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Climate Change Resilience and Sustainable Tropical Agriculture: Farmers' Perceptions, Reactive Adaptations and Determinants of Reactive Adaptations in Hainan, China

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Abstract: The adversities of a changing climate in developing countries and the related impact on agriculture are directly dependent on the adaptive behavior of local farmers towards climate change events. The perception of farmers as basic executers of agricultural production plays a crucial role in their adaptation decisions. Through a field survey of 200 farmers in Hainan, China, this study covers the methodological gap in determining the reactive adaptations for coping with the changing climate and the underlying factors of farmers' adaptive behavior. The results indicated that the smallholder farmers are well aware of climate change, and the majority of them are taking adaptive measures such as following up on weather forecast, changing crop varieties, conserving agriculture through soil conservation and/or agroforestry, modifying different farm operations, increasing investment in infrastructure, increasing non-agricultural income of household, switching to new genetically modified cultivars, and engaging in water conservation methods. A binary logistic regression analysis was performed to study the determinants of farmers' adaptive behavior, and the results highlighted 10 significant factors affecting farmers' adaptations, including the age and gender of the farmer, non-agricultural income, training, credit access, policy demand, and perceived changes in climate change events. Our results are in line with the extant literature. The percentage of consistency (POC) was also calculated to evaluate the BLR results, and the overall POC was 60.7%. On the policy front, several suggestions are made based on derived conclusions, such as arranging training programs as a supplement to policymaking, incorporating significant factors for the development of high protection capacity, accounting for gender differences, and supporting crop insurance via subsidies.

Keywords: reactive adaptations; binary logistic regression; adaptation scoring; climate change perception

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1. Introduction

For developing countries, changing climate is becoming an obvious and growing threat [1], and across the Asian region, it is anticipated to worsen in the coming decades [2]. Human survival is mainly based on agricultural land and its development [3], as the world population relies heavily on agricultural production for feeding purposes [4]. The nexus between changing climate and agriculture is undeniable, and in recent decades, the agriculture sector has been adversely affected by climate change [5,6]. The farming system and agricultural production has been forecasted to face the formidable impact of climate disasters, along with weather extremes [7]. China has been listed among the top disaster-prone regions in terms of the potential impacts of climate change. Different climate models projected the accelerated warming in China, along with increased frequency of weather extremes and changing patterns of precipitations [8]. Out of total economic losses caused by natural disasters in China, 60% are caused by droughts [9]. The changing climatic conditions not only affect China's agricultural production, but also deprive the country's food self-sufficiency [10] and cause rural to urban labor migration, mainly due to developments of non-agricultural sectors [11]. Reduced crop production under climate change threatens food security and the sustainable development goals of the United Nations [9].

Surprisingly, in-depth studies related to reactive adaptations by local farmers are rarely found in literature, though they are the basis of human welfare and survival in the battle against climate change. For the national food security of China, mitigation and adaptations are vital for minimizing the negative impacts of climate change. Among various types of adaptations, two are most studied, viz. reactive and anticipatory, with the former being related to individual response to changing climate and the later dealing with government decisions implemented through different policies [12]. Smallholder farmers are most vulnerable to climate change through the disruption of stable livelihoods. At the same time, small growers are considered basic executors of adaptations in agricultural systems, to circumvent their vulnerability and sustain their income and livelihoods. Thus, quick adaptations to cope with the changing climate is the need of the time [1], particularly for small scale farmers [13]. However, no single solution regarding adapting agriculture to changing climate has been found, mainly due to regional differences and the complexity of climate change events. In general, limited research has been conducted to explore the farmers' perceptions and reactive adaptations to changing climatic conditions [12,14,15], especially in developing countries.

To adapt to a changing climate and its formidable effects, it is vital that farmers' perceptions about the issue are explored and studied. The theory of planned behavior in psychological and environmental research widely discusses the influence of behavior on environmental attitudes of people [16–19]. There exists a strong relationship between people's perception of risk and adaptive attitudes [20]. Farming system innovation is highly dependent on individual perception [21]. The theory of protection motivation also emphasizes that farmers' adaptive behavior is linked to the intention to adapt, based on their perception [22]. Literature has revealed the increasing perception of climate change occurrence among farmers from various regions [23–25], with some strands typically focused on Chinese farmers' perceptions and behavior towards this arduous phenomenon [20,26,27]. For instance, a study by Guo et al. [1] found that 92% farmers accepted the occurrence of climate change, out of which 45% were planning to adapt in the future. Similarly, Jianjun et al. [28] revealed that the majority of the farmers in the Yongqiao District of China are well aware of changing climatic patterns, and their risk attitudes were vital in various production decisions.

In terms of the policymaking of different countries regarding planned adaptations towards climate change, existing policies are too general, which can result in maladaptative measures. As far as China is concerned, the National Strategy on Climate Change Adaptation put forward by the Chinese government in 2013 highlighted agriculture among the top priorities. Nonetheless, main policy measures related to agriculture are of a descriptive nature, and these are not based on local farmers' perceptions and adaptive behavior, thus ignoring the expectations of small farmers [1]. Thus, these policy measures cannot be effectively implemented due to the ignorance of their perception and behavior.

