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Assessing Climate Change Sensitivity and Technology Adoption in Muda River Basin Farming Communities

Nurul Amiera Khalid[1], Nik Ahmad Sufian Burhan[2,3]*, Jasmin Arif Shah[1,3], Hayrol Azril Mohamed Shaffril[3,4], Asnarulkhadi Abu Samah[3,5], Haliza Abdul Rahman[3], Nobaya Ahmad[2,3], Shaufique Fahmi Ahmad Sidique[6], Samsul Farid Samsudin[7], Fredolin Tangang[8,9], and Liew Juneng[8]

[1]*Department of Agriculture Technology, Faculty of Agriculture, Universiti Putra Malaysia, Selangor, Malaysia*
[2]*Department of Social and Development Sciences, Faculty of Human Ecology, Universiti Putra Malaysia, Selangor, Malaysia*
[3]*Institute for Social Science Studies, Universiti Putra Malaysia, Selangor, Malaysia*
[4]*Department of Social Science Education, Faculty of Social Sciences, Universitas Negeri Malang, Malang City, Indonesia*
[5]*Malaysian Research Institute on Ageing, Universiti Putra Malaysia, Selangor, Malaysia*
[6]*School of Business and Economics, Universiti Putra Malaysia, Selangor, Malaysia*
[7]*Department of Library and Information Science, Faculty of Art and Social Science, Universiti Malaya, Kuala Lumpur, Malaysia*
[8]*Department of Earth Sciences and Environment, Faculty of Science and Technology, Universiti Kebangsaan Malaysia, Selangor, Malaysia*
[9]*Faculty of Arts and Social Sciences, Universiti Brunei Darussalam, Brunei*

ABSTRACT

The Muda River Basin (MRB), Malaysia's main rice region, is increasingly vulnerable to climate change. This study examines how economic, political, cultural, and institutional sensitivities influence farmers' adoption of climate adaptation technologies. Despite MRB's agricultural importance, empirical research on these social dimensions remains limited. A quantitative survey involving 382 farmers across five districts in Kedah was conducted using homogeneous convenience sampling. Data were collected through validated questionnaires and analysed using descriptive, correlation, and regression techniques. On a five-point Likert scale (1 to 5), the results showed that farmers had moderately high levels of technology adoption (3.68), economic (3.46), and political (3.10) sensitivity, and moderately low levels of cultural (2.04)

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E-mail addresses:
amierakhalid@gmail.com (Nurul Amiera Khalid)
nikahmadsufian@upm.edu.my (Nik Ahmad Sufian Burhan)
jasmin.arifshah@upm.edu.my (Jasmin Arif Shah)
hayrol82@gmail.com (Hayrol Azril Mohamed Shaffril)
asnarulhadi@gmail.com (Asnarulkhadi Abu Samah)
dr.haliza@upm.edu.my (Haliza Abdul Rahman)
nobaya@upm.edu.my (Nobaya Ahmad)
shaufique@upm.edu.my (Shaufique Fahmi Ahmad Sidique)
samsulfarid@um.edu.my (Samsul Farid Samsudin)
tangang@pkrisc.cc.ukm.my (Fredolin Tangang)
juneng@ukm.my (Liew Juneng)
*Corresponding author

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and institutional (2.52) sensitivity. Correlation analysis indicates that technology adoption was positively related to economic, political, and institutional sensitivity, but negatively related to cultural sensitivity. Regression results indicated that economic and institutional factors encouraged technology adoption, while cultural factors hindered it, and political influences were minimal. Among the sensitivity dimensions, cultural sensitivity exerted the strongest influence on technology adoption, followed by institutional and economic sensitivity. Although the model's explanatory power was modest ($R^2 = 0.295$), findings underscore the need for stronger institutional support, culturally sensitive extension services, and financial incentives to build farmers' adaptive capacity and resilience. Findings suggest that policymakers should promote technology adoption by fostering cultural integration, strengthening institutions, offering economic incentives, diversifying communication, and prioritising institutional over political support for climate adaptation.

Keywords: Adaptative measures, agricultural innovation, climate resilience, institutional support, social sensitivity

INTRODUCTION

The Muda River Basin is one of the river basins in Peninsular Malaysia. It is critical in providing freshwater resources to states for domestic, industrial, and agricultural use for the states of Kedah and Penang (Ibrahim & Chan, 1996; Shamsiah Omar et al., 2023). The Muda River Basin's climate is characterised by the Northeast Monsoon from November to March, the Southwest Monsoon from May to August, and two inter-monsoons in April and October. The Muda River Basin typically receives more rainfall during the inter-monsoons because the Titiwangsa and Sumatra Mountain ranges reduce heavy rainfall brought by the northeast and southwest monsoons (Suhaila et al., 2010; Zulkafli et al., 2021).

In recent decades, the area has experienced intense weather patterns and climatic events, such as the devastating droughts caused by El Nino in 1997 and the floods caused by La Nina in 2011 and 2012. Monsoon floods have also caused significant losses, including fatalities, in various parts of the country hit by monsoon winds. The 2010 monsoon floods in Kedah and Perlis were among Malaysia's most severe. Climate variability causes annual floods in the Muda River Basin, which are a significant source of concern. According to Ghani et al. (2010), the basin floods almost every year during the rainy season. One of the severe floods in October 2003 affected approximately 45,000 people. Furthermore, in 2011, Muda Agricultural Development Authority (MADA) reported that rice production in Kedah was hampered by a natural disaster. Floods between 2005 and 2010 damaged 48,693 hectares of fields, affecting 32,794 paddy farmers (Firdaus et al., 2017). These disruptions highlight the significant impact that climate change has on agricultural productivity.

