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ORIGINAL ARTICLE

An investigation of small and marginal holder farmers' adaptation strategies to climate variability and its determinants in coastal agriculture: evidence from east coast of India

Sumit Panja[1] · **Sayani Mukhopadhyay**[1]

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Abstract

The Intergovernmental Panel on Climate Change (IPCC) has mentioned that coastal areas would be the worst sufferers of climate change-induced variabilities and extremes, severely affecting the farming community, particularly in developing countries. Farmers are developing different field-based and livelihood-based adaptive mechanisms depending on several socio-economic, institutional and locational factors. Previous studies were concentrated on agriculture and its adaptation strategies against climate change, but considering coastal agriculture in the context of climate variability is largely unexplored. This study aims to find controlling factors of coping mechanisms against climate variability for coastal agriculture on the east coast of India. A questionnaire survey and focused group discussion have been conducted to collect and validate farmers' perceptions of climate variability. The study has applied a binary logit model and established that socio-economic farming system attributes and locational factors influence farmers' decision to adopt farm-level and livelihood adaptations. Most farmers (> 80%) have perceived that rainfall variability has increased, which is a major issue for agriculture in this area. The logistic regression models successfully predicted nearly 70% of the variables in each model. The model indicated that variables like experience, education, land ownership, involvement with marine fishing and distance from the coast influenced adaptation mechanisms against climate variability. The findings of the study have underlined the factors that need more attention for better management of coastal agriculture in the context of climate variability and can help to formulate better climate adaptation policies in the coastal areas of India and areas with similar backgrounds.

Keywords Climate variability · Coping mechanism · Farmers' perception · Logistic regression

✉ Sayani Mukhopadhyay
mukherjee.sayani@gmail.com

[1] Department of Geography, Asutosh College, University of Calcutta, Kolkata, West Bengal, India

1 Introduction

Global climate change and climate change-induced phenomena like climate variability and extremes would have the worst impact on the agricultural sector worldwide (IPCC 2021, 2012). Climate variability is the short-term variation in climatic parameters and their extremes, which become very prominent in the era of human-induced climate change (IPCC 2014, 2022; Karl et al. 1995; Rind et al. 1989; Salinger 2005; Smith 2010). Several studies have already revealed that climate variability, particularly rainfall variability (i.e., anomalies and internal variability), is a leading and recurring challenge for the agricultural sector (FAO 2015; Lesk et al. 2016), and it is more striking in a warmer climate (Hawkins and Sutton 2011; Pendergrass et al. 2017). Variations in daily, monthly, seasonal, yearly or even decadal rainfall significantly impact crop production and food security, predominantly in developing countries (Kinda and Badolo 2019; Rahman et al. 2017). Low adaptive capacity, high dependency on agriculture, intensive but low productivity and technological backwardness will make developing countries more vulnerable to climate change and climate extremes, specifically in areas where agriculture is highly dependent on rainfall (Lybbert & Sumner 2012; Mendelsohn 2008; Mendelsohn & Wang 2017; Mirza 2003). India, where 60% of total agricultural land is directly dependent on monsoon rainfall for agriculture, will face more difficulty due to the increasing variability of the availability of monsoon rainfall (Mall et al. 2006; Kulkarni 2012; Loo et al. 2015).

The Intergovernmental Panel on Climate Change (IPCC) has mentioned in its reports that the phenomena related to climate change will have the utmost impact on coastal areas (IPCC 2007; 2014). Rising sea levels, increasing sea surface temperature, increasing intensity of cyclonic storms and storm surges will severely affect agriculture, aquaculture, fisheries, coastal tourism and community life in coastal areas (Wong et al. 2013). Several studies (Geethalakshmi et al. 2016; Gopalakrishnan et al. 2019) have stated that India's coastal areas will face more strains since its groundwater and canal irrigation scope is significantly lower due to the intrusion of saline water in groundwater and unavailability of freshwater. According to a report (Krishnan et al. 2020), the frequency and intensity of floods, drought and severe cyclonic storms, particularly in the post-monsoon season, have increased in India from 1986 to 2015 and are predicted to worsen in the coming decades. In the coastal parts of India, rainfall variability and mean air temperature are projected to increase, significantly reducing irrigated rice production by 4% and the yield rate of rain-fed rice by 10% (Gangwar 2013). In the case of the east coast of India, the scenario is more hostile due to the frequent occurrence of tropical cyclones, storm surges, heavy cyclonic rainfall, shortage of summer monsoon rainfall and saline water intrusion (Banerjee et al. 2018; Kantamaneni et al. 2019; Patnaik 2009; Sudha Rani et al. 2015; Rao et al. 2011). In this situation, small-scale and marginal farmers will be the worst sufferers because they cannot adapt and cope with the changing characteristics of the climate, leading them to face an economic, social and cultural crisis (Kantamaneni et al. 2020).

Previous studies have mentioned that introducing an adaptation strategy is the only way to reduce the severity of the negative impact of climate change and climate variability (Adger et al. 2003; Anwar et al. 2013; Crane et al. 2011; Hertel and Lobell 2014). Risk and vulnerability reduction via adjusting the current system is known as the adaptation to climate change (IPCC 2022). A wide range of adaptation strategies are available worldwide, but more extensive adaptations are needed to sustain future climate change (IPCC 2007). Farmers are already practising some common adaptation strategies to cope with the short-term as well as long-term effects of climate change all over the world (Akinnagbe and Irohibe 2015; Ali and Rose 2021; Aryal et al. 2021; Harvey et al. 2018; Nhemachena & Hassan 2007). Various studies have categorised these common adaptation strategies into two broad categories: on-farm or farm-level and non-farm or livelihood-based (Danso-Abbeam et al. 2021; Harmer & Rahman 2014; Voss 2021). Since agricultural adaptations are complex mechanisms, farmers always try to adjust to the changing situation by applying multiple adaptive techniques rather than one at a time, and various factors often influence these adaptive techniques (Jha & Gupta 2021a).

In the context of decision-making to adapt to climate variability and climatic extremes, the effectiveness of the adaptation depends on previous experience (IPCC 2014). Various micro-level studies have found that, in the local agricultural system, farmers' perceptions mainly deal with variability, uncertainty and extremes of specific climatic parameters rather than long-term change (Banerjee 2015; Datta et al. 2022; Mertz et al. 2009; Varadan & Kumar 2014). Thus, local-scale farmers' perception of climate variability plays a vital role in selecting the proper adaptation strategy and helps policymakers to understand the ground-level scenario (Akhtar et al. 2018; Hameso 2018). Identifying and interpreting the determinants and constraints of farmers' adaptation to climate variability is another major concern of policy implication; here, the micro-level study can provide substantial assistance for better understanding (Below et al. 2015; Gebrehiwot & Van Der Veen 2013; Pandey 2019; Sertse et al. 2021; Uddin et al. 2014).

A lot of studies have found that different socio-economic, demographic, institutional and locational factors have a direct influence on farmers' decision-making process to adapt against climate variability and climate change (Abid et al. 2019; Akinnagbe and Irohibe 2015; Aryal et al. 2021; Burnham & Ma 2017; Mase et al. 2017; Tesfahunegn et al. 2016). However, there is a lack of studies considering the influence of coast, tourism, out-migration and other important socio-economic, farming and locational factors in adopting climate variability in the agricultural sector. In the case of India, some studies have attempted to understand the climate change perception and its adaptation to agriculture, but all of them are not concerned with the coastal scenario (R. R. Banerjee 2015; Jha & Gupta 2021b; Kumar et al. 2023; Singh 2020). In a study, Narayanan and Sahu (2016) assessed the impact of climate change on the household economy in the Kendapara district of Odisha on the east coast of India, but it is devoid of coastal agriculture, adaptation and its determinants. To the best of our knowledge, this study is a first attempt to understand the perception of climate variability, adaptation and its determinants on coastal agriculture considering the small and marginal farmers. Therefore, the study has been carried out on the West Bengal coast, a part of India's east coast, where most farmers belong to small or marginal categories like other developing countries. The main objectives of the study are as follows:

1. To understand the farmers' perception of climate variability in the coastal environment.
2. To explore the adaptation strategies that the local farmers are using.
3. To find out the determinants of the adaptation strategies.

2 Materials and methodology

2.1 Study area

The study was conducted in the Purba Medinipur coastal area, a part of India's east coast (Fig. 1). The surveyed villages are distributed in six administrative blocks, namely Ramnagar I, Ramnagar II, Contai I, Deshapran, Khejuri II and Nandigram I of Purba Medinipur district, West Bengal. The latitudinal and the longitudinal extension of the study zone is 21° 36′ N to 22° 05′ N and 87° 29′ E to 87° 59′ E. The tropical monsoon climate is predominant in the area, and the area is also regularly affected by tropical cyclones. The study zone falls under the "coastal saline" agro-climatic, and rice is the major cultivated crop in this area. In this area, 57.48% of the total working population engaged in agricultural activity (Directorate of Census Operations 2011), and most of them are small and marginal farmers. Previous studies have found that climate variability, especially rainfall variability, significantly affects rice cultivation in this area (Hazra 2012; Nandargi & Barman 2018; Pal et al. 2015; Panja & Mukhopadhyay 2022); thus, it is very important to study the adaptation mechanism of this area intensively.