A battery of extant literature highlighted a range of adaptive measures by local farmers across the world [23,29,30]. Suresh et al. [31] studied potential adaptation practices and their impacts on the rice productivity of Sri Lankan farmers by using an endogenous switching regression analysis and found that cultivation of pest-resistant and disaster-tolerant varieties are adopted by 60% of surveyed farmers. Pakistani rice farmers are also reported to take various adaptation measures to cope with adversities of changing climate, such as an alteration in fertilizer application, increased use of organic manure, increased irrigation, and various soil conservation techniques [12]. Similarly, a study on Chinese farmers' adaptative behavior highlighted the various changing land-use patterns and farm management practices as major adaptations at farm level [6]. Several other practices, such as purchasing the drought weather index, crop diversification, panting new drought-resistant varieties, higher irrigation infrastructures' investment, and new water conservation technologies by Chinese farmers [32]; advanced land use management measures, changing farm management practices, and changing cropping practices by Pakistani farmers [33]; soil and water conservation measures, social networking through cooperatives, crop and farm diversification, and use of information and communication technology by Indian farmers [23]; use of hoses and pumps for irrigation, cleaning of canals, and changing planting and harvesting dates by Chile farmers [29], are also reported in the literature. Table 1 provides a review of the literature regarding various adaptation measures taken by farmers across the world.

A range of socio-economic factors affect the adaptive behavior of local farmers under climate change, and understanding such factors would support policy ratification in accordance with the farmers' decision-making behavior. There is ample evidence from an exploration of the nexus between various factors and climate change adaptations among rural community [11,12,22]. Table 2 presents various socio-economic factors and personal attributes of farmers that are reported hitherto to affect adaptation measures. Amid these factors, education, climate-related-information level of farmers, membership in farmers' organizations, and plot size are found to be significant in the case of Sri Lankan farmers' adaptation behavior [31]. Similarly, the frequency of going to the market, farmland quantity, and non-farming income affected the adaptation efficacy of Chinese farmers [27]. Other factors with an influence on the adoption of adaptation strategies include agricultural training [1]; landforms [11]; technical, financial and physical support of farmers [15]; distance from markets [12]; descriptive norms and efficacy beliefs [22]; and water consumption [34].

Hainan Island became the 12th free trade zone (FTZ) and the first envisioned free trade port (FTP) of the country in 2018 [35]. The Hainan Economic Development Plan aims towards sustainable agriculture through high-value addition, which lies amid a targeted strategy of "One province-two bases". At current, the economic achievements of Hainan are moderate as compared to other coastal special economic zones (SEZs), ranking it as a less developed coastal province [35]. Among many factors responsible for this moderate development, agriculture production is a prominent one. Coastal agriculture sustainability is affected under climate change, which could be sustained through a combination of farmer' perceptions and their adaptation behavior into policy ratification [36]. Thus, by studying farmer perceptions and their adaptation options in the first envisioned FTP of China, we can further enrich the literature related to FTP and provide a future research path for Hainan FTP development through upgrading the research base for FTP and sustainable agriculture.

In light of the background given above, as shown by extant literature, there is a dearth of research regarding sustainable agriculture under climate change, especially in coastal areas such as Hainan FTP. Thus, to bridge this gap, the current study aims to explore the perception of local farmers towards climate change, alongside various reactive adaptations in Hainan Island of China. The main objectives of the study are: (1) to understand the perception of local farmers about climate change in Hainan FTP; (2) to explore the reactive adaptations adapted by local farmers as per their knowledge and perception; and (3) to investigate various influencing factors in the way of successful implementation of adaptation measures. The contribution of our research to the extant literature is threefold: First, the perceptions of individual farmers regarding changes in climatic conditions would be beneficial for policy formulation based on existing knowledge. Second, it will bridge the gap between policymaking and actual reactive adaptations by the local farmers. Third, the factors influencing the adaptive strategies will be examined deeply, which will aid in formulating effective and responsive policies by incorporating the factors affecting the implementation of adaptation strategies. Such policies can also be implemented in other areas in developing countries that are similar to our study area.

Table 1. Adaptation measures taken by local farmers across the world.

Adaptations: Crop Adjustments: Planting new cultivars	Intercropping	Crop diversification	Change crop variety	Crop rotation	Water/Soil: Irrigation adjustments	Soil management	Farm-Operation Management: Technology	Fertilizer/pesticide adjustment	Adjust farming time	Off-Farm Management: Insurance	Weather forecasting	Technical/financial support	Others	Research Area	References
			■					■	■				■	Pakistan	Abid et al. [33]
■			■						■					Pakistan	Ali & Erenstein [37]
			■	■	■				■				■	Thailand	Arunrat et al. [38]
■	■			■	■			■				■	■	Tanzania	Below et al. [39]
■		■			■	■	■	■					■	Iran	Esfandiari et al. [34]
		■			■		■						■	India	Funk et al. [23]
■		■			■		■			■				China	Jianjun et al. [28]
		■	■					■	■	■				Pakistan	Khan et al. [40]
			■		■		■					■	■	China	Kuang et al. [20]
■			■	■	■	■		■	■	■	■	■	■	Pakistan	Shahid et al. [12]
			■		■	■			■	■	■		■	China	Shi et al. [27]
			■		■			■		■	■		■	China	Song & Shi [41]
■		■			■			■	■				■	Sri Lanka	Suresh et al. [31]
■			■		■				■					Mexico	Torres et al. [30]
■	■		■						■		■			Vietnam	Trinh et al. [42]
					■			■	■	■			■	China	Wang et al. [3]
		■								■		■	■	China	Zhang et al. [43]

Source: Author's own elaboration.

Table 2. Various socio-economic factors and personal attributes of farmers affecting adaptation measures.