In recent years, the Muda River Basin's climate has changed dramatically, and extreme weather events have had an impact. Climate change poses significant risks to the basin, as evidenced by rising temperatures, shifting precipitation patterns, and increased frequency of extreme weather events (Luhaim et al., 2021). Droughts have become more frequent and severe, owing to decreased rainfall during the southwest monsoon and increased evapotranspiration rates caused by rising temperatures. Droughts have a significant economic impact, particularly on agriculture. For example, a prolonged drought in 2018 caused supply disruptions in palm oil production, affecting Malaysian economic growth, particularly in the fourth quarter of 2019. Furthermore, it was discovered that even slight temperature increases have a significant negative impact on paddy yield. According to Siwar et al. (2013), climate inconsistency has reduced rice production by 13-80% and other crops by 10-30%.

The agriculture sector in the Muda River Basin is facing significant challenges as a result of climate change, particularly in dealing with droughts and floods. Extreme weather events cause significant crop damage, financial difficulties, and reduced farmer incomes. Many efforts have been launched in Muda River Basins to mitigate climate change and assist farmers in adapting to changing climatic conditions in response to droughts and floods. Using technology is a common strategy for adapting to climate change. The use of new technology tools will help farmers improve their farming techniques (Lakhan et al., 2020). Local farmers face significant barriers to adopting agricultural technologies, resulting in a persistent lack of uptake despite the potential benefits. According to research, extreme weather conditions force farmers to implement strategies to improve their ability to withstand challenges and maintain their means of subsistence, prompting government intervention. According to Akhtar et al. (2019), farmers in Kedah who are more adaptable to climate change have higher agricultural outputs, while those with a moderate level of adaptability also have minimal positive outcomes. There are opportunities to improve extension services and government support by providing grants and training to increase adaptability and output levels. According to Afroz et al. (2017), Malaysian rice farmers' willingness to invest in crop insurance as a disaster coping strategy has increased as extreme weather conditions have become more common. Furthermore, Chan (2014) emphasised the significance of political factors in determining the effectiveness of disaster response, highlighting that the speed and efficiency of institutional actions play a crucial role in supporting farmers' resilience. Despite these insights, limited attention has been given to how farmers' social sensitivity such as their economic, political, cultural, and institutional experiences shapes their ability and willingness to adopt agricultural technologies for climate change adaptation.

While previous studies have explored farmers' perceptions and economic responses to climate change, few have examined how multiple dimensions of social sensitivity influence farmers' ability to adopt adaptive technologies. This study is innovative in integrating social sensitivity theory with

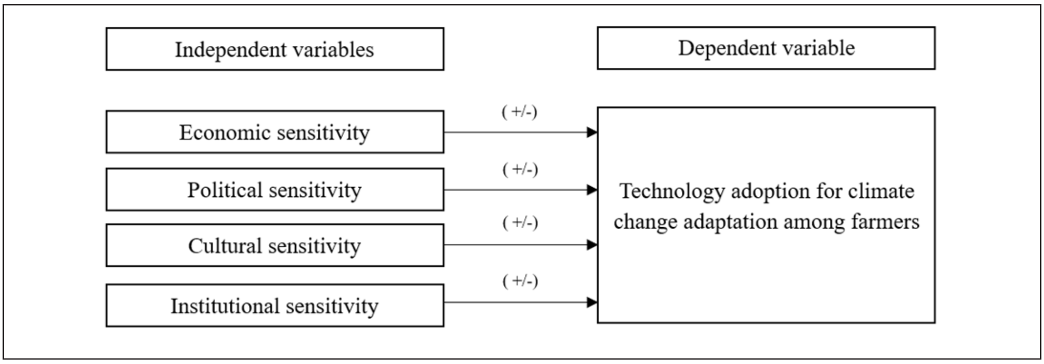

Figure 1. A conceptual framework for the relationship between sensitivity factors and farmer adoption of technology for climate change adaptation

the technology adoption framework to explain how farmers respond to climate change in the Muda River Basin. By analysing four domains of social sensitivity namely economic, political, cultural, and institutional. This research provides a more comprehensive understanding of the social factors that shape technology adoption behaviour.

The purpose of this study is to examine how these four sensitivity dimensions influence farmers' adoption of agricultural technologies for climate change adaptation in the Muda River Basin, Kedah. Specifically, it seeks to identify which sensitivity domains most strongly affect technology adoption and to generate policy insights that strengthen farmers' adaptive capacity through targeted economic and institutional support.

Figure 1 depicts the study's research framework, which conceptualises four sensitivity factors as independent variables and technology adoption for climate change adaptation as a dependent variable that is hypothetically influenced by climate change sensitivity.