2.2 Data collection

The study was carried out through a household survey and focus group discussion (FGD). The information collected through the household surveys is verified through

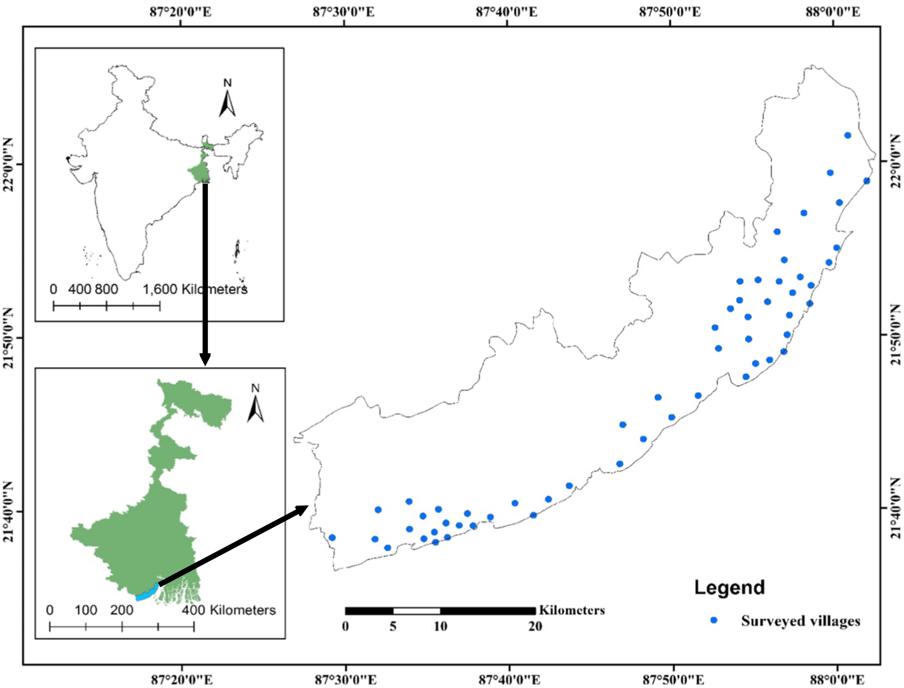

Fig. 1 Location of the study area with distribution of sample villages

focused group discussion. Group discussion and group interviews also helped determine the factors affecting the decision-making process to change crop calendars due to climate variability.

The household survey was conducted with a questionnaire to determine the factors influencing the decision to adjust the crop calendar against climate variability. The questionnaire also asked about farmers' perceptions of climate variability and adaptation mechanisms. Climate variability perception questions were designed using the Likert scale (Likert 1932). The options for the answers ranged from 1 to 5 where 1 means strongly disagreed and 5 means strongly agreed. Finally, some socio-economic parameters are also included in the survey, considering these may affect farmers' decision-making procedures. As the study targeted the farming community, 251 farmers were surveyed following a stratified random method. For example, to know about the influence of the coast, we have made buffer zones up to 5 km with an interval of 1 km and randomly selected the villages from each zone (Fig. 2). The collected primary data was then processed in the statistical software SPSS 25. The complete analysis, including the study of perception, adaptation and determinants, is done based on these 251 samples.

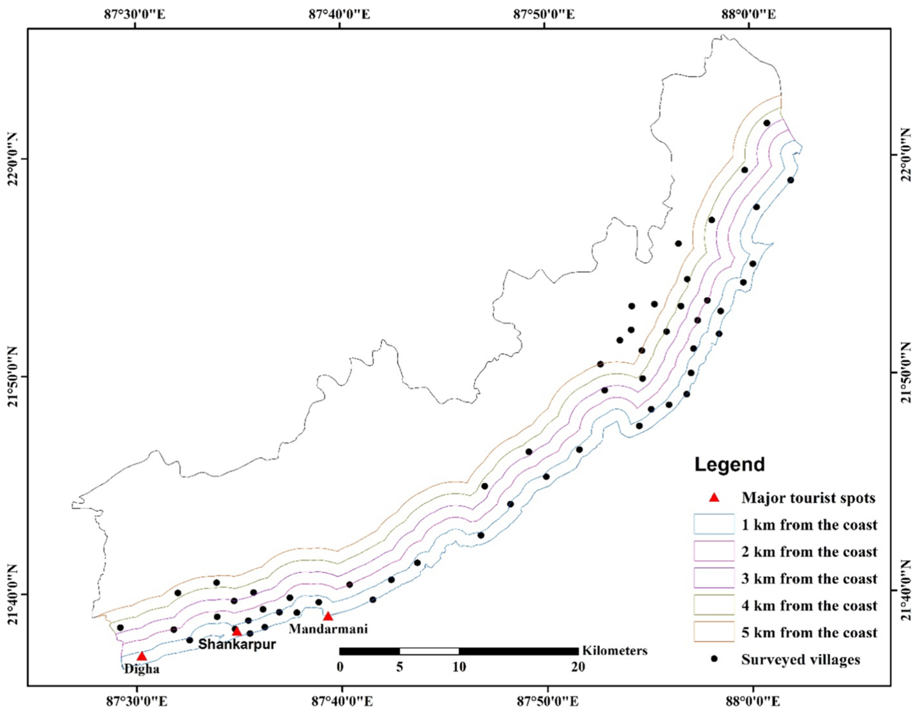

Fig. 2 Location of sample villages with reference to distance from the coast

2.3 Methods of data analysis

2.3.1 Descriptive statistics

Descriptive statistics give us a general description of the data (absolute and relative frequency, mean and standard deviation). This study calculates descriptive statistics of quantitative and qualitative data collected through a household survey.

2.3.2 Empirical modelling of farmers' decision to adopt climate variability

Several factors are associated with the decision-making process of choosing a suitable adaptation strategy to cope with changing climatic scenarios and manage the agricultural system sustainably (Fig. 3). Therefore, a binary logistic regression model has been applied to determine the determinative variables affecting farmers' decision-making to adopt climate variability in agricultural practices. This regression analysis helps to predict the discrete outcomes of the dichotomous dependent variables, which may be continuous, discrete, dichotomous or a combination (Retherford & Choe 1993). In this paper, the dependent variables are dichotomous. The farmers' response to a dependent variable is represented with 1 or 0. At the same time, independent variables combine continuous and discrete (Table 1).

A multicollinearity test is essential before performing a logistic regression; thus, this paper chose the Spearman correlation test. Furthermore, as most of the variables are non-parametric, hence a non-parametric correlation (Spearman) has been performed to test the collinearity among the variables selected for the study.

Previous studies (Abid et al. 2019; Banner et al. 2020; Burnham & Ma 2017; Mase et al. 2017; Yegbemey et al. 2014) have confirmed that the socio-economic condition of farmers, farming system and farm location plays a significant role in making decisions to change in an agricultural system. Thus, the study categorised the driving factors (independent variables) into three major categories: socio-economic characteristics, attributes of the farming system and farm location, and it assumed that the decision is a function of these three significant factors.

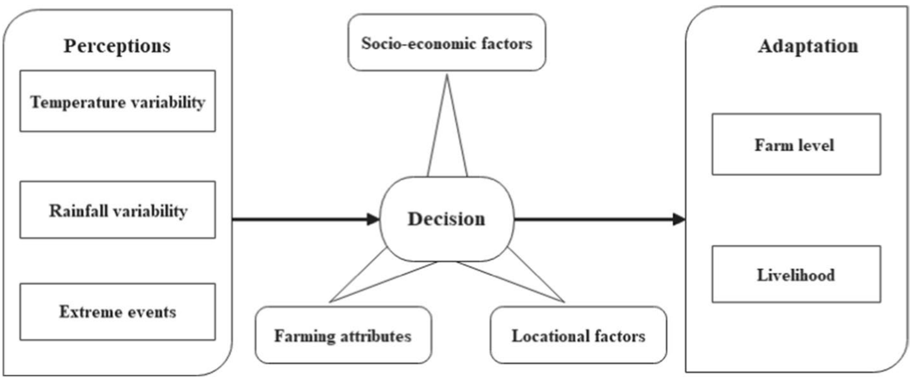

Fig. 3 Adaptation process

Table 1 Selection of independent variables

Variables	Types	Modalities	Effect
Socio-economic characteristics			
Age (years)	Continuous	-	-
Gender	Dummy	Male = 1, female = 0	±
Level of education (years of schooling)	Continuous	-	+
Number of working members	Continuous	-	+
Number of dependent members	Continuous	-	-
Experience in agriculture (years)	Continuous	-	+
Membership of agricultural organisation (yes/no)	Dummy	Yes = 1, no = 0	+
Loan/credit accessibility (yes/no)	Dummy	Yes = 1, no = 0	+
Land ownership (own/rented)	Dummy	Own = 1, rented = 0	+
Engaged in marine fishing	Dummy	Yes = 1, no = 0	-
Farming system attributes			
Amount of land under cultivation (ha)	Continuous	-	+
Land category	Dummy	Double or more cropping = 1, single cropping = 0	-
Households size (person)	Continuous	-	+
Family labour available for agriculture	Dummy	Yes = 1, no = 0	+
Economic background	Dummy	Middle and above = 1, poor = 0	+
Locational factors			
Distance from the coast (km)	Continuous	-	+
Distance from major tourist spots (km)	Continuous	-	-

The binary logistic regression function estimated the likelihood of the effects of the independent variables on the dependent (response) variable (Hosmer & Lemeshow 2000) is described as:

$$In\left[\frac{P}{P-1}\right] = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 \cdots + \beta_k x_k$$

The $\left[\frac{P}{P-1}\right]$ is the odds ratio or the probability; if P is the probability of farmers adopting the strategy, then $P-1$ is not. β_0 is the intercept, and β_1, β_2,...β_k are regression coefficients for the independent variables of χ_1, χ_2, χ_3 and χ_k. Here in this study, χ_1 is socio-economic characteristics, χ_2 is the characteristics of the farming system and χ_3 is the location of agricultural farms.

2.3.3 Why the binary logit model?

Contrary to many studies, where farmers opt for multiple adaptation methods from a set of various strongly correlated strategies, less or non-correlated binary decisions remain undescribed, making the implementation of a multivariate model less efficient (Bel et al. 2018; Yila and Resurreccion 2013; Ojo et al. 2021; Ojo & Baiyegunhi 2020). In comparison, binary regression makes it possible to comprehend the factors that affect each choice of adaptation strategy separately and individually.