Factors: Socio-Economic Factors: Distance to markets	Credit accessibility	Extension/Training	Non-farm activities	Personal Attributes: Gender	Farm Area	Experience	Education	Environmental Beliefs	Household size	Age	Income	Other	Research Area	References
		■			■	■	■		■			■	Pakistan	Abid et al. [33]
		■				■					■	■	Thailand	Arunrat et al. [38]
■	■	■		■	■	■	■	■	■		■	■	Tanzania	Below et al. [39]
				■			■			■		■	China	Duan & Hu [44]
		■			■	■	■			■	■	■	Iran	Esfandiari et al. [34]
		■		■	■	■	■		■	■	■		India	Funk et al. [23]
		■					■	■				■	China	Guo et al. [1]
		■				■	■					■	Benin	Idrissou et al. [45]
				■		■	■	■		■	■	■	China	Jianjun et al. [28]
	■				■		■	■	■	■		■	Pakistan	Khan et al. [40]
					■	■	■	■	■	■		■	China	Kuang et al. [20]
■	■	■		■	■	■	■	■	■	■	■		Philippines	Mariano et al. [46]
				■			■			■	■		Malysia	Masud et al. [47]
	■	■			■				■		■	■	Bangladesh	Maya et al. [48]
	■	■		■	■	■	■	■	■		■	■	Ethiopia	Mihiretu et al. [49]
■	■	■	■		■	■	■	■	■				Pakistan	Shahid et al. [12]
■				■							■	■	China	Shi et al. [27]
								■		■	■		China	Song & Shi [41]
	■	■		■	■	■	■					■	Vietnam	Trinh et al. [42]
■		■			■	■			■	■		■	China	Wang et al. [50]
				■		■	■						China	Zhang et al. [43]

Source: Author's own elaboration.

2. Methodology

2.1. Study Area

The study site includes the Hainan Island of Southern China (18°10′–20°10′ N and 108°37′110°03′ E.), covering an area of 33,907.7 km^2 [51] and located at the northwest of the South China Sea [52]. It is the second-largest island of China [53], having a tropical maritime climate with clearly different wet and dry seasons, frequent typhoon visits, ample rainfall in autumn and summer, and high temperatures throughout the year [51]. The annual average temperature is recorded as 23–25 °C, with mean annual rainfall of above 1600 mm. This area has been selected as it is the first envisioned FTP of China, and has sustainable agriculture as a top priority and aimed strategy, as mentioned in Hainan Economic Development Plan [35]. Out of total land area of province, tropical and subtropical land occupies around 42.5%. The population of the province is predominantly rural, as at around 68.5% of the total population.

A variety of crops are grown in the region, including industrial crops such as tea, sesame, peanut, hemp, and sugarcane; and grain crops such as beans, millet, sorghum, rice, cassava, taro, sweet potato, upland rice, and wheat. Recently, rapid urbanization has been observed in the province [54], which may be due to changing climatic events and the related development of non-agricultural sectors [11]. The island coast has been affected by changing climate [52], with a recent increasing trend in temperature [55], and the farmers of this area are using various cropping systems to cope with changing climate [10]. Moreover, among various climatic events, Hainan has been reported to be highly affected by tropical cyclones [54,56]. Recently, amid major coastal provinces of China, Hainan province recorded the highest hazard risk of typhoons—the most destructive and frequent climatic event among all disasters [57]. A typhoon is usually accompanied by high tide events, heavy rains, and strong winds [57], and causes severe economic damages to agriculture and fishery production [56,57]. Thus, the agricultural land and farmers' adaptations towards climate change threats, such as tropical cyclones, are necessary to be investigated for the protection of agricultural economy of Hainan FTP tropical and sub-tropical zones. The location of the study area is provided in Figure 1.

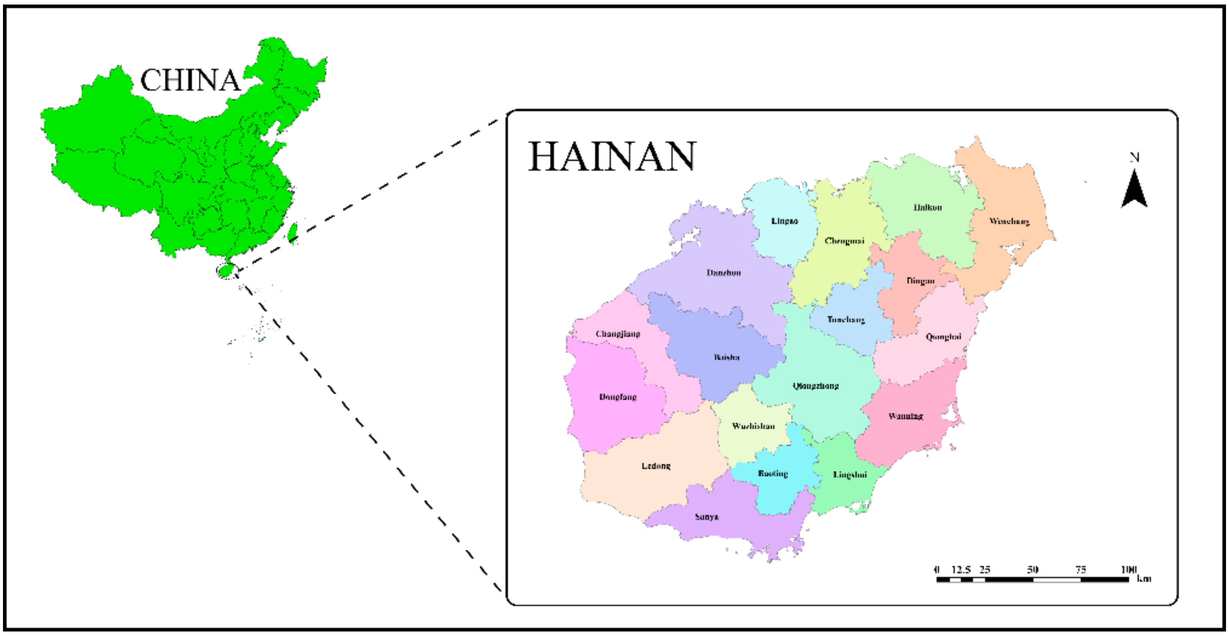

Figure 1. Location of the study site.