Definition of Terms

This section provides a precise definition of the terms used in this study.

a. Technology adoption

In this study, technological adoption refers to people's willingness and ability to integrate and implement agricultural technologies that can mitigate the negative effects of extreme climate conditions. Assessing the relative advantages, compatibility, complexity, trialability, and observability of these technologies improve farmers' efficiency and adaptability, resulting in increased productivity and adaptive capacity to climate change impacts (Amadu et al., 2020; Davis, 1989; Li et al., 2024; Rogers, 2003).

b. Climate change sensitivity

The International Union for Conservation of Nature (IUCN) defines sensitivity as a system's responsiveness or susceptibility to climate change. The interdependence of social systems is shaped by a variety of factors, including the economy, politics, culture, and institutions, as examined by Fenton et al. (2007) and Marshall et al. (2010). These four factors have the potential to exacerbate or alleviate the effects of climate exposure.

i. Economic sensitivity

Economic sensitivity to climate change refers to how people perceive its effects on their financial well-being. This includes income, financial stability, livelihoods, living expenses, job security, employment, business operations, and economic stability. It includes concerns about adaptation costs, income loss, and productivity gains from adaptation (Abbass et al., 2022; IPCC, 2007; Nath & Behera, 2010; World Bank, 2010).

ii. Political sensitivity

Political sensitivity to climate change refers to farmers' perception of the political system's ability to address climate change as a significant factor in adaptation. Political will, the influence of political institutions on mitigation and adaptation measures, political stability, decision-making, and policy advocacy are all important factors (Adger et al., 2013b; Barnett & Adger, 2007; Gemenne et al., 2014; Silchenko & Murray, 2023).

iii. Cultural sensitivity

Cultural sensitivity to climate change refers to farmers' perceptions that climate change has impacted on their cultural values, identities, and social practices, thereby affecting traditional lifestyles and community cohesion. Cultural sensitivity involves incorporating cultural heritage, traditional ecological knowledge, and community identities into climate change adaptation strategies (Adger et al., 2013a; Crate & Nuttall, 2016; Fatorić & Egberts, 2020; Kostis & Kafka, 2023).

iv. Institutional sensitivity

Institutional sensitivity to climate change refers to farmers' perceptions of relevant institutions and organizations' ability to deal with climate change and its consequences. These institutions can implement and enforce climate policies, support adaptation and mitigation efforts, and manage resources (Adom et al., 2023; Ampaire et al., 2017; Azhoni et al., 2017; Jaaffar et al., 2018; World Bank, 2010).

LITERATURE REVIEW

Farmers are being forced to modify their agricultural operations in order to ensure the sector's long-term viability as the effects of climate change worsen. The adoption of agricultural technology is a critical factor in determining an agricultural community's ability to successfully deal with climate variability. Adoption of technologies refers to the integration of new innovations, such as tools, strategies, and practices. It is critical to understand the relationship between economic, political, cultural, and institutional sensitivity to encourage farmers to use new technology during climate extremes.

Economic Sensitivity of Farmers towards Technology Adoption for Climate Change Adaptation

Economic sensitivity to climate change refers to how extreme weather affects farmers' financial stability, income, and overall economic situation. Financial capacity and sound financial behaviour play an important role in supporting Malaysian household economic well-being (Sabri et al., 2021, 2022, 2023). When farmers experience significant economic losses because of disasters such as droughts, floods, or heatwaves, their financial constraints increase, forcing them to seek adaptive solutions, including new technologies. For starters, economic losses resulting from climate extremes may encourage farmers to use technology to reduce future risks and boost productivity. Many agricultural technologies aim to reduce climate risk, either by reducing sensitivity or exposure to climate impacts (Biagini et al., 2014). Farmers who have suffered significant financial losses due to poor weather conditions are more likely to invest in technology that promises higher yields or better risk management (Harvey et al., 2018). According to Alvi and Jamil (2018), the use of technology in South Asia increases maize, rice, and wheat yields. Furthermore, drought tolerance varieties assist farmers in dealing with extreme weather conditions because they are more resilient and provide farmers with higher productivity (Simtowe et al., 2019).

Furthermore, economic sensitivity can influence farmers' decisions regarding technology adoption. In times of economic difficulty, farmers are more likely to adopt technologies that provide immediate cash benefits or cost savings, even if they require an initial investment (Hassan et al., 2008). Financial incentives, such as subsidies or grants, can also increase their willingness to try new approaches (Wu et al., 2022). Tanti et al. (2022) discovered that smallholder farming groups will only take active and ongoing climate adaptation measures if they receive financial assistance from government-funded initiatives. Furthermore, one of the primary reasons for Pakistani farmers stated unwillingness to pay more for green energy adoption was a lack of financial resources (Elahi et al., 2022). According to Nguyen et al. (2021), the availability of financial resources increases farmers' ability to invest, particularly in high-cost technologies. When faced with financial hardship, their priority is not climate change adaptation, but rather family expenses (Kichamu et al., 2017). Furthermore, farmers could devote more attention to climate change adaptation if they were freed from economic constraints such as spending money on fertiliser (Esham & Garforth, 2013). Thus, the potential economic benefits of new technology play an important role in motivating farmers to adopt it.