Similar methodologies like the cartel model could be grouped to analyse adaptation decisions (Bryan et al. 2013), although this classification into self-defined categories could be misleading. Additionally, it was anticipated that a group of predictors affecting farmers' choices would differ for various adaptations. As a result, a binary logit model seems to be the most appropriate method for researching farmers' adaptation choices. Finally, various studies have successfully applied this model to understand the influencing factors for multiple adaptation decisions and found impressive results (Ali & Rose 2021; Sertse et al. 2021); thus, this study has selected this model for the same purpose.

2.4 Selection of explanatory variables for binary logistic regression

Based on the literature review and field survey, the following explanatory variables are selected for the binary logistic regression model (Table 1).

2.4.1 Socio-economic factors

- Age: Older farmers mainly produce for self-sufficiency and are less likely to consider climate variability (Jha & Gupta 2021a; Nhemachena & Hassan 2007). Thus, the study hypothesises that age will negatively correlate with adapting to climate variability.
- Gender: Male-headed households positively influence the decision to adopt the change more than female-headed families (Danso-Abbeam et al. 2021; Etana et al. 2021; Tesfahunegn et al. 2016). Social factors allow male-headed households to perceive climate variability and take the needed decision to modify or change any agricultural characteristics.
- Experience in agriculture: Those farmers who have been practising agriculture for a long time are habituated to the climate. Therefore, having a good knowledge of climate behaviour will preferably try to adjust to climate variability (Abid et al. 2019; Kabir et al. 2021). So, the experience will be a positive factor to adopt against climate variability.
- Level of education: Educated farmers will likely have more knowledge about climate change and variability; thus, they would like to adapt to it (Burnham & Ma 2017; Maddison 2007). So, we hypothesise that level of education has a positive correlation with the decision to adopt management strategies.
- The number of working members: More working members in a family means more family income, strengthening the family's economy. Thus, working members positively correlate with the decision (Below et al. 2012).
- The number of dependent members: If the number of dependent family members increases, it creates extra economic pressure on the household and makes them economically weaker. So, the number of dependent family members will be a negative factor in decision-making (Below et al. 2012).
- Membership of any agricultural organisation: Different agricultural organisations are significant sources of information regarding agriculture and related problems. So, farmers with membership in any agricultural organisation may adapt to climate variability (Yegbemey et al. 2014). Thus, membership in an agricultural organisation may be a positive factor in adopting climate variability.
- Credit or loan accessibility: Access to credit or loans gives the farmers temporary financial back. Thus, we hypothesise that accessibility to credit will be positively correlated to adapting to climate variability (Burnham & Ma 2017; Yegbemey et al. 2014).

- Land ownership: Won land makes the farmers more confident to change and experiment with the agricultural system (Abid et al. 2019; Nigussie et al. 2017). Thus, we assumed that farmers who have won land will likely adapt to climate variability.
- Engaged in marine fishing: Since the study was conducted in a coastal region, marine fishing will thus have a significant influence on agricultural adaptation. In addition, marine fishing is one of the major economic activities in coastal areas. Sometimes, it may act as an alternative livelihood option for the farmers, reducing dependency on agriculture (Danso-Abbeam et al. 2021; Voss 2021). Thus, engagement in marine fishing may be a negative factor in adopting strategies against climate variability for agricultural practice.

2.4.2 Farming attributes

- Land size: Farmers with a large amount of land under rice cultivation generally produce large, and besides household consumption, they used to sell rice into the market (Banner et al. 2020; Burnham & Ma 2017; Khanal et al. 2021). On the other hand, farmers with small land usually produce rice at the subsistence level. Thus, we assumed that land would positively correlate with adopting climate variability in agriculture.
- Land category: Farmers who produce crops once a calendar year in a particular land (single cropping) are more likely to adjust the climate variability in agriculture than those with multiple cropping lands. So, we hypothesise cropping intensity will negatively correlate with the decision to adapt to climate variability.
- Household size: More family members mean more workforce. A bigger family size serves as more labour for rice cultivation and provide the ability to adjust to any changes in the agricultural system (Banner et al. 2020; Nigussie et al. 2017). Thus, we assumed that family size would have a positive correlation.
- Family labour available for agriculture: In developing countries, family members are a significant source of labour support for agriculture. It helps to cut the extra expenditure of labour and give labour assurance (Thoai et al. 2018). Thus, we hypothesise that the involvement of family members in agricultural activity will act as a positive factor.
- Economic background: A strong economic background gives more assurance when making any decision regarding agricultural practice (Tesfahunegn et al. 2016). Thus, a better financial background might be a positive factor in adapting to climate variability for agricultural practice.

2.4.3 Locational factors

- Distance from the coast: The location of the agricultural lands plays a significant role in introducing any adaptive measures (Abid et al. 2019; Yegbemey et al. 2014). For this study, we have considered the influence of the coast on agriculture. We have considered the distance of agricultural land from the coast. Being nearer to the coast means more risk of cyclone and storm surge damage, which occur seasonally (pre- and post-monsoon). Thus, it is assumed that the distance of the agricultural farm from the coast will positively correlate with the decision to take adaptive measures for climate variability in agriculture.
- Distance from the major tourist spot: Being near any famous or major tourist attraction gives the local farmers an extra opportunity to find other off-farm tourism-related activ-

Table 2 Descriptive statistics of continuous variables

Variables	Mean	Std. deviation
Age	47.12	11.60
Experience in agriculture (years)	26.89	11.35
Years of schooling	3.75	3.83
Household size	6.07	2.15
No. of working member	1.55	0.55
No. of dependent members	4.55	1.73
Land size (ha)[1]	0.17	0.11
Distance from the coast (km)	2.23	1.40
Distance from the nearest tourist spot (km)	14.02	11.10

[1]Category-wise landholdings: small holders (1–2 ha) = 10.36% and marginal holders (< 1 ha) = 89.64%

Table 3 Relative frequencies of categorical variables

Variables	Actual frequency	Relative frequency (%)
Sex (1)	235	93.63
Economic category (0)	52	79.28
Land ownership (1)	191	76.10
Land category (1)	172	68.53
Member of any agricultural organisation (1)	62	24.70
Accessible to loan or credit for agriculture (1)	89	35.46
Family labour available for agriculture (1)	159	63.35
Marine fishing (1)	39	15.54

ities. So, we assumed that distance from the major tourist spot would positively influence the decision to adopt or not to adopt climate variability in agricultural practice.

3 Results

3.1 General description of the surveyed farmers

Tables 2 and 3 show the descriptive statistics of quantitative and categorical data. In the case of quantitative data, the mean of responded farmers' age is 47.12 years with a standard deviation of 11.60 years. The average year of schooling among the respondent farmers is 3.75 years, and they have an average experience of 26.89 years in rice farming, with a high standard deviation of 11.35 years. The distribution of educational qualifications and farmers' experiences is shown in Table 2. Farmers have a family composed of 6 (± 2) members. The average number of working member and dependent members per family is 1.55 and 4.55, with a standard deviation of 0.55 and 1.73, respectively. Farmers have used an average of 0.17 (± 0.11) ha of land under cultivation, and around 12,500 (± 7687) Rupees of capital have been invested for rice farming in a season. Lastly, the mean distance of the surveyed villages from the coast of the Bay of Bengal is 1.94 (±1.55) km. and the average distance from the nearest tourist spot is 14.02 (±11.10) km.

Among the surveyed respondents, 93.63% were male, and 79.28% of the total respondents belonged to the low economic category. According to farmers' responses, 24.70% of the respondents have membership in an agricultural organisation, 35.46% of the farmers are enjoying the credit/loan facility, 76.10% of the respondents are practising rice cultivation on their own land, 68.53% of respondents have double-cropping or multiple-cropping land, 63.35% of the respondents mentioned having family labour support for agriculture and, finally, 15.54% of respondents were associated with marine fishing.

3.2 Farmers' perception regarding climate variability in the coastal environment

A set of 21 statements regarding climate variability were given to the farmers, and five options for each statement were offered based on the Likert scale (Fig. 4). The allotted five options were strongly disagreed, disagreed, uncertain, agreed and strongly agreed. These statements considered three major aspects of climate variability: temperature, rainfall and extreme events.

About 54% of surveyed farmers agreed that temperature has increased, and 45% of them strongly agreed with the statement. Farmers have not noticed any change in summer characteristics except an increase in temperature; 60% and 68% of farmers either disagreed or had an uncertain response to the statements about longer summer and early summer, respectively. A mixed response has been received from the farmers regarding the change in winter characteristics in the area. An increase in winter temperature was perceived by 52%

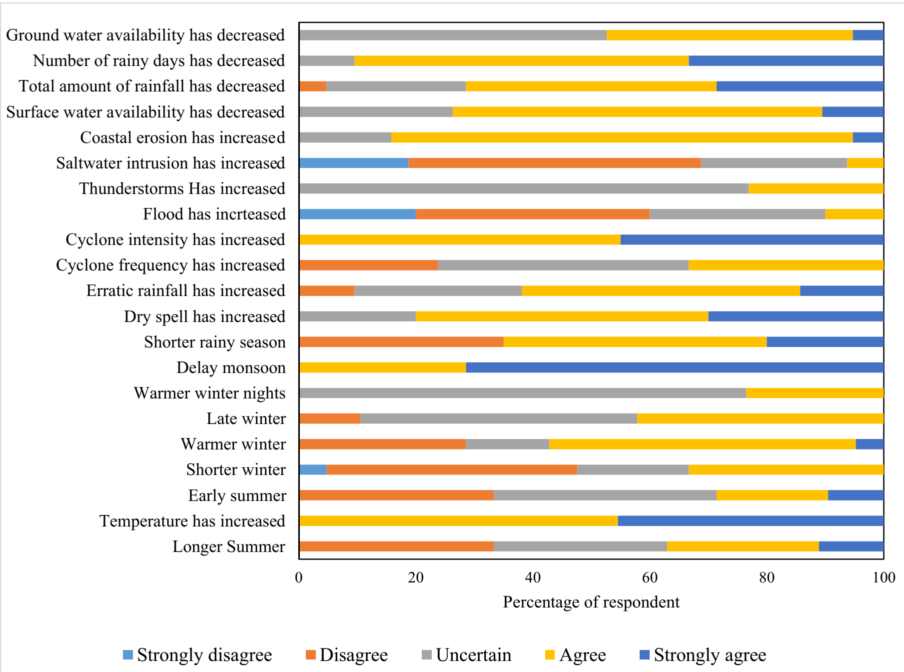

Fig. 4 Farmers' perceptions regarding climate variability

of the respondents, but the answer was uncertain (76%) for the statement warmer winter nights. According to the survey, 42% of the respondents agreed that the winter is delaying, but 47% were indecisive. A contradiction is noticed in the farmers' response regarding whether winter has become shorter; about 33% of farmers perceived that winter has become more concise, but 43% disagreed.