2.2. Conceptual Framework

The theory of planned behavior (TPB) suggests that there exists a nexus between farmers' perceptions and adaptive behavior. The pro-environmental behavior to cope with climate change is positively influenced by an individual's perception and attitude [47]. Moreover, farmers' adaptive behaviors, for their survival under changing climate threats, is based on the theory of protection motivation (PMT). According to PMT, different perceptions regarding the criticality of a threat leads to different coping mechanisms [58]. Thus, environmental protective behavior is opted for by individuals who perceive the threats of changing climate. The same is the case with farmers; if they perceive that climate change is happening and is a threat to sustainable agriculture, they will opt for protection behavior through different adaptation measures. Once the adversities of changing climate are well perceived by the local farmers, they implement various adaptation strategies, mainly on the basis of their perception of the advantages of such measures. Moreover, different socio-economic factors, as well as personal attributes of individual farmers, can affect the process of adaptation implementation (Table 1). Therefore, the current study is aimed at studying the perception of farmers regarding changing climatic conditions, their reactive adaptation actions, and the factors affecting the adoption of such adaptations. Climate change-resilient agriculture can contribute to the long-term goal of sustainable agriculture [59]. The conceptual framework of the current study is presented in Figure 2.

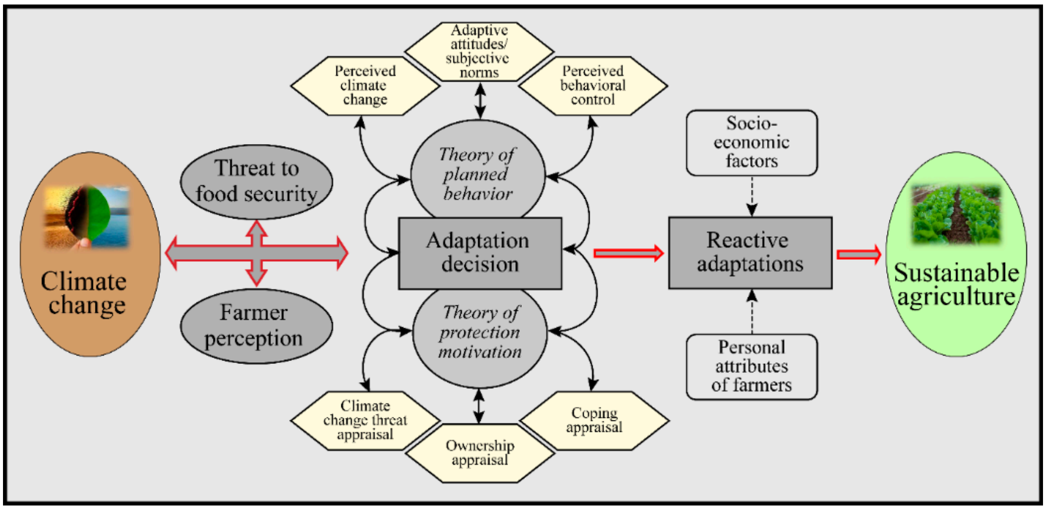

Figure 2. Conceptual framework of the study.

2.3. Data Collection

A household questionnaire survey including three stages was designed to collect the research data. In the first stage, using indicators from extant literature on similar areas, a preliminary questionnaire was constructed comprising three main parts: (1) personal attributes and socio-economic factors; (2) farmer's perceptions of climate change; and (3) reactive adaptations carried out in response to changing climate. At stage two, focus group discussions were carried out with local farmers for taking recommendations [12]. Finally, at stage three, a pre-testing of the questionnaire was performed through a pilot survey of non-respondents. After ensuring that the questionnaire was understandable for local farmers and taking feedback from local growers, we revised the preliminary questionnaire by omitting redundant questions, and the final questionnaire was developed [12] (Table S1). A formal survey of farmers was conducted from October 2021 to February 2022 by trained researchers from the lead author's university. Further, the questionnaire was available in two languages (Chinese and English), thereby reducing the communication gap. For improving sampling efficiency and reducing variation, a multi-stage sampling technique was followed [60,61]. A total of 28 administrative villages from nine counties of Hainan province were selected randomly for formal survey. Firstly, 221 interviews were conducted, out of which 21 were omitted due to errors and incomplete information regarding important questions, and 200 questionnaires were selected as final and valid for data analysis. Moreover, the data were kept anonymously for individual farmers, and questionnaires did not contain personal information to ensure the data was confidential. The average duration of interview was 25 min per respondent, and the effective questionnaire turn-out was 90.4%. A complete methodological framework is presented in Figure 3.