Political Sensitivity of Farmers towards Technology Adoption for Climate Change Adaptation

Political sensitivity to climate change refers to political actions or responses to the consequences of climate change that are heavily influenced by policies and political stability. The adoption of new technologies by farmers can be influenced by government policies, whether supportive or restrictive. Policies that help, such as financial incentives for climate-resilient technology or increased funding for agricultural research, have been shown to increase farmers' willingness to adopt new technologies. For example, studies have shown that political ideology can influence farmers' beliefs about climate change and their willingness to use technologies as adaptation strategies (Amadou et al., 2022; Ricart et al., 2018). Farmers in politically stable environments with supportive agricultural policies are more likely to adopt climate-resilient practices (Azadi, 2021). Political instability or unfavorable policy developments, on the other hand, have the potential to create an uncertain environment and discourage investment in cutting-edge technologies (Aisen & Veiga, 2013; Bertin et al., 2016).

Farmers' trust in the government and willingness to adopt new technologies are influenced by their level of political awareness. Sarcheshmeh et al. (2018) investigated the acceptance of nuclear technology in Iran's agricultural sector and discovered that political factors have the greatest influence on farmer adoption of nuclear technology in agriculture. On the other hand, if farmers perceive a lack of attention or support from political leaders, they may be more hesitant to adopt new technologies (Crentsil et al., 2020). Furthermore, farmers' risk perceptions and willingness to invest in new technologies are influenced by political concerns. According to Wu et al. (2023), political uncertainty can impede the adoption of new technologies. As a result, political sensitivity to climate change should be considered when promoting technological adoption for climate change adaptation within the agrarian community.

Cultural Sensitivity of Farmers towards Technology Adoption for Climate Change Adaptation

Cultural sensitivity to climate change entails understanding how climate change has influenced agricultural communities' cultural values, identities, and social practices, resulting in changes to traditional lifestyles and community cohesion. Cultural factors can have a significant impact on farmers' willingness to adopt new technologies, which may call into question established norms and practices. Smallholder farmers' indigenous and religious beliefs can influence their ability to adjust traditional and agricultural practices in response to the effects of climate change (Aidoo et al., 2021). In cultures where traditional agricultural methods are strongly adhered to, new technologies that differ from established practices may face resistance (Shen et al., 2023). Curry et al. (2021) found that farmers are hesitant to adopt technology because they believe modern farming practices will corrupt their indigenous values and practices. Technologies that require changes in farming methods may face opposition if they appear to contradict cultural values or traditional knowledge of agricultural communities. According to Mohan et al. (2021), technological advances that necessitate changes in agricultural practices may face opposition if they appear to contradict cultural beliefs or established traditions.

Nonetheless, cultural sensitivity can make it easier to adopt new technologies if they complement or improve cultural norms. Any technology that improves the effectiveness of existing methods or incorporates indigenous knowledge is more likely to be adopted (Denashurya et al., 2023). Organisational cultures also have an impact on the effectiveness and efficiency of technological adoption (Schiller and Cui, 2010). Respect for cultural values can help to increase the adoption and acceptance of these technologies. In societies with strong community connections, methods that involve the community, such as demonstrations or peer learning, are more effective than approaches that focus on individuals (Dutta, 2007). As a result, it is critical to consider cultural sensitivity to climate change while encouraging farmers to adopt technological solutions for climate change adaptation.

Institutional Sensitivity of Farmers towards Technology Adoption for Climate Change Adaptation

Institutional sensitivity to climate change refers to farmers' perceptions of the involvement of institutions such as research organisations and agricultural cooperatives in responding to climate change impacts. The effectiveness and support of these institutions have a significant impact on farmers' willingness to adopt new technologies. Institutions play a critical role in facilitating technology adoption by providing resources, information, and technical support. For example, institutional support provided through extension services plays a significant role in the widespread adoption of technology such as climate change adaptation strategies in agriculture. Furthermore, technical assistance from extension services helps farmers improve productivity, resilience to climate change, and overall environmental management (Mashi et al., 2022). In fact, agricultural extension services offer agricultural training to help farmers successfully implement new technology (Makate, 2020).

Many agricultural technologies are typically complex, expensive, and unaffordable for small-scale farmers without significant financial assistance in the form of loans, insurance, and effective regulatory frameworks. According to Tanti et al. (2022), institutions play an important role in encouraging grassroots farmer cooperatives to adopt agricultural technologies by providing financial incentives such as subsidies and loans. Supporting inclusive farmer groups with financial resources will ensure the long-term viability of a climate-smart agricultural system. Furthermore, access to institutional financial support, such as loans or grants, can help farmers invest in innovative technologies (Geng et al., 2024). However, the credibility and dependability of institutions influence farmer perceptions. Positive interactions with reliable and effective institutions increase the likelihood of adopting recommended technologies (Fan et al., 2023). On the other hand, negative attitudes from institutions may impede their readiness to adopt new technologies (Cafer & Rikoon, 2018). As a result, the effectiveness of these institutional supports is critical for meeting farmers' needs while encouraging the adoption of technology.

METHODOLOGY

This section provides an overview of the study's sampling, location, and instrumentation, including the validity and reliability of the research instrument. This section also discusses sampling techniques and data collection methods.