Rainfall variability is one of the most accurately perceived phenomena by farmers because they depend highly on rainfall for their agricultural activity. According to the primary survey, almost every farmer either strongly agreed (71%) or agreed (29%) that the arrival of the monsoon had become significantly delayed. Most farmers have perceived that the amount of rainfall has decreased (61%) and the rainy season has become shorter (65%). About 90% of the farmers agreed (57%) or strongly agreed (33%) with the statement that the number of rainy days has decreased. Farmers also noticed a significant increase in erratic rainfall (62%) and dry spells (80%), which amplified the extremity of the rainfall variability. As a result, the farmers found that the availability of surface water (74%) and groundwater (47%) decreased, affecting the irrigation system in the area. A tropical cyclone is one of the most crucial extreme weather events which have a devastating impact on agriculture in the area, and farmers think that the frequency (76%) and intensity (100%) of the cyclones have increased over the two decades.

Our study found that the coast, as a locational factor, plays a vital role in agricultural activity in the area. According to farmers, saltwater intrusion has decreased (agreed = 50%, strongly agreed = 18%) due to the construction of concrete embankments, but coastal erosion has increased (agreed = 78%, strongly agreed = 5%) over the last two decades.

3.3 Adaptive strategies developed by farmers against climate variability

According to the farmers, only a few strategies are available in the area to cope with climate variability. Still, they have tried to cope with the situation with the help of some adaptive mechanisms (Fig. 5). After collecting information regarding the adaptive measures through household surveys and focused group discussion, we have broadly categorised the adaptive strategies into farm-level and livelihood-based adaptation strategies.

3.3.1 Farm-level adaptation strategies

The local farmers apply various farm-level adaptation strategies to cope with climatic variability, especially rainfall variability. Still, the success of those adaptation measures

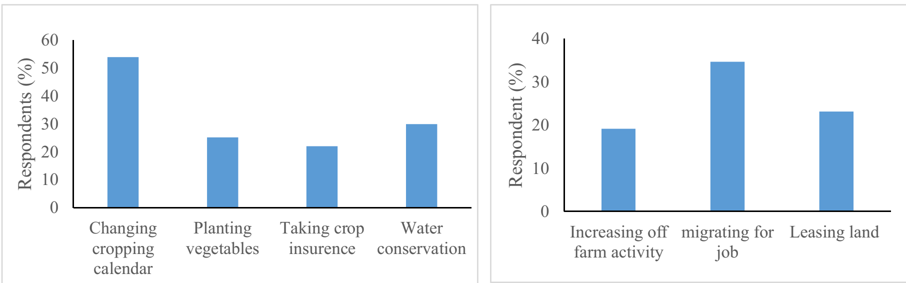

Fig. 5 Adaptation strategies: **a** farm-level adaptations and **b** livelihood adaptations

depends on the severity of the variability. Among the respondents, 53.78% are modifying their cropping calendar to deal with the delayed monsoon. They are trying to adjust their showing season with the availability of monsoon rainfall, especially with the onset of monsoon. Farmers informed that they could delay their showing season of rain-fed rice to a maximum of 15–30 days; more than that could severely reduce the production. Water conservation techniques are practised by 29.88% of respondents to manage the impact of the shortage of rainfall and the long dry season. They dig a small pond beside the farm or dig a community tank to harvest rainwater. Furthermore, 21.91% of respondents protect their crops by taking crop insurance from the government undertaking agricultural cooperative societies. Finally, 25.10% of farmers diversify their cropping patterns by planting vegetables like chilli, brinjal and potato (Fig. 5a).

3.3.2 Livelihood-based adaptation strategies

Apart from the farm-level adaptive measures, farmers also try to manage their livelihood through other non-farm activities besides agriculture. To fulfil family needs, 19.12% of the respondents increase off-farm activities like pulling an electric rikshaw, installing a tea shop, hawking in tourist spots and working as daily labour. Moreover, 34.66% of respondents or their family members migrate outside the districts or the state for livelihood. This migration is sometimes seasonal. Finally, 23.11% of respondents are leasing their cropland for non-cropping activity, especially for brackish water fish farming (Fig. 5b).

3.4 Factors determining the adaptation strategies

3.4.1 Factors determining the farm-level adaptive strategies

Out of seventeen explanatory variables, two variables were found to be significant for crop calendar modification. The most important factor for changing the cropping calendar was the availability of family labour for agriculture, with a 99% confidence level. The second most crucial factor for crop calendar modification was engagement in marine fishing, which has a confidence level of 99%.

In this model, the positive sign of the estimated coefficient (β) means the variable positively influences the dependent variable. In the case of a negative sign, the influence is negative. For instance, the coefficient of the variable, engagement to marine fishing, was -1.581, which means for every one unit change in this variable, there is a constant 1.581 decrease in the log odds of farmers' decision to change the crop calendar when the other independent variables are statistically controlled. The reverse applies to the positive sign.

The Wald statistics value is preferred to indicate the power of influence of the independent variables on the dependent variable (Cary and Wilkinson 1997). A higher Wald statistics value means a more significant impact on the dependent variable. Among the two important factors, the availability of family labour has the maximum Wald statistics value of 14.470 (Table 4).

The odds ratio (Exp.β) of these two independent variables showed a significant association with the probability of changing the crop calendar (Table 4) when other independent variables were kept constant. For instance, the availability of family labour for agriculture had an odds ratio of 4.677. For every one-unit increase in this independent variable, the odds of crop calendar change increased by 4.677 times, while other variables held constant.

Table 4 Influencing factors for farm-level adaptation strategies

Parameters		Changing cropping calendar	Water conservation	Planting vegetables	Crop insurance
Age	β	−0.099	−0.05	−0.031	0.09
	Wald[a]	0.999	0.227	0.095	0.777
Sex	β	−0.228	−0.223	0.16	−0.218
	Wald[a]	0.143	0.118	0.049	0.129
Experience in agriculture (years)	β	0.101	0.028	−0.01	−0.089
	Wald[a]	1.021	0.069	0.01	0.727
Years of schooling	β	−0.021	−0.004	−0.12**	−0.003
	Wald[a]	0.18	0.008	4.052	0.003
Economic category	β	−0.17	−0.045	−0.025	0.151
	Wald[a]	0.224	0.014	0.003	0.176
Household size	β	0.205	−0.075	−1.789	1.097
	Wald[a]	0.198	0.041	0.582	0.602
No. of working members	β	−0.391	0.805	2.797	−1.083
	Wald[a]	0.466	2.414	1.369	0.562
No. of dependent members	β	−0.119	0.095	1.717	−1.093
	Wald[a]	0.062	0.06	0.526	0.586
Land ownership	β	0.045	1.728***	1.942***	2.383***
	Wald[a]	0.014	10.27	12.34	20.531
Land size in hectare	β	1.363	2.08	−1.72	1.879
	Wald[a]	0.701	1.789	0.804	1.496
Land category	β	0.311	0.285	1.592***	−0.696*
	Wald[a]	0.819	0.56	10.345	3.693
Member of any agricultural organisation	β	0.067	−0.112	−0.426	0.024
	Wald[a]	0.023	0.062	0.707	0.003

Table 4 (continued)

Parameters		Changing cropping calendar	Water conservation	Planting vegetables	Crop insurance
Accessible to loan or credit for agriculture	β	0.526	−0.029	−0.279	−0.166
	Wald[a]	1.674	0.005	0.385	0.195
Family labour	β	1.543***	−0.669	−0.25	−0.056
	Wald[a]	14.47	2.289	0.238	0.02
Marine fishing	β	−1.581***	−0.1	−1.472 **	−0.617
	Wald[a]	10.86	0.048	5.518	1.947
Distance from the coast in km	β	0.023	−0.424***	−0.754***	0.125
	Wald[a]	0.029	7.964	18.14	0.88
Distance from the nearest tourist spot (km)	β	0.011	0.04**	0.032	0.009
	Wald[a]	0.444	5.109	2.528	0.263
Model chi-squared (χ^2)		60.523	36.483	65.527	53.125
Model Nagelkerke R-squared (R^2)		0.286	0.196	0.34	0.257
Model correct prediction		70.9	72.5	78.1	66.1

β = estimated coefficient; R^2 = coefficient of determination.

[a]The Wald statistic is the square of the ratio of the estimated coefficient and its standard error, which closely approximates a chi-squared distribution (Cary and Wilkinson 1997).

