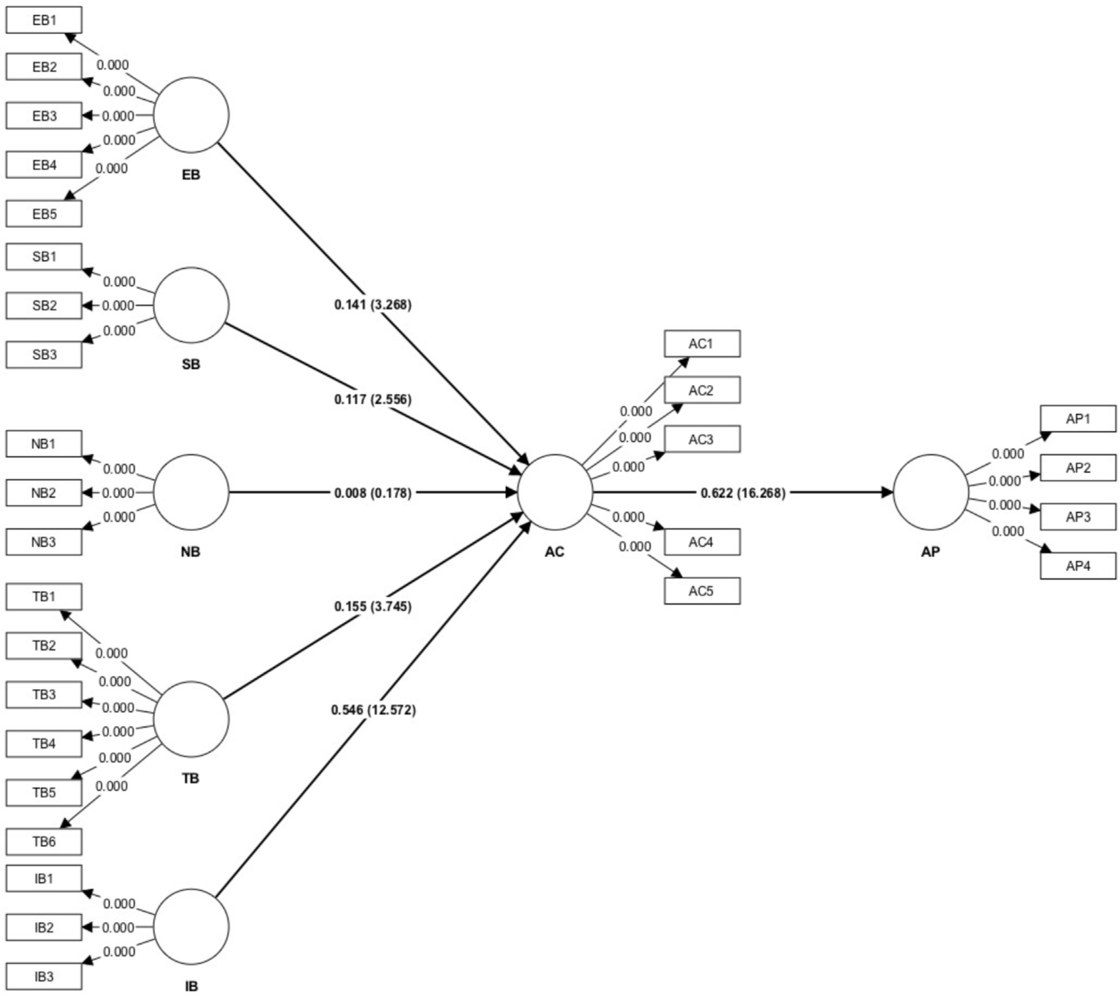

FIGURE 3
Research hypothesised model.

H6. On the contrary, natural barriers lack any significant effects on adaptation measures, given the positive beta coefficient (β = 0.008), thereby disproving H3.

Mediating effects of adaptive capacity

When examining the mediating effects between economic, social, technological and institutional barriers as well as adaptation practices, we identified a partial mediation effect of adaptive capacity and adaptation practices with β = 0.088, 0.073, 0.096 and 0.340 respectively, at 1% significant level (Table 5). However, no mediating effect of farmers' adaptive capacity was observed between natural barriers and adaptation practices.

Discussions

The results revealed that economic barriers have significant impact on adaptive capacity and represent a key issue in adaptation measure, as substantial investment in adaptation practices will bring long-term benefits. In this regard, Islam et al. (2014) identified two key economic barriers: low-income and lack of access to credit for investment in other means of subsistence. Muller and Shackleton (2014); Smit and Skinner (2002) also stated that lack of financial capital and government support critically affects climate change adaptation. Other types of economics barriers that are associated with adaptive practices include small and insufficient delivery of proper financial amenities (loan and coverage) to rural poor and marginal small-scale farmers (Singh et al., 2019); lack of market access for farmers as well as poor agricultural marketing (Elum et al., 2017), absence of post-harvest and storage accommodations (Rahiel et al., 2018); and the lack of power (Verma et al., 2019). The above evidence also indicates that the level of economic development as a measure of regional economic development can also be used to reflect the extent to which rural areas are receptive to new things and technologies. Rural areas with higher levels of economic development are more receptive to new technologies because of the ease of information flow, market openness, and transparency, and farmers have better perceived adaptive capacity. At the same time, farmers in areas with higher levels of economic development are also able to bear the risks associated with the failure of technology adoption due to their economic strength, which may also be one of the important reasons for this result.

Besides economic barriers, the result also revealed that social barriers influence adaptation capacity. It is greatly acknowledged that social aspects shape individual and influence their perception of risks associated with some climatic phenomenon. As an instance, lack of education, appropriate adaption skills and training will limit the farmers' ability to adopt suitable adaptation procedures and policies (Nelson et al., 2009; Wright et al., 2014).