Study Location

This study was conducted in Kedah, specifically in the Muda River Basin. The Muda River Basin is a tropical basin in Northern Peninsular Malaysia, spanning 5°20'-6°20' N latitude and 100°20'-101°20' E longitude. It has a drainage area of approximately 4,111 km^2 and a length of 180 km, starting at Muda Dam and flowing through the districts of Baling, Kuala Muda, Kulim, Padang Terap, and Sik in Kedah (Ghani et al., 2010) (Figure 2). Therefore, these five districts are included as the focus areas of this study.

Sampling and Data Collection

The study employed a non-probability sampling method known as convenience sampling, which allows researchers to collect data from easily accessible subjects in a timely and efficient manner. Furthermore, convenience sampling has several notable advantages, including low cost, high efficiency, and ease of implementation (Jager et al., 2017). Homogeneous samples are those that are deliberately restricted to a specific sociodemographic subgroup (Rashighi & Harris, 2017). The study employed a homogeneous convenience sampling technique, focusing on farmers with similar socioeconomic characteristics, farming experiences, and exposure to climate change impacts.

The study covered the main agricultural districts within the Muda River Basin, namely Baling, Kuala Muda, Kulim, Padang Terap, and Sik. A total of 382 rice farmers participated in the survey, with their distribution proportionate to the relative representation of each district: Kuala Muda (27.0%), Baling (22.0%), Kulim (21.0%), Sik (17.3%), and Padang Terap (12.7%). Respondents to this study were drawn from agricultural communities in the Muda River Basin, Kedah, who had experienced similar environmental conditions, relied on agricultural practices for their primary source of income, had at least 5 years of farming experience, and had lived in the

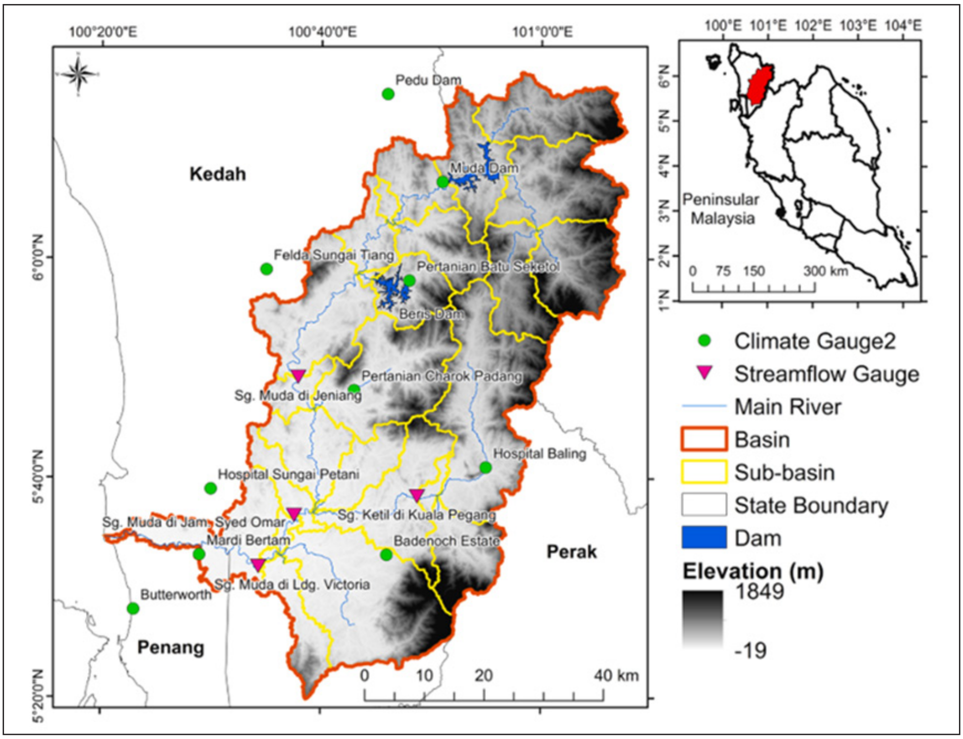

Figure 2. Illustration of the location of the study
Source: Tan et al. (2021)

Muda River basin for at least 10 years. As a result, it is possible to conclude that the homogeneity of the agriculture communities in the Muda River Basin significantly contributes to the findings' applicability to the target population. Furthermore, the study's sample size was determined using an online calculator called Raosoft.com. According to Raosoft.com's sample size calculation, a minimum of 382 respondents were required to achieve a 95% confidence level.

Research Instrument

The study used a quantitative approach, collecting information from selected respondents via a set of questionnaires as the research instrument. This study developed the climate change sensitivity instrument primarily using the International Union of Conservation for Nature's (IUCN, 2009) Social Adaptation Framework for Climate Change Sensitivity. The items in the technology adoption section were adapted from previous research, including Al-Jabri and Sohail (2012) and Atkinson (2007). Focus group discussions (FGD) were conducted with selected farmers from the Muda River Basin to ensure that the items accurately reflected the current on-field agricultural and climatic conditions experienced by local farmers. The FGD helped refine the wording and contextual relevance of the items. Subsequently, a pilot test was conducted with 30 farmers from non-sampled areas to ensure that respondents could clearly understand the meaning and intent of each question.