*Significant at $p \leq 0.1$

**Significant at $p \leq 0.05$.

***Significant at probability level, $p \leq 0.01$.

Three explanatory variables were found to impact the decision on water conservation significantly. Among the three determinant factors, ownership of land and distance from the coast had a confidence level of 99% (<0.01), and another factor, distance from the nearest tourist spot, had a 95% (<0.05) confidence level. Out of these three significant factors, ownership of land and distance from the nearest tourist spot positively correlated with the decision to conserve water or not, with an estimated coefficient of 1.728 and 0.040, respectively. On the other hand, distance from the coast negatively influenced water conservation, with an estimated coefficient of −0.424. Furthermore, land ownership had the highest odds ratio of 5.628, and distance from the coast and distance from the nearest tourist spot had an odds ratio of 0.654 and 1.041, respectively (see Appendix Table 6).

Four of the sixteen explanatory variables were significant in the context of vegetable cultivation as an adaptation strategy. Land ownership and distance from the coast were the most important determinants, with a confidence level of 99%. Another two determinants were years of schooling and engagement in marine fishing, with a 95% confidence level. Distance from the coast, involvement in marine fishing and years of education negatively influenced the decision to plant vegetables or not, with an expected coefficient of −0.754, −1.472 and −0.120, respectively. At the same time, land ownership positively influences this adaptation strategy, with an expected coefficient of 1.942. In this model, the factor land ownership had the highest odds ratio of 6.973, and years of schooling, distance from the coast and engagement in marine fishing had odds of 0.887, 0.470 and 0.229, respectively (see Appendix Table 6).

Land ownership and land category significantly influenced crop insurance as an adaptation choice. Land ownership positively influenced taking crop insurance with a 99% confidence level. On the other hand, the land category was affected negatively, with a confidence level of 90%. Land ownership had an estimated coefficient value of 2.383 with an odds ratio of 10.832, whereas land category had a low estimated coefficient value of −0.696 with an odds ratio of 0.499 (see Appendix Table 6).

3.5 Factors determining livelihood adaptive strategies

One of the essential livelihood management strategies was to increase off-farm activities or diversify livelihood rather than solely depending on agriculture. Nine variables were significant among the selected explanatory variables. Among these nine variables, age and experience in agriculture had a confidence level of 99% (Table 5). Meanwhile, years of schooling, land ownership, access to loans, availability of family labour, distance from the nearest coast and distance from the nearest tourist spot had 95% confidence, and land size had a 90% confidence level. Among the nine significant determinants, only age and accessibility to loans had a positive influence; the other seven negatively impacted the dependent variable. The details of the determinant in the model are given below in Table 5.

Five variables were significant in leasing agricultural land to non-cropping activity. Land ownership, distance from the coast and distance from the nearest tourist spot were important at a 99% confidence level. In comparison, years of schooling and experience in agriculture had 95% and 90% confidence levels, respectively. In this model, experience in agriculture, level of education and distance from the coast were negatively influenced with an estimated coefficient of −0.266, −0.128 and −0.639, respectively. On the other hand, land ownership and distance from the nearest tourist spot positively influenced the dependent variable with an estimated coefficient of 2.369 and 0.053, respectively. The factor, land

Table 5 Influencing factors for livelihood adaptation strategies

Parameters		Increasing off-farm activity	Leasing land for non-farm activity	Migrating for job
Age	β	**0.809***	0.229	−0.193
	Wald[a]	7.791	2.418	0.95
Sex	β	0.24	−0.383	−0.439
	Wald[a]	0.07	0.32	0.56
Experience in agriculture (years)	β	**−0.89***	**−0.266***	0.176
	Wald[a]	9.188	3.157	0.783
Years of schooling	β	**−0.133**	**−0.128**	−0.023
	Wald[a]	3.868	4.62	0.226
Economic category	β	0.247	0	−0.287
	Wald[a]	0.264	0	0.63
Household size	β	−0.444	−1.854	0.612
	Wald[a]	1.289	0.514	0.935
No. of working members	β	1.246	1.607	0.112
	Wald[a]	3.874	0.377	0.024
No. of dependent members	β	0.696	2.024	−0.476
	Wald[a]	2.852	0.608	0.546
Land ownership	β	**−0.948**	**2.369***	−0.016
	Wald[a]	3.854	12.309	0.002
Land size in hectare	β	−5.23*	0.267	**−4.927**
	Wald[a]	2.852	0.02	6.028
Land category	β	0.16	0.323	0.157
	Wald[a]	0.118	0.558	0.207
Member of any agricultural organisation	β	−0.063	0.025	0.409
	Wald[a]	0.013	0.003	0.924
Accessible to loan or credit for agriculture	β	**1.238**	0.238	−0.132
	Wald[a]	5.479	0.304	0.115
Family labour	β	**−1.132**	−0.147	−0.205
	Wald[a]	3.878	0.093	0.249
Marine fishing	β	−0.543	0.397	**−1.981***
	Wald[a]	1.009	0.738	11.604
Distance from the coast (km)	β	**−0.464**	**−0.639***	−0.009
	Wald[a]	4.142	13.375	0.005
Distance from the nearest tourist spot (km)	β	**−0.046**	**0.053***	0.008
	Wald[a]	4.098	7.517	0.235
Model chi-squared (χ^2)		77.724	56.885	40.144
Model Nagelkerke R-squared (R^2)		0.427	0.307	0.202
Model correct prediction		86.9	81.3	69.3

β = estimated coefficient; R^2 = coefficient of determination.

[a]The Wald statistic is the square of the ratio of the estimated coefficient and its standard error, which closely approximates a chi-squared distribution (Caryand Wilkinson 1997).

*Significant at $p \leq 0.1$

**Significant at $p \leq 0.05$.

***Significant at probability level, $p \leq 0.01$.

ownership, had a maximum odds ratio of 10.692, while the distance from the coast had a minimum odds ratio of 0.528 among the significant variables (Table 5).

Land size and engagement in marine fishing were found significant for this livelihood management strategy. Conversely, both the determinant variables had a negative influence on this model. Land size had an estimated coefficient value of − 4.927 with an odds ratio of 0.007, while engagement in marine fishing had an estimated coefficient of − 1.981, with an odds ratio of 0.138 (see Appendix Table 7). Further details of the said model are given in Table 5.

4 Discussion

Coping with the current climate variability is essential to adopt long-term climate change for the rain-fed agricultural system (Cooper et al. 2008). Farmers have already developed different strategies to adapt to climate variability in other parts of the world. Different types of adaptation in agriculture and allied livelihood, like on-farm, land-based, family-based and technology-based, have become popular among farmers (Harmer & Rahman 2014; Voss 2021). In the current study, we have categorised the adaptation strategies into field-based and livelihood adaptation strategies, separately discussed in different studies (Delfiyan et al. 2021; Gebrehiwot & Van Der Veen 2013; Harmer & Rahman 2014; Talanow et al. 2021).

In the perception study, we found that the farmers perceived rainfall variability more accurately than temperature variability because rainfall has a severe and instantaneous impact on agricultural activity (Banner et al. 2020; Tesfahunegn et al. 2016). Tropical cyclones are common on the east coast of India; thus, farmers in this area perceive extreme events like cyclones very well (Bhardwaj & Singh 2020; Mishra & Vanganuru 2020; Rao et al. 2020; Singh 2007). Since the Purba Medinipur coast is prone to coastal erosion and seawater intrusion (Bandyopadhyay et al. 2009; Hossain et al. 2022; Samanta & Paul 2016), farmers precisely figured out in the perception study.

The study aimed to determine the influence of socio-economic factors, farm attributes and locational factors on the adaptation to climate variability in the coastal area. The analysis showed that some socio-economic and farming factors significantly influence adaptation strategies. For example, age and agricultural experience influenced vegetable cultivation, off-farm activity and land leasing for non-farm activity. Since ageing causes a decrease in the ability to work hard, the aged farmers decide to increase relatively light off-farm activities besides farming (Danso-Abbeam et al. 2021). On the other hand, experienced farmers always feel emotionally attached to their land; thus, they generally deny leasing their farmland for non-farm activity, especially for brackish water fish farming, which may cause permanent damage to the land. Education helps farmers think logically and scientifically and helps prepare a plan for future generations. Therefore, the years of schooling were significant for planting vegetables, increasing off-farm activity and leasing land for non-farm activity. The educated farmers are not interested in growing vegetables because they need to permanently raise their land to make it well drained and protect it from salinisation through saltwater intrusion, which may perpetually affect the food grain (rice) cultivation, distressing food security. Higher-educated farmers do not prefer to increase off-farm activities because of the fewer off-farm job options that suit them. They might think that being highly educated will hurt their sentiment to pull a rikshaw or install a tea shop or hawk in the tourist spots. The farmers with better educational qualifications are also not interested in leasing their cropping land to the business people who will do brackish water shrimp farming on the same land after getting a lease. Because educated farmers are well aware of the saline water fish-farming process, they know that the agricultural land will be permanently salinised, and they would not be able to cultivate food grain in it ever again. These results of our study broadly confirm the findings of other studies where education and experience were found to be significant determinants of farmers' decisions (Banner et al. 2020; Below et al. 2012; Jha & Gupta 2021a).

The availability of family labourers for agricultural activity was significant for crop calendar modification as a field-based adaptation strategy and increasing off-farm activity as a livelihood adaptation strategy, which was also confirmed in previous studies (Adimassu & Kessler 2016; Bhatta & Aggarwal 2016; Brown et al. 2019; Dogliotti et al. 2014; Enete 2013). The availability of family labourers for agriculture gives the farmers the strength to complete farming activities quickly in need and solve the crisis of labourers during peak demand. Delay in the sowing season due to delayed monsoon needs fast completion of transplanting session when rainfall starts, and family labour could take action in this situation. Furthermore, family labourers also act expeditiously when it needs to be harvested fast before a cyclone or in the aftermath of the cyclone. As a result, families with sufficient available agricultural labour rely more on agriculture than opting for other off-farm activities.