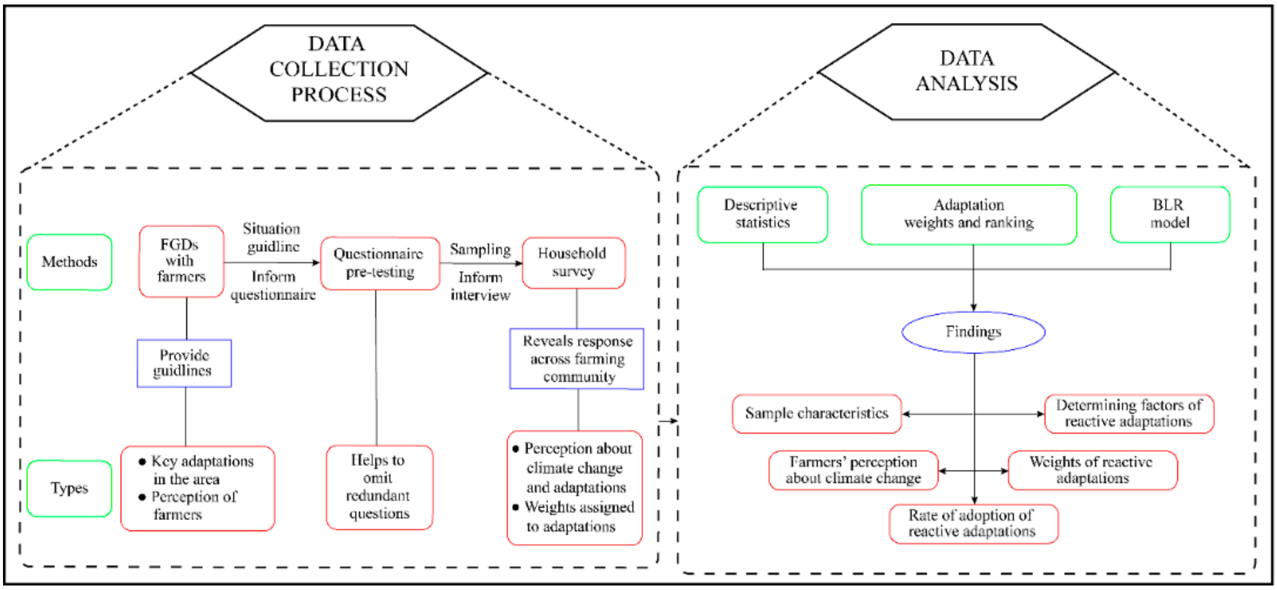

Figure 3. Methodological framework of study.

2.4. Analytical Framework

2.4.1. Description of Variables

The data on personal attributes comprised age, gender, education, inhabit time, and experience of the household head; household size; proportion of family labor in farm labor; and types of agricultural products grown on the farm. Moreover, the socio-economic factors of the respondents included total household income, proportion of agricultural income in total income, land area under agricultural production, insurance, distance of farmland to nearest county center, credit access, policy demand, trainings, market visits, and community linkage. The variables related to climate perception included perceived changes in the patterns of climate, temperature, precipitation, rainfall, typhoon, drought, and floods by the farmers. Based on the extant literature and results of the pilot survey, 15 adaptive behaviors were added in the final questionnaire under 6 main categories, including changing the crop varieties (for example early maturing, stress resistant varieties, etc.) [12,20]; switching to new cultivars (e.g., genetically modified varieties) [42]; intercropping, mixed cropping and crop diversification; modification of farm practices [39,42]; water conservation [28]; conservation of agriculture [12]; adjustment of planting and/or harvesting time [38]; increasing/decreasing area under cultivation; mulching, increased investment in infrastructure; purchasing weather index insurance for crops [2,28]; increasing the non-agricultural income; migration to cities [62]; and following forecasting system [12].

2.4.2. Farmers' Knowledge and Perceptions about Changing Climatic Parameters and Related Impact on Agriculture

Perceptions of farmers regarding changing climate and related parameters were recorded through 6 questions. As described earlier, these questions were included on the basis of extant literature and pilot survey. Farmers were asked about their perceptions over last decade about whether they noticed any changes in climate, temperature, precipitation, rainfall, typhoon, drought, and floods. Moreover, data on farmers' perceptions regarding the impacts of changing climate on agriculture were also collected through different questions. For each of these parameters, descriptive statistics were calculated, including frequency and percentage of responses.

2.4.3. Adaptation Weights and Adoption Rate

As mentioned by Shahid et al. [12], various practices are adopted by local growers for adapting to climate change. We have categorized 15 adaptation strategies into 6 main categories, as described previously. Farmers have devised a variety of adaptation measures to cope with changing climate, however these adaptations are not equally effective in reducing the effects of climate change. These approaches vary in terms of their feasibility, efficacy, and long-term sustainability. Therefore, weights were given to all adaptation mechanisms discovered in the region, based on interviews with respondents. Each exercise was scored using a 10-point Likert scale, with 1 representing ineffective and 10 representing very effective, based on all 3 criteria. For sustainability and feasibility, a similar Likert scale was utilized. The overall weight of each adaption was calculated by adding the ratings from all 3 Likert-scales [12]. Moreover, the adoption rate of each strategy was also calculated.

2.4.4. Binary Logistic Regression

To explore the underlying factors of local farmer's perceptions and adaptive behavior toward climate change, the current study employed logistic regression analysis. The logistic regression analysis is well suited for dealing with non-continuous variable regression issues [1]. We utilized a Binary Logistic Regression (BLR) model to evaluate how socioeconomic characteristics impact climate change adaptation, as our dependent variable was binary [63]. Following the method of [1], a BLR model was used in this research to explore the complicated link between several factors that may impact farmers' perceptions and adaptive behavior in response to climate change. The model was constructed to answer the following fundamental question: "What is the extent of possible determinants affecting adaptive actions of local farmers towards changing climate?" On the basis of this fundamental question, the current study describes the event as follow: Whether the farmer has implemented at least one adaptation practice or not. Thus, the adoption level is the dependent variable, which is a binary variable, in which 1 indicates that the farmer has implemented at least one adaptation practice and 0 indicates that the farmer has not adopted any adaptation.