The questionnaire is in Malay to make it easier for farmers to understand, as the majority of respondents are Malay and live in rural areas. The questionnaire is divided into several sections, some of which include the respondents' demographic and farm profiles, while others contain items used to assess the study's variables, specifically technology adoption and climate change sensitivity. The constructions are built with a variety of items that are then scored on a Likert scale ranging from 1 to 5, with 1 indicating "strongly disagree" and 5 indicating "strongly agree."

Climate Change Sensitivity

Four factors of climate change sensitivity were evaluated using conceptual frameworks proposed by Fenton et al. (2007) and Marshall et al. (2010). To assess farmers' perceptions of the impact of climate change on their economy, sociocultural practices, political system, and relevant institutions, 30 items were developed for the current study. Table 1 summarises the four sensitivity factors, including the number of items and representative sample statements used to measure each construct. A higher score on a five-point Likert scale indicates a higher level of climate change sensitivity, implying that respondents are more affected by extreme weather (both culturally and economically) and that politicians and relevant institutions are more responsive to the effects of climate change. The following four items are examples of the four sensitivity factors (Table 1).

Technology Adoption

Rogers (2003) developed the Innovation Diffusion Theory, which served as the foundation for developing a set of 20 items related to the technology adoption construct in this study. This framework depicts the five perceived attributes that influence the spread of innovations throughout society: relative advantages, compatibility, complexity, trialability, and observability. Four items

Table 1
Summary of constructs measuring climate change sensitivity

Variables	No. of items	Example of item
Economic sensitivity	9	"Extreme climate change impacts the output of my agricultural operations."
Political sensitivity	7	"The current leaders assisted the community in mitigating the effects of extreme climate change."
Cultural sensitivity	7	"Extreme climate change causes the practices and traditions of my village community to change."
Institutional sensitivity	7	"Relevant institutions always provide early information about current climate changes from time to time."

Table 2
Summary of constructs measuring technology adoption for climate change adaptation

Domain	No. of items	Example of item
Relative advantage	4	"I use agricultural technology to enhance production yields in extreme climate change conditions."
Compatibility	4	"I am comfortable to use agricultural technology in the midst of extreme climate change condition"
Complexity	4	"It is easy for me to use agricultural technology to deal with the impacts of extreme climate change."
Trialability	4	"Agricultural technology can be used anytime and anywhere in the midst of extreme climate change."
Observability	4	"I have seen farmers using agricultural technology to address the impacts of extreme climate change."

were created for each of these domains in this study. A five-point Likert scale is used to assess the score level, with higher scores indicating greater technological adoption. Table 2 presents a summary of the construct measuring technology adoption for climate change adaptation, including the five sub-dimensions, number of items, and representative sample statements.

Validity and Reliability

The study used expert validation to evaluate the items used in the measurement of the research instrument's components. To be more specific, our research instrument was validated by experts in agricultural economics, agricultural extension, and climate change. In addition, this study demonstrated the questionnaire's reliability by conducting a pilot study with 100 respondents. The pilot study was conducted in Sungai Petani, Kedah. Cronbach's alpha was used as a statistical measure to assess the internal consistency of a questionnaire, which helped to determine its reliability. Cronbach alpha values for all constructs in the pilot test exceeded 0.75, including economic sensitivity (0.820), political sensitivity (0.765), cultural sensitivity (0.873), institutional sensitivity (0.852), and technology adoption (0.919). A Cronbach's alpha value of 0.6 or higher indicates the instrument's reliability. This demonstrates that all items are reliable in assessing their respective constructs (Cronbach, 1951).

RESULTS

This section presents the study's findings, which are organised into three sections: descriptive analysis, correlation analysis, and regression analysis. The first section looks at farmers' sensitivity to climate change and their adoption of technology. The second section investigates the correlation between the sensitivity domains and technological adoption. Meanwhile, the final section used regression analysis to investigate the strength of the impact of sensitivity variables on technology adoption for climate change adaptation in agricultural communities.

Table 3
Level of sensitivity factors and technology adoption

	Mean	Standard Deviation	Level
Economic sensitivity	3.46	0.688	Moderately high
Political sensitivity	3.10	0.795	Moderately high
Cultural sensitivity	2.04	0.880	Moderately low
Institutional sensitivity	2.52	0.804	Moderately low
Technology Adoption	3.68	0.723	Moderately High

Note. Mean scores relative to five-point Likert scale 1-5 (low-high)

Descriptive Analysis

Among the 382 respondents, 345 were male and 37 were female farmers who live in the Muda River Basins. The results show that the mean age of respondents is 49.37 years old (std dev = 14.58), the average monthly income is RM2,035.60 (std dev = 2780.95), and the average number of years of farming experience is 14 years (std dev = 12.54). To assess the level of each domain, this study used a five-point Likert scale with values ranging from 1 to 5. Nunnally and Bernstein (1994) proposed the following mean value interpretation method for five-point Likert scale categories: 1.00-2.00 (low), 2.01-3.00 (moderately low), 3.01-4.00 (moderately high), and 4.01-5.00 (high).

Table 3 presents the descriptive mean values that reflect the current levels of each sensitivity dimension and technology adoption among farmers. These results provide an overview of the existing conditions and serve as a basis for subsequent correlation and regression analyses. According to Table 3, technology adoption has the highest mean score (3.68) among all variables, indicating that technology adoption among farmers is moderately high. This demonstrates that the rate of technological adoption among agricultural communities is high under the current climate conditions. It is followed by political sensitivity (3.10) and economic sensitivity (3.46), both of which indicate a moderately high level. Meanwhile, farmers' institutional sensitivity (2.52) and cultural sensitivity (2.04) are moderately low.