The findings also suggest the vulnerability of farmers to natural barriers. The agricultural sector is not resilient due to its complex interaction with climate variability (Roy and Haider, 2018). Recent decades have witnessed a rise in the frequency of natural disasters such as flooding, cyclones and sandbars, which constrain adaptation practices and dwindle the potential for growth and export of agricultural products (Alboghdady and El-Hendawy, 2016; Jones and Boyd, 2011; Islam et al., 2014).

Institutional barriers exhibit a direct and indirect impact on adaptation (Adger et al., 2009). Institutions contribute significantly to the preparation of the locals to tackle climate change and provide approaches that enhance the societal interactions (Antwi-Agyei et al., 2015). In addition, institutions need to enforce adaptation at every level and majorly, they are required to organise sufficient supports for farmers to adapt to climate variability. Besides, the institutions should emphasize technological advancement to enhance farmer's adaptive capacity and ensure improved rice production. Several studies have identified different types of institutional barriers against adaptation practices, which include gaps in policy implementation and weak inter-agency synchronisation to enforce adaptation activities (Azhoni et al., 2017); poor institutional arrangement for the collection and synthesis of data (Government of India, 2010); inadequacy of policymakers and other stakeholders in understanding climate change and its effect on agricultural research and development programmes (Antwi-Agyei et al., 2015); poor communal activities and insufficient involvement of public self-help groups in the combat against the effects of climate change (Karim and Thiel, 2017).

Technological and informational barriers also present significant hindrances to the sustainable development of agriculture. These barriers, which delay the adaptation attitudes, include farmers' insufficient information, absence of weather predictions and inadequate knowledge of the impact of climate variability (Adger et al., 2009; Islam et al., 2014). According to Islam et al. (2014) and Adger et al. (2009), the sectors that openly rely on ecosystems, for example fisheries and agriculture, are most vulnerable due to their lack of powerful engines and directional tools. Farmers are also affected by the lack of information and awareness about climate change (Taraz, 2017; Singh et al., 2018) in addition to their weak command of technology and extension.

Conclusion

Policy implications

It is crucial to address the barriers associated with the climate change adaptation in agricultural sector. The findings of this study revealed that economic, social, natural, and institutional barriers are the leading impediments towards the adaptation to climate change. They represent pressing issues that need to be addressed to enhance farmers' adaptive capacity and promote adaptation practices in Malaysian agricultural sector. Therefore, this study makes the following recommendations based on its findings: First, to lessen economic barriers, farmers should have easy access to credit or loan from financial institutions. Similarly, the price of all agricultural input materials should be made affordable and cheaper labour force from labour-intensive countries should be encouraged to fill the labour shortage of this sector. Second, to minimise social barriers, awareness program, skills development program as well as capacity-building programmes need to be introduced to educate farmers about climate change adaptation practices. Third, it was observed that farmers' encounter of soil degradation, soil erosion, water logging, water scarcity, frequency of floods and drought are increasing over the years. Therefore, it is imperative to train farmers on adaptive skills that promote sustainable use of agricultural land. Fourth, all type of institutional support such as favourable credit scheme, sufficient enforcement of farming regulation, market access and agro-advisory services should be provided. Otherwise, institutional barriers will weaken the capacity of rural farmers to deal with extreme weather events. Last but not least, adaptation policy framework is needed to address climate-related challenges and ensure sustainable agricultural development.

Finally, it should be noted that there are still some limitations to this study. First, the study did not give specific characteristics of sustainable agricultural management and the main ways to do so when conducting the data survey. Future researchers could try to include more specific types of technologies on this basis. Second, the theoretical basis and research framework of this study are still not complete, and other factors may appear in the results that are not part of this study's variables, such as knowledge bias, gender bias, age bias, etc. Further categorization of the respondent population may be needed in the future to investigate whether demographic characteristics such as age are also a factor affecting perceived adaptive capacity and new technology adoption.

Data availability statement

The raw data supporting the conclusion of this article published as Supplementary Material with this article.

Ethics statement

Ethical review and approval was not required for the study on human participants in accordance with the local legislation and institutional requirements. The patients/participants provided their written informed consent to participate in this study.

Author contributions

RA, MU, LS, and QY—Conceptualisation, Survey Instrument, Writing—Original Draft. MM and AA—Conceptualisation, Formal Analysis, Writing—Revision.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fenvs.2022.963465/full#supplementary-material

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Appendix 1Survey instrument.

Economic Barrier (EB)
I have financial problem due to the high cost of adaptation
I do not have access to credit
High costs for agricultural inputs
High cost of adaptation measures
Shortage of labour
Social Barrier (SB)
Lack of education and skills
Lack of understanding of adaptation practices
I am not well-informed about climate change adaptation
Natural Barrier (NB)
Water scarcity is increased
Droughts and floods are increased
Frequency of flooding promote crop damage
Technological Barrier (TB)
There is an absence of radio signal
No access to long-term weather forecasts
Lack of effective early warning systems
Availability of new technologies
Lack of technical knowledge on adaptation
Insufficient irrigation and water-efficient infrastructure in rainfed areas
Institutional Barrier (IB)
Unfavorable credit schemes
Inadequate enforcement of farming regulations and criminal laws
I do not have access to agriculture markets
Adaptation Practices for Sustainable Agriculture Management (AP)
I use organic fertilizers to increase the production
I try to improve the irrigation system in the agriculture sector
I change my farming location
I encourage my neighbors towards adaptation against climate change
Farmers' Perceived Adaptive Capacity (AC)
I am knowledgeable of adaptation strategies
I use adaptation strategies
Adaptation strategies are available for use
Adaptation strategies are easily accessible
I have the opportunity to consult with experts regarding adaptation strategies