The final BLR model is constructed as follows:

$$P_j = \frac{e^{\beta_0+\beta_1 X_1+\beta_2 X_2+\ldots+\beta_i X_i}}{1+e^{\beta_0+\beta_1 X_1+\beta_2 X_2+\ldots+\beta_i X_i}} \quad (1)$$

where P_j is the probability of occurrence of event j. If the event occurs, a value of 1 is assigned to P_j, and 0 otherwise. $X_1, X_2, \ldots, X_i$ represent the determinants of adaption level, while $\beta_1, \beta_2, \ldots, \beta_i$ represent the coefficients of these determinants, with $i = 26$.

The selection of independent variables was based on the extant literature, the characteristics of the sample, and the competence of the authors [20,44,64]. These variables are from 3 main factors, including personal attributes of farmers, socio-economic factors, and climate perception of local growers. Three main statistical parameters are calculated for these factors, including coefficient of regression (Coefficient), statistical significance of coefficient (Sign.), and odd ratios (Table 3). The detail of selected farmer level independent variables used in the BLR model is given in Table 4.

Table 3. Testing parameters for BLR model.

Parameter	Description	The Influence of Factor to Event Occurrence
Coefficient	Regression coefficient of the independent variable	>0, positive correlation <0, negative correlation =0, no relationship
Sign.	Significance level that implies the probability of making mistakes	<0.05, greatly significant (95% confidence interval) <0.1, significant (90% confidence interval)
Odd ratio	Odd ratio or $e^{(B)}$, the measure of association between an exposure and an outcome	>1, the higher, the higher possibility <1, the higher, the lower possibility =1, no relationship

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Table 4. Description of variables used in BLR model.

Category	Variable Name	No.	Description of Variable	Mean Value	Standard Deviation
Personal attributes (X_1–X_9)	Age	X_1	Age of farmer (years); 1 = 0–25, 2 = 26–25, 3 = 46–65, 4 = 66 and above	3.01	1.62
	Gender	X_2	Gender of farmer; 1 = male, 0 = female	0.86	0.98
	Household head	X_3	Farmer is household head or not; 1 = yes, 0 = no	0.73	0.54
	Education	X_4	Education of farmer in years; 1 = illiterate, 2 = primary, 3 = junior high school, 4 = high school and above	2.5	2.6
	Experience	X_5	Involved in farming activities since (years); 1 = 0–5, 2 = 6–15, 3 = 16–25, 4 = 26 and above	2.16	2.08
	Inhabit time	X_6	The time since respondent is living in the area (years); 1 = 0–5, 2 = 6–10, 3 = 11–15, 4 = 16–20, 5 = 21–25, 6 = 26 and above	4.38	4.95
	Household size	X_7	Number of household members (No.); 1 = 1–3, 2 = 4–6, 3 = 7–9, 4 = 10 and above	1.21	1.56
	Farm labor proportion	X_8	Family members engaged in farming out of total household (No.); 1 = 1–3, 2 = 4–6, 3 = 7–9, 4 = 10 and above	0.93	1.18
	Agro-type	X_9	Types of agricultural products; 1 = food crops, 2 = cash crops, 3 = animal husbandry, 4 = aquatic products	2.19	1.96
Socio-economic factors (X_{10}–X_{19})	Agri-income proportion	X_{10}	The percentage of agricultural income in annual total household income (%)	0.67	1.11
	Logged non-agricultural income	X_{11}	Log value of annual total household income excluding agricultural income (RMB)	4.22	6.31
	Farm land	X_{12}	Land area under agricultural use (acre)	12.09	9.59
	Insurance	X_{13}	Insurance for extreme weather events and related loss; 1 = yes, 0 = no	0.42	0.69
	Distance to county center	X_{14}	Distance of farm land to nearest county center (km); 1 = 0–5, 2 = 6–10, 3 = 11–15, 4 = 16 and above	2.08	2.21
	Policy demand	X_{15}	Whether the farmer demands for any training/guidance/awareness program from government; 1 = yes, 0 = no	0.95	0.82
	Training	X_{16}	Whether the farmer received any training related to climate change and relevant adaptations; 1 = yes, 0 = no	0.64	0.83
	Credit access	X_{17}	Does the farmer have access to any credit source; 1 = yes, 0 = no	0.39	0.42
	Market visits	X_{18}	The frequency of market visits (times per month)	2.5	3.51
	Community linkage	X_{19}	Does the farmer link to any farming community? 1 = yes, 0 = no	0.53	0.76
Climate perception (X_{20}–X_{26})	Perceived changes in climate	X_{20}	Did farmer notice any change in climate in last decade; 1 = yes, 0 = no	0.47	0.58
	Perceived changes in temperature	X_{21}	Did farmer notice any change in temperature in last decade; 1 = yes, 0 = no	0.36	0.5
	Perceived changes in precipitation	X_{22}	Did farmer notice any change in precipitation in last decade; 1 = yes, 0 = no	0.16	0.18
	Perceived changes in rainfall	X_{23}	Did farmer notice any change in rainfall in last decade; 1 = yes, 0 = no	0.18	0.21
	Perceived changes in typhoon	X_{24}	Did farmer notice any change in typhoon in last decade; 1 = yes, 0 = no	0.31	0.29
	Perceived changes in drought	X_{25}	Did farmer notice any change in drought in last decade; 1 = yes, 0 = no	0.23	0.37
	Perceived changes in flood	X_{26}	Did farmer notice any change in flood in last decade; 1 = yes, 0 = no	0.09	0.12

Source: Author's own elaboration.