Correlation Analysis

The study used a correlation analysis to determine the relationship between climate change sensitivity factors and farmers' adoption of climate change adaptation technologies. Table 4 displays all correlation metrics for each variable used in this study. The findings of this study indicate that technology adoption was significantly correlated with all sensitivity factors. Technology adoption showed a positive correlation with economic sensitivity ($r=0.186$, $p<0.01$), political sensitivity ($r=0.130$, $p<0.05$), and institutional sensitivity ($r=0.168$, $p<0.01$). Technology adoption and cultural sensitivity were found to be negatively correlated ($r= -0.336$, $p<0.01$). Cultural sensitivity and technology

Table 4
Relationship between sensitivity factors and technology adoption

Variables	1	2	3	4	5
(1) Economic sensitivity	1.00				
(2) Political sensitivity	0.314**	1.00			
(3) Cultural sensitivity	-0.147**	-0.290**	1.00		
(4) Institutional sensitivity	0.238**	0.240**	-0.023	1.00	
(5) Technology adoption	0.186**	0.130*	-.336**	0.168**	1.00

** Correlation is significant at the 0.01 level (2-tailed)
* Correlation is significant at the 0.05 level (2-tailed)

Table 5
Results of regression analysis

Independent variable	Coefficients: Unstandardized Coefficient β	Unstandardized Coefficient Std. Error	Standardized Coefficient β	t-statistic	Sig. level	F-statistic
(Constant)	3.719	.283		13.139	.000	12.841***
Economic sensitivity	.130	.054	.114**	2.425	.016	
Political sensitivity	.004	.044	.005	.099	.921	
Cultural sensitivity	-.289	.040	-.351***	-7.184	.000	
Institutional sensitivity	.087	.042	.097**	2.086	.038	

R^2 =0.295, Adj. R^2 =0.272, Std. Error of the Estimate= 0.61774
* Statistically significant at 0.10 level
** Statistically significant at 0.05 level
*** Statistically significant at 0.01 level

adoption had the strongest correlation of any of the four sensitivity variables studied. This shows that farmers who believe climate change is significantly altering their sociocultural practices have a lower rate of technological adoption.

Regression Analysis

This study used regression analysis to determine the most significant factor among climate change sensitivity that influences farmers' adoption of technology for climate change adaptation in the Muda River Basin. Table 5 displays the results of a regression analysis in which four variables (economic sensitivity, political sensitivity, cultural sensitivity, and institutional) were hypothesised to influence farmer technology adoption.

The relationship between climate change sensitivity dimensions and technology adoption was examined using a multiple linear regression model. The estimated model, based on standardised regression coefficients, can be expressed as follows:

$$Y = \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \varepsilon_i$$

Substituting the regression coefficients, the model becomes:

$$Y = 0.114X_1 + 0.005X_2 - 0.351X_3 + 0.097X_4 + \varepsilon_i$$

where:
Y = Technology Adoption
X_1 = Economic Sensitivity
X_2 = Political Sensitivity
X_3 = Cultural Sensitivity
X_4=Institutional Sensitivity
ε_i = Error term

According to Table 5, economic sensitivity, cultural sensitivity, and institutional sensitivity all had a significant influence on farmer technology adoption. Meanwhile, political sensitivity was found to be non-significant, indicating that political actions had no influence on farmers' technological adoption for climate change adaptation among farmers in the Muda River Basin. However, while economic and institutional sensitivity were positive towards technology adoption, cultural sensitivity had a negative impact. The regression results corroborate the direction of the correlation shown earlier in Table 2. Cultural sensitivity (β=-.351) significantly influenced technological adoption at the $p<0.001$ level, demonstrating a markedly greater effect than economic sensitivity (β=.114) and institutional sensitivity (β=.097), both of which were significant only at the 5% level. Therefore, cultural sensitivity had a threefold greater effect than economic or institutional sensitivity. The regression model explained 29.5% of the variance in technology adoption (R^2 = 0.295), indicating a moderate level of explanatory power. Although this value suggests that the model captures only part of the variability in adoption behaviour, it remains meaningful. Thus, the model provides moderate but reliable support for the influence of climate change sensitivity dimensions on technology adoption among farmers in the Muda River Basin.

According to the findings, farmers are more likely to adopt agricultural technologies if they believe their economic sensitivity or adverse impact of climate change on productivity is greater, to improve their adaptation to the negative effects of climate change. Similarly, the positive impact of institutional sensitivity on technology adoption suggests that farmers are more likely to adopt technology if they believe relevant institutions are more competent or responsive to the detrimental impacts of climate change. Thus, farmers are more likely to adopt agricultural technology in response to climate extremes when they believe relevant institutions can address the impact of climate change. However, it is surprising that this study discovered a negative relationship between cultural sensitivity and technology adoption. Although the researchers hypothesized earlier in this study that higher cultural sensitivity would increase farmers' awareness of using technology in their agricultural activities, contradictory findings in this study show that farmers who feel socially and culturally disengaged as a result of climate extremes are less likely to use technology to adapt to climate change.