Marine fishing is a good livelihood option in the coastal area. Though it is not a whole-year livelihood option, it has a peak season (June–September) that coincides with the principal cropping season (winter rice) in this area. Therefore, the farmers engaged partly or entirely with marine fishing were not interested in modifying the crop calendar. Vegetable cultivation needs regular care like irrigation, weeding and harvesting, which needs continuous labour supply, since the farmers engaged with marine fishing spend a maximum of their time in the boat, remaining unavailable for a long time, causing a lack of interest in vegetable cultivation and engaging in other off-farm activities. Engagement with marine fishing also provides a stable work opportunity with better financial support and jobs during the lean season in rice farming (growing season), which causes less migration among the farmers attached to marine fishing.

In line with the result of the previous studies, our study has also found that the ownership, size and category of the agricultural land were significant determinants for several adaptation strategies in this study (Banner et al. 2020; Danso-Abbeam et al. 2021; Tesfahunegn et al. 2016). For example, those farmers with their own land can modify it for water conservation by digging small ponds beside the cultivation, but the farmers who rent land for agriculture cannot do this. Furthermore, it is necessary to have a land record to claim crop insurance; hence, the farmers renting land from others based on seasonal or yearly agreements could not enjoy the benefit of crop insurance. On the contrary, farmers with relatively large landholdings are more intensively engaged in agriculture instead of diversifying their livelihood in off-farm activities or migrating outside for jobs.

Finally, the locational factor of the agricultural land, especially the influence of the coast, was very significant for the adaptation practices. Water conservation was negatively related to distance from the coast. As the distance increases from the coast to the interior, the availability of irrigation facilities increases; thus, farmers far from the coast are less concerned with water conservation. The well-drained sandy-loamy soil of the east coast of India, especially the West Bengal and Odisha coast, is categorised as moderate to highly suitable for the cultivation of vegetables like chilli, brinjal and potato (Mandal et al. 2020; Rukhsana and Molla 2023; Srinivasan & Beeman 2018) that encourages farmers to plant vegetables. Although there is a very high chance of salinisation by seawater intrusion, farmers are raising their land level and cultivating vegetables nearer to the coast as protection. Similar findings have also been reported previously in different studies that rice-based farms are transforming into vegetable fields in different parts of West Bengal, and coastal areas like Purba Medinipur are no exception to this (Maity et al. 2013; Maity & Basu 2009; Mandal et al. 2022).

Closeness to the coast provides two major alternative livelihood options: fishing and coastal tourism. Thus, farmers who are living beside the coast less tend to migrate outside the area for jobs. Another crucial outcome of the study was that distance from the coast was negatively correlated with leasing land for non-farming activity. An abundance of brackish water fishing grounds has increased in the study area in the last few decades. These saline water fishing ponds were formed mainly by converting paddy fields. This conversion process is more prominent in areas where saline water is easily available. Since the accessibility of saline water closer to the coast and the tidal inlets is effortless, most of these conversion processes took place nearer to the same. Thus, farmers with agricultural land nearer to the saline water source are more prone to lease their land for non-agricultural activity, especially for brackish water shrimp farming.

5 Conclusion and policy implications

Small and marginal farmers are always on the frontline of threat from any change in the agricultural system in developing countries where food security and the livelihood of a vast percentage of the population are dependent solely on agriculture. The potential risk of the growing number of climate variability and climate extremes in the era of climate change is way higher in coastal agriculture than in other zones of the world; thus, small and marginal holder farmers of this area are currently at the tip of the knife. In the long run, adaptations would be the better and more sustainable solution to cope with the changing climate scenario. Although adaptations are localised practices, they have global applicability; therefore, understanding the determinants of the adaptations at the household level would help to make a better plan. Thus, this study assessed the perception of climate variability among the small and marginal farmers engaged in coastal agriculture, reviewed the adaptation strategies already being applied and identified the determinants of those adaptation measures.

The result of the study primarily indicated that most of the surveyed farmers almost accurately perceive climate variabilities. According to the farmers, the rainfall variabilities had a greater impact on agricultural activity; thus, they adapted farm-level adaptations like modification of the cropping calendar and water conservation to counter the rainfall variability. In an effort to reduce the economic loss due to climate variability and extremes, some farmers are taking crop insurance, and some are planting vegetables as cash crops. Moreover, besides the farm-level adaptations, farmers are also concerned with their livelihood. Off-farm activities are an alternative way to diversify the livelihood of most of the farmers, but the opportunity to have other off-farm activities is less in the region, forcing them to migrate outside for jobs. Finally, a portion of the farming community is lease-in their cropland for non-cropping activity, especially for saline water shrimp farming.

The outcome of the binary logit model revealed the potential influencing factors for the various adaptation decisions of the farmers. The farmers' age positively influences adapting to off-farm activities because they need less physical abilities than doing agriculture. The emotional attachment of the experienced farmers to their farmlands is pulling them back to lease their lands and do some off-farm activities. Therefore, some policies could be introduced to support older farmers and their families for better adaptation to this situation. Planting vegetables by modifying ricefields or leasing them for non-cropping activity may cause permanent damage to the agricultural land; thus, farmers with higher education are unwilling to adopt these strategies. Furthermore, the education level also negatively influences the farmers' decision to increase off-farm activities as a coping measure. This may be due to the lack of stable off-farm job options, which higher educated farmers think are not suitable for them, and agriculture is better than those options.

Land ownership, land size and land category (single, double or more cropping), considered one of the most important parameters to identify the small and marginal category of the farmer, has a significant influence on adaptation decisions. Farmers with their own land can easily make farm-level adaptation decisions like planting vegetables, water conservation and taking crop insurance, which the farmers who rent the land can not. On the other hand, farmers with won and larger farming lands do not either choose any off-farm activity or migration as an adaptation option. Therefore, the farmers who rent land and have low landholdings are the most unadapted and vulnerable category, and they should be taken into special consideration during policy formulation.

The area is predominated by traditional rice farming, which needs labour for every cultivation stage, making the availability of family labour an important determinant for adaptation. Families with available family labour for agriculture rely more on agriculture than other off-farm activities and tend to modify crop calendars as a vital field-level adaptation option, proving that the agriculture of the area is still very labour-intensive and impacts adaptation. Furthermore, the accessibility to loans or credits influences farmers to increase their off-farm activities. This may be because they cannot pay the lends from the only agricultural income and are forced to diversify their livelihood. This outcome shows the insufficiency of agricultural loans and poor management, causing an aimless and unmethodical adaptation scenario in this area.

Apart from socio-economic and farming aspects, the coast as a locational factor significantly influences the local farmers' adaptation decisions. Nearer to the coast, providing farmers with the extra potential to diversify their livelihood in the fishing and tourism sectors decreases their sole dependency on agriculture. The farmers engaged in marine fishing are neither modifying their crop calendar nor migrating for jobs because the peak season of marine fishing could coincide with the sowing season if they alter the cropping calendar or do seasonal migration. They are also not cultivating vegetables, which is a labour-intensive practice, and farmers engaged in marine fishing are not always available for that. The agricultural fields near the coast are prone to be salinised by storm surges or even high tides in some areas, making water conservation a non-generative option. Thus, farmers are raising their land level to protect it from salinisation and planting vegetables or leasing it for saline water fish farming. Additionally, coastal tourism is well known in this area, giving farmers extra livelihood opportunities to increase off-farm activities. Hence, the coast positively impacts livelihood adaptation but distresses agricultural land management and farm-level adaptations. Therefore, planning better on-field and land management strategies could give a better adaptation result nearer to the coastal area.

From the findings described above, prioritising the dissemination of knowledge about the implications of initiatives and possible adverse effects of climate variability and extremes should be the top priority when promoting farmer adaptation. Since most farmers are marginal and economically backward, the local governing bodies can play a vital role by identifying and prioritising those families for better adaptation. Off-farm activities are good livelihood choices for most off-farmers, but it demotivates the farm-level adaptations. Thus, it should be monitored and controlled, and agricultural organisations could play an essential role in this. Furthermore, farmers near the coast are leasing their farmland to non-farm activities for economic profit, severely affecting the agriculture in this area and challenging its sustainability. This transformation of agricultural land could be controlled by regular monitoring through local governing bodies with the collaboration of different non-governmental organisations. Finally, policymakers should design proper land-use management guidelines, and a monetary reward can also be provided to the marginal families who are correctly implementing the adaptations. Nonetheless, the given financial compensation should be carefully monitored and managed for the appropriate adaptation strategies, especially for farm-level adaptations.