2.4.5. Percentage of Consistency

For testing the applicability of our BLR model in predicting the probability of adaptation behavior of farmers, the percentage of consistency (*POC*) is calculated using the survey data. POC basically describes the performance of the prediction level of BLR results [1]. The predicted probability of the adaptation behavior of farmers ranged between 16–86%, with a mean value of 51.3%. For *POC* calculation, we followed the method of Guo et al. [1] and used 50% predicted probability as a threshold for categorizing our *POC* into 2 classes, viz. farmers taking adaptation measures with low probability and farmers taking adaptation measures with high probability. The formula for *POC* is as follow:

$$POC = \begin{cases} P_h/O_h, p > 50\% \\ P_l/O_l, p \leq 50\% \end{cases} \quad (2)$$

where,
P_h = number of predicted farmers taking adaptation measures with high probability ($p > 50\%$)
O_h = number of observed farmers taking adaptation measures with high probability ($p > 50\%$)
P_l = number of predicted farmers taking adaptation measures with low probability ($p \leq 50\%$)
O_l = number of observed farmers taking adaptation measures with low probability ($p \leq 50\%$)

The formula for overall POC (T_{POC}) is as follow:

$$T_{POC} = {}^{P_h + P_l}/_{O_h + O_l} \quad (3)$$

3. Results

3.1. Descriptive Statistics of Various Factors

Basic socio-economic factors, personal attributes of farmers, and their climate change perceptions are reported in Table 4. On average, a typical respondent was between 46–65 years old, and 86% participants were male farmers. Moreover, 73% of total respondents were household heads, and their average level of education was between primary and junior high school. The mean farming experience of the respondents was recorded as 6 to 15 years. The mean household size was one to six persons per family, with an average of 67% of income coming from agricultural resources. Average inhabitation time, since the respondent is living in the area, was 16–20 years. The majority of farmers were growing cash crops and visit the market two to three times in a month. Out of total sample, 42% of respondents bought crop insurance for extreme weather events and related losses. In terms of policy making, 95% farmers demanded any type of training, guidance, and/or awareness program from the government regarding climate change and possible adaptations, which indicates their expectation and reliance on government policies. A small numbers of farmers had access to credit (39%), while 52% farmers had links to different farming communities.

3.2. Farmer's Perceptions Regarding Climate Change Events in Last Decade

Climate change in the current study is defined as any perceived change in overall climate, temperature, precipitation, rainfall, typhoon, drought, and/or floods by the farmers (Figure 4, Table 4). Findings reveal that, over the last decade, a vast majority of farmers perceived changes in flooding patterns (91%), precipitation (84%), rainfall (82%), and overall climate (53%). On average, an overwhelming number of respondents are aware of changing climate, suggesting a higher level of awareness amid farmers in the area. These findings are consistent with other similar studies, where local farmers perceived climate change events very well [27,28].

3.3. Perceived Adversities of Climate Change for Agriculture

The survey revealed that farmers are mainly exposed to agricultural risks from changes in overall climate, temperature, flooding patterns, precipitation, and rainfall (Figure 5). Out of total sample, 86% respondents reported damage to agriculture due to various climate change events, while 14% farmers reported no damage. We also inquired with the farmers about the annual percentage loss in crop and agricultural production due to climatic changes over the last decade. Results show that, over the last decade, a large number of respondents (76%) reported an annual percentage crop loss of more than 30%. Out of these losses, most of the damage was caused by higher flooding (69%), followed by increased rainfall (52%), typhoons (36%), and heat waves (26%). These responses indicate the adversities of climate change for agriculture in the study area.

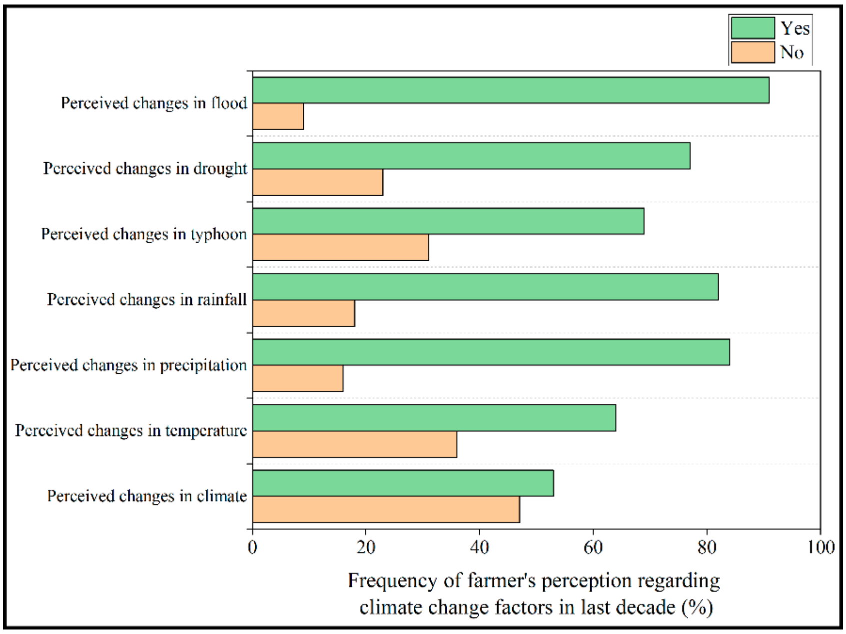

Figure 4. Farmer's perception regarding climate change in last decade.