DISCUSSION

The study's aim is to investigate the impact of climate change sensitivity on the adoption of agricultural technology for climate change adaptation among agricultural communities in the Muda River basin. The four dimensions of climate change sensitivities studied were economic, political, cultural, and institutional. According to the findings of both correlation and regression analyses, economic sensitivity was positively associated with technology adoption for climate change adaptation among farmers in the Muda River Basin. This demonstrates that farmers who have been severely impacted by climate extremes are more likely to use agriculture technologies as an adaptation strategy to increase productivity. Even though technology can be costly for farmers, our research shows that they are willing to adopt it because it provides better opportunities in current climate conditions. The finding is consistent with Harvey et al. (2018), who discovered that farmers who have suffered significant losses are more willing to invest in technology because it promises increased yields.

Furthermore, this study discovered that higher institutional sensitivity is associated with higher levels of technological adoption. Farmers in the Muda River Basin may have benefited from increased technological adoption as a result of more responsive actions and support from relevant institutions during climate change events. Relevant agricultural and climate change institutions should play an important role in effectively addressing climate change's effects on farmers. For example, extension services should play a significant role in the successful adoption of technology by providing farmers with resources, information, and technical assistance. Mashi et al. (2022) found that farmers who received technical assistance from extension services increased their productivity and resilience to climate extremes. As a result, farmers in the Muda River Basin with higher economic and institutional sensitivity may be more willing to adopt agricultural technologies as a means of mitigating climate extremes.

Furthermore, while the level of technology adoption among farmers in the Muda River Basin is moderately high (i.e., 3.68/5), this study believes that technological knowledge is primarily disseminated among farmers through traditional channels, such as face-to-face interactions. According to the findings of this study, the negative impact of cultural sensitivity on technology adoption demonstrates that when farmers are socially and culturally disintegrated, they are more likely to have missed recent technological knowledge and proficiency updates. As a result, farmers who were culturally impacted by climate extremes are less likely to use technology as a strategy for adaptation. This viewpoint is consistent with Schiller and Cui's (2010) observation that the success of technology adoption is heavily influenced by organisational cultures and norms. Curry et al. (2021) also proposed that deculturation of indigenous values and practices would render technology adoption ineffective.

However, this study found that political action (typically through political or community leaders) had no significant impact on farmer technology adoption. Although some studies, such as Ricart et al. (2018) and Amadou et al. (2022), have shown that politicians can influence farmers' beliefs about climate change and their willingness to adopt technology as a climate change adaptation plan, the findings of this current study show that this mechanism did not occur in the case of Muda River Basin farmers. In particular, technology adoption among farmers in the Muda River Basin is dependent on the significant role of relevant institutions rather than politicians.

Overall, the findings of this study have significant potential to guide policy actions aimed at increasing national adoption of agricultural technology. To encourage widespread adoption of technologies among farmers, the government must priorities the creation of a favorable environment that addresses the agriculture sector's unique demands and constraints. Given that cultural sensitivity emerged as the strongest determinant of technology adoption, policy design should first recognise and incorporate local values, traditions, and social norms into agricultural programmes. Strengthening culturally embedded approaches can foster greater trust and willingness among farmers to adopt innovation. Building on this foundation, institutional and economic considerations should function as supportive mechanisms that create the enabling conditions for sustained adoption. To mitigate the financial barriers associated with the adoption of new technology, policymakers should establish financial support programmes such as subsidies, low-interest loans, or tax incentives. This could include assistance with purchasing equipment, improving irrigation systems, or adopting climate-resilient crop varieties, ensuring that farmers, particularly smallholders, can afford these advancements.

Furthermore, policymakers should strengthen institutional capacity, which is critical for granting farmers access to resources, expertise, and technical assistance. While institutional and economic factors also influence adoption, their effects are comparatively smaller and should serve as supporting mechanisms that reinforce culturally grounded interventions. To bridge the gap between innovation development and on-farm adoption, policymakers can direct resources towards agricultural extension services, research institutes, and technology dissemination initiatives. Building on this foundation, effective communication and community engagement are essential to promoting technology adoption. Policymakers should expand communication channels and encourage cultural integration among agricultural communities. Recognising the cultural contexts in which farmers operate is essential for designing interventions that resonate with their lived experiences. Policies should therefore prioritise community-based and culturally sensitive interventions, such as involving local leaders and farmer groups in awareness campaigns, integrating indigenous knowledge with modern practices, and designing training modules that respect local traditions and communication styles. Such participatory and culturally grounded strategies can foster greater trust, acceptance, and long-term adoption of agricultural innovations.

Building upon these community-based and culturally sensitive approaches, institutional support remains crucial but should complement rather than replace them. Policymakers should establish transparent and stable institutional mechanisms that empower culturally rooted adaptation efforts instead of politically motivated initiatives. This includes ensuring consistent funding, encouraging public-private partnerships, and protecting agricultural initiatives from political fluctuations. By focusing on these issues, governments can create an environment that encourages farmers to adopt technology that improves production and strengthens their ability to adapt to climate change problems. These policies will benefit the agricultural sector while also improving national food security, economic stability, and resilience to extreme weather events.

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