Appendix

Table 6 Descriptive statistics of farmers' perceptions regarding climate variability based on the Likert scale

Statements	Mean	Standard deviation
Longer summer	3.15	2.79
Temperature has increased	4.45	3.95
Early summer	3.05	2.67
Shorter winter	2.81	2.45
Warmer winter	3.33	2.94
Late winter	3.32	2.85
Warmer winter nights	3.24	2.72
Delay monsoon	4.71	4.21
Shorter rainy season	3.50	3.18
The dry spell has increased	4.10	3.63
Erratic rainfall has increased	3.67	3.24
The total amount of rainfall has decreased	3.10	2.65
The number of rainy days has decreased	4.45	3.95
Cyclone frequency has increased	2.30	1.95
Cyclone intensity has increased	3.23	2.72
Flood has increased	2.19	1.80
Thunderstorms have increased	3.89	3.39
Saltwater intrusion has increased	3.84	3.36
Coastal erosion has increased	3.95	3.52
Surface water availability has decreased	4.24	3.75
Groundwater availability has decreased	3.53	3.04

Table 7 Result of binary logit model for farm-level adaptation strategies

Parameters	Changing cropping calendar			Water conservation			Planting vegetables			Crop insurance		
Influencing factors	SE	Sig	Exp.(β)	SE	Sig	Exp.(β)	SE	Sig	Exp.(β)	SE	Sig	Exp.(β)
Age	0.099	0.317	0.906	0.104	0.634	0.952	0.101	0.758	0.969	0.103	0.378	1.095
Sex	0.601	0.705	0.796	0.649	0.731	0.8	0.724	0.825	1.174	0.608	0.719	0.804
Experience in agriculture (years)	0.1	0.312	1.107	0.105	0.793	1.028	0.104	0.921	0.99	0.104	0.394	0.915
Years of schooling	0.05	0.672	0.979	0.05	0.931	0.996	0.06	0.044	0.887	0.049	0.954	0.997
Economic category	0.358	0.636	0.844	0.388	0.907	0.956	0.431	0.954	0.975	0.36	0.675	1.163
Household size	0.46	0.656	1.227	0.371	0.841	0.928	2.345	0.446	0.167	1.414	0.438	2.996
No. of working member	0.573	0.495	0.677	0.518	0.12	2.237	2.39	0.242	16.395	1.445	0.453	0.338
No. of dependent members	0.478	0.803	0.888	0.39	0.807	1.1	2.367	0.468	5.569	1.429	0.444	0.335
Land ownership	0.383	0.907	1.046	0.539	0.001	5.628	0.553	0.000	6.973	0.526	0.000	10.832
Land size (ha)	1.628	0.402	3.908	1.555	0.181	8.006	1.918	0.37	0.179	1.536	0.221	6.547
Land category	0.344	0.366	1.365	0.381	0.454	1.33	0.507	0.401	0.653	0.362	0.055	0.499
Member of any agricultural organization	0.44	0.879	1.069	0.447	0.803	0.894	0.45	0.535	0.757	0.412	0.954	1.024
Accessible to loan or credit for agriculture	0.406	0.196	1.691	0.405	0.943	0.971	0.512	0.626	0.779	0.377	0.659	0.847
Family labour	0.406	0.000	4.677	0.442	0.13	0.512	0.627	0.019	0.229	0.4	0.889	0.946
Marine fishing	0.48	0.001	0.206	0.459	0.827	0.904	0.177	0.000	0.47	0.442	0.163	0.54
Distance from the coast (km)	0.134	0.865	1.023	0.15	0.005	0.654	0.02	0.112	1.032	0.133	0.348	1.133
Distance from the nearest tourist spot (km)	0.017	0.505	1.011	0.018	0.024	1.041				0.017	0.608	1.009

SE standard error, *Sig*. significance, *Exp.(β)* odds ratio.

Table 8 Result of binary logit model for livelihood-based adaptation strategies

Parameters	Increasing off-farm activity			Leasing land for non-farm activity			Migrating for job		
	SE	Sig	Exp.(β)	SE	Sig	Exp.(β)	SE	Sig	Exp.(β)
Age	0.29	0.005	2.246	0.147	0.12	1.257	0.198	0.33	0.825
Sex	0.906	0.791	1.271	0.677	0.572	0.682	0.587	0.454	0.645
Experience in agriculture (years)	0.294	0.002	0.41	0.149	0.076	0.767	0.199	0.376	1.192
Years of schooling	0.068	0.049	0.875	0.059	0.032	0.88	0.049	0.634	0.977
Economic category	0.481	0.607	1.28	0.439	1	1	0.361	0.428	0.751
Household size	0.391	0.256	0.642	2.586	0.473	0.157	0.633	0.334	1.844
No. of working member	0.633	0.049	3.476	2.618	0.539	4.985	0.722	0.877	1.118
No. of dependent members	0.412	0.091	2.006	2.597	0.436	7.571	0.644	0.46	0.621
Land ownership	0.483	0.05	0.387	0.675	0	10.692	0.379	0.967	0.984
Land size (ha)	3.097	0.091	0.005	1.906	0.889	1.306	2.007	0.014	0.007
Land category	0.466	0.732	1.173	0.432	0.455	1.381	0.346	0.649	1.171
Member of any agricultural organisation	0.56	0.911	0.939	0.474	0.959	1.025	0.426	0.337	1.506
Accessible to loan or credit for agriculture	0.529	0.019	3.448	0.431	0.582	1.268	0.389	0.735	0.876
Family labour	0.575	0.049	0.322	0.481	0.761	0.864	0.412	0.618	0.814
Marine fishing	0.541	0.315	0.581	0.462	0.39	1.487	0.582	0.001	0.138
Distance from the coast (km)	0.228	0.042	0.629	0.175	0	0.528	0.13	0.943	0.991
Distance from the nearest tourist spot (km)	0.023	0.043	0.955	0.019	0.006	1.054	0.016	0.628	1.008

SE standard error, *Sig*. significance, *Exp.(β)* odds ratio.

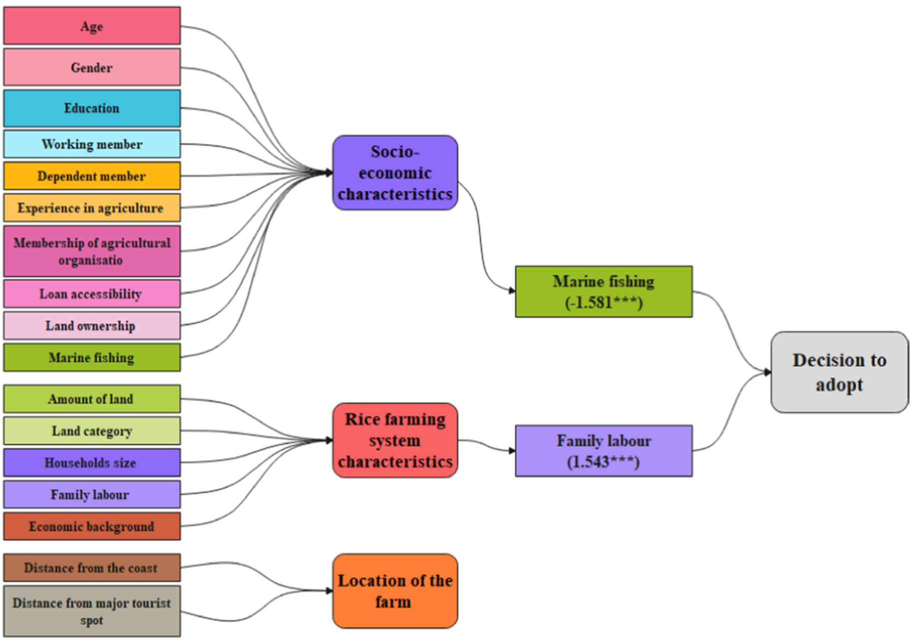

Fig. 6 Factors influencing crop calendar change. ***Significant at probability level, $p \leq 0.01$. **Significant at $p \leq 0.05$. *Significant at $p \leq 0.1$

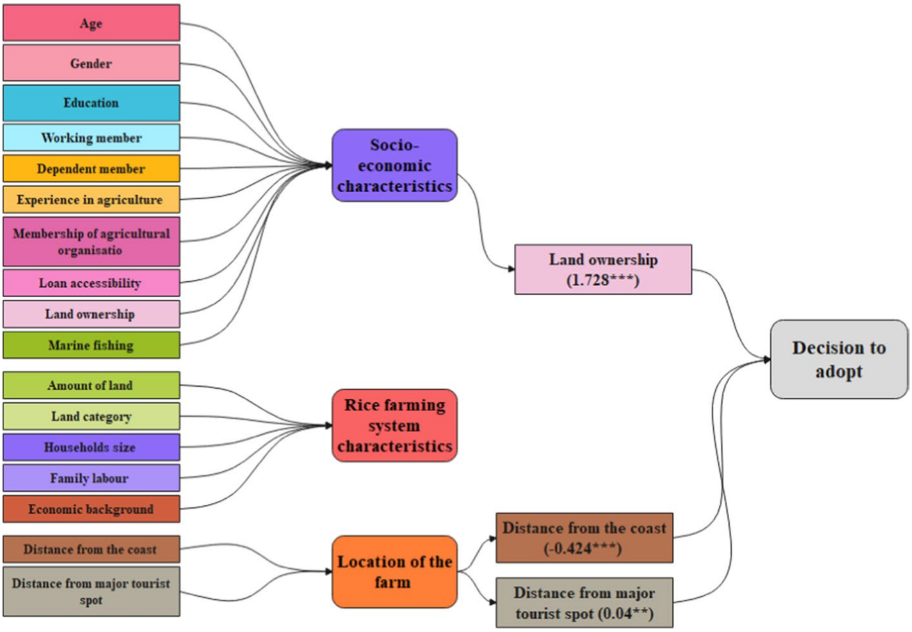

Fig. 7 Factors influencing water conservation. ***Significant at probability level, $p \leq 0.01$. **Significant at $p \leq 0.05$. *Significant at $p \leq 0.1$

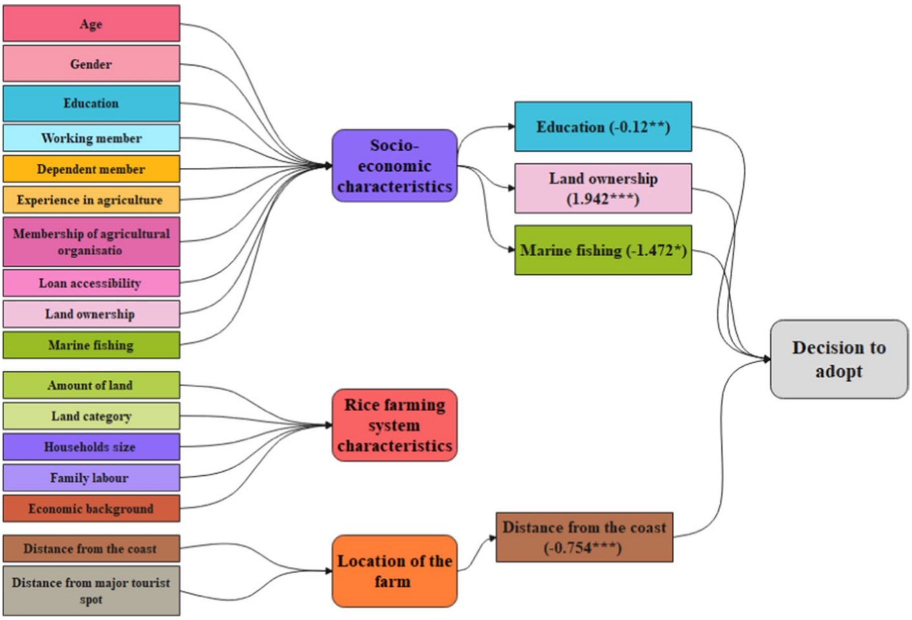

Fig. 8 Factors influencing planting vegetables. ***Significant at probability level, $p \leq 0.01$. **Significant at $p \leq 0.05$. *Significant at $p \leq 0.1$

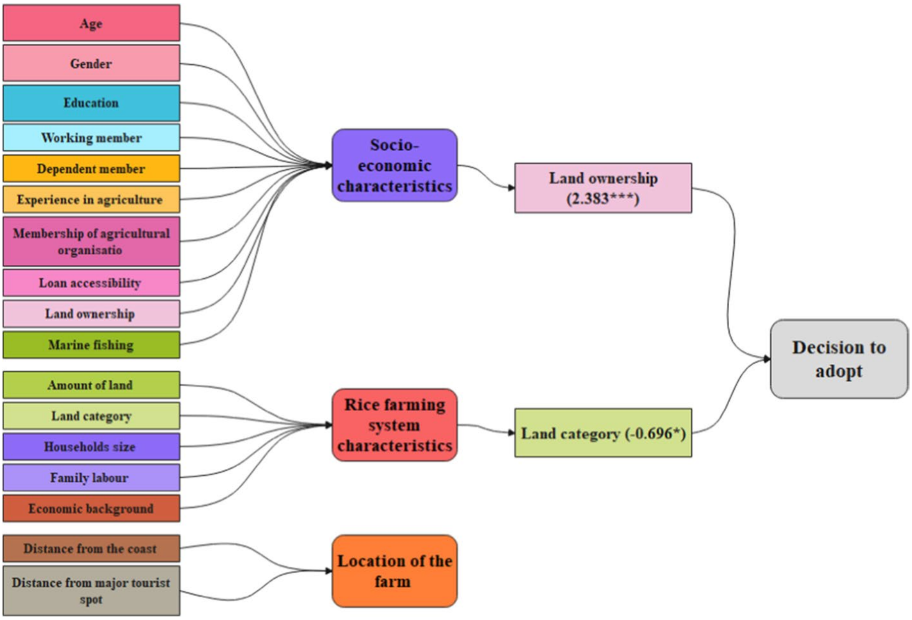

Fig. 9 Factors influencing crop insurance. ***Significant at probability level, $p \leq 0.01$. **Significant at $p \leq 0.05$. *Significant at $p \leq 0.1$

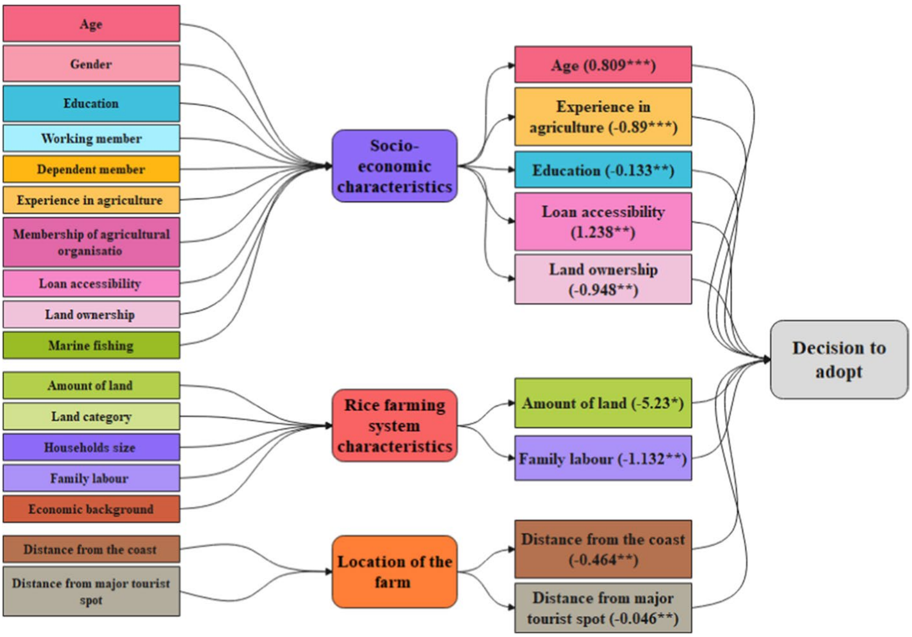

Fig. 10 Factors influencing increasing off-farm activities. ***Significant at probability level, $p \leq 0.01$. **Significant at $p \leq 0.05$. *Significant at $p \leq 0.1$

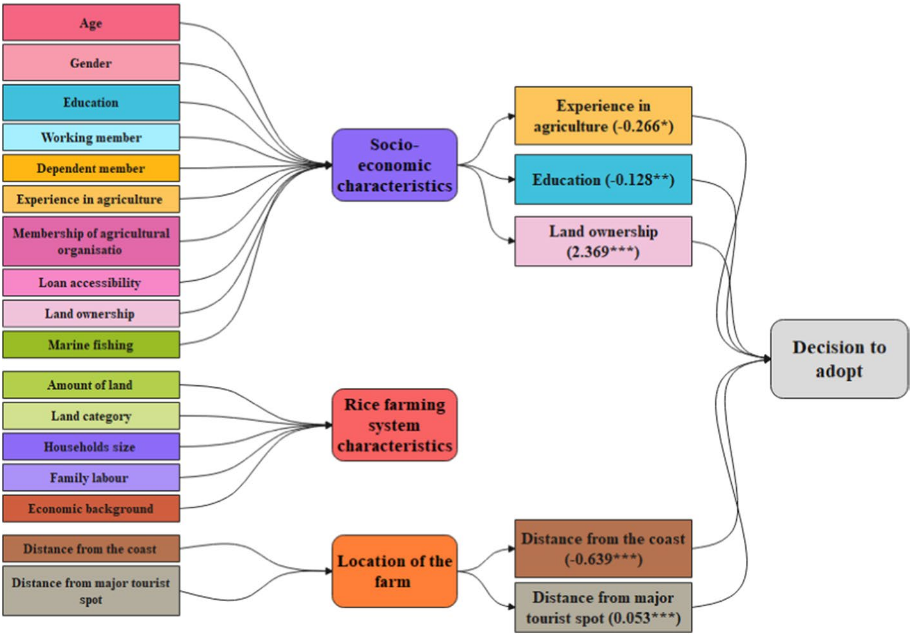

Fig. 11 Factors influencing leasing land. ***Significant at probability level, $p \leq 0.01$. **Significant at $p \leq 0.05$. *Significant at $p \leq 0.1$

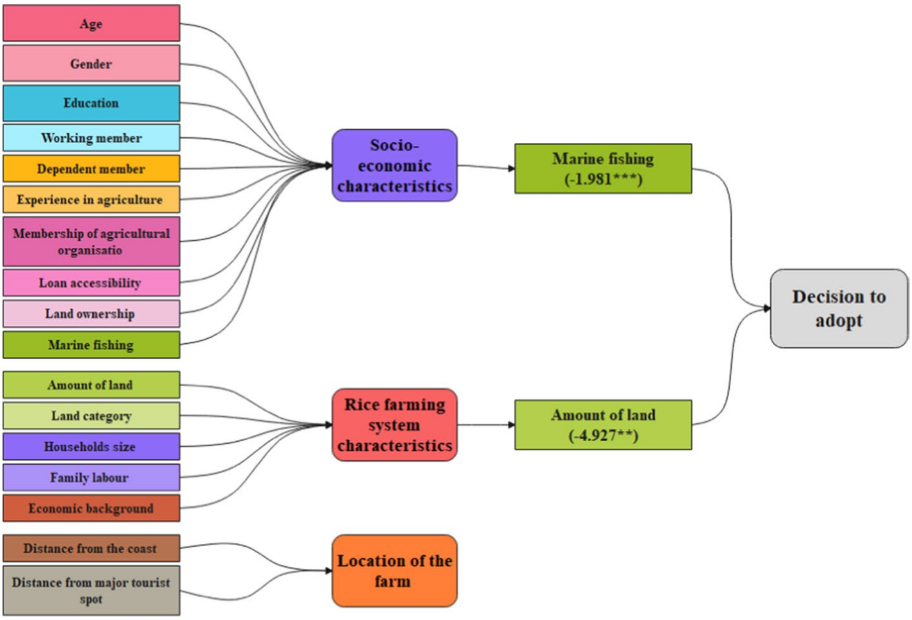

Fig. 12 Factors influencing migrating for job. ***Significant at probability level, $p \leq 0.01$. **Significant at $p \leq 0.05$. *Significant at $p \leq 0.1$

Supplementary Information The online version contains supplementary material available at https://doi.org/10.1007/s11027-024-10118-4.

Data availability The datasets generated during and/or analysed during the current study are available from the corresponding author upon reasonable request.

Declarations

Conflict of interest The authors declare no competing interests.

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