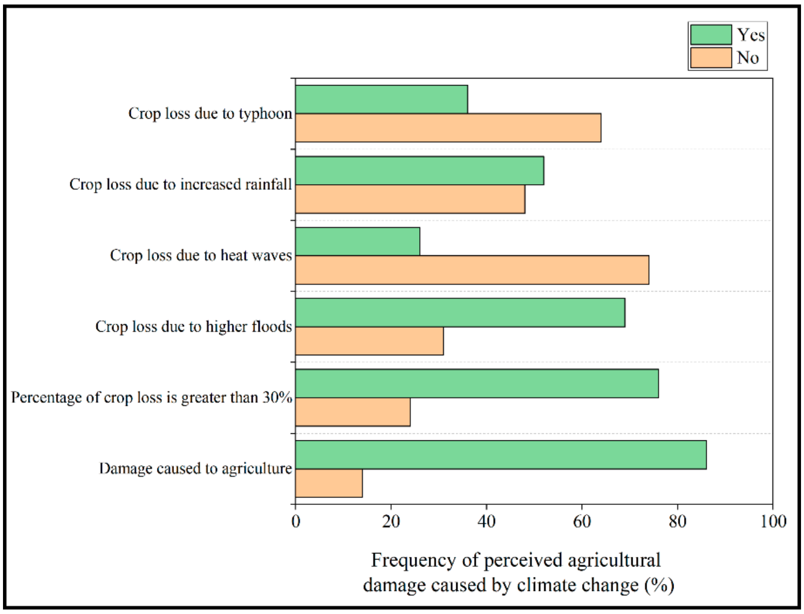

Figure 5. Farmer's perceptions regarding impact of climate change on agriculture.

3.4. Adoption Rate and Weights of Various Reactive Adaptations

For mitigating the adversities of climate change and related risks, an overwhelming majority of farmers (>85%) adopt various coping and adaptation strategies in Hainan (Table 5). Following up weather forecasts for adjusting farming operations is recorded as the most commonly adopted strategy (84%), followed by other strategies such as changing crop varieties, for example, using early maturing, stress resistant varieties (81.6%); conservation of agriculture including soil conservation and/or agroforestry (81.3%); modifying different farm practices including adjustment of fertilizer, pesticide application and/or planting and harvesting modifications (71.6%); increasing investment in infrastructure (61.3%); increasing non-agricultural income (59.3%); switching to new cultivars (genetically modified varieties) (56.2%); and water conservation through controlled irrigation, new technology or re-allocation of use of water (52.7%). Some other adaptations are also adopted by a small number of farmers, including intercropping (31.2%), mixed cropping and/or crop diversification (34.8%), modifying planting and/or harvesting time (46.2%), mulching (12.5%), increasing or decreasing area under cultivation (39.5%), and migration to cities (21.8%). In accordance with the previous literature, our results also highlight the higher adoption of following adaptations: weather forecasting [12], changing crop varieties [20,63,65], conservation of agriculture [65,66], modification of farm operations [20] increasing investment in infrastructure [32,63], increasing non-agricultural income [12], switching to new cultivars [63], and water conservation [12,65].

Table 5. Rate of adoption and weights of various reactive adaptations.

Adaptation Strategy	Code	Weights				Adoption Rate (%)
		Sustainability	Feasibility	Effectiveness	Aggregate Weights	
(1) Crops adjustment						
Changed crop varieties (for example early maturing, stress resistant varieties etc.)	A1	9	4	7	20	81.6
Switch to new cultivars (genetically modified varieties)	A2	7	8	4	19	56.2
Intercropping	A3	5	3	4	12	31.2
Mixed cropping/Crop Diversification	A4	6	5	3	14	34.8
(2) Modifying farm practices (adjusting fertilizer, pesticide application or planting and harvesting modifications)	A5	6	3	8	17	71.6
(3) Conservation techniques						
Water conservation (through controlled irrigation, new technology or re-allocation of use of water)	A6	7	4	2	13	52.7
Conservation of agriculture (for example soil conservation or agroforestry etc.)	A7	5	6	5	16	81.3
(4) Management of farm operations						
Adjust farming time (modifying planting, harvesting time etc.)	A8	7	5	8	20	46.2
Change area under cultivation (increased or decreased)	A9	4	5	5	14	39.5
Mulching	A10	7	5	2	14	12.5
(5) Off-farm Management						
Increased investment in infrastructure	A11	7	2	9	18	61.3
(6) Other adjustments						
Purchasing weather index insurance for crops	A12	3	7	2	12	41.8
Increasing non-agricultural income	A13	6	5	6	17	59.3
Migration to cities	A14	4	3	7	14	21.8
Follow up weather forecasts	A15	6	5	4	15	84.2

Source: Author' own calculation.

The aggregate weights on the basis of their feasibility, sustainability and effectiveness are given in Table 5. There exists a difference between the feasibility, sustainability, and effectiveness of various adaptations as perceived by the farmers, and the range of these weights lies between 12 and 20. The strategies with highest perceived aggregate weight (20) were adjustment in the farming time (modifying planting, harvesting time, etc.) and the change in crop varieties (for example early maturing, stress resistant varieties, etc.). Switching to new cultivars (genetically modified varieties) is the strategy ranked at second (19), followed by increased investment in infrastructure (18), modifying farm practices and increasing non-agricultural income (17), conservation of agriculture (16), and following up weather forecasts (15). These results are consistent with other studies on the significance of farmers' adaptations [20,65,66]. Other strategies are ranked lower as per farmers' perceptions and assigned weights. The aggregate weights of all adaptation strategies as per farmers' perceptions are presented in Figure 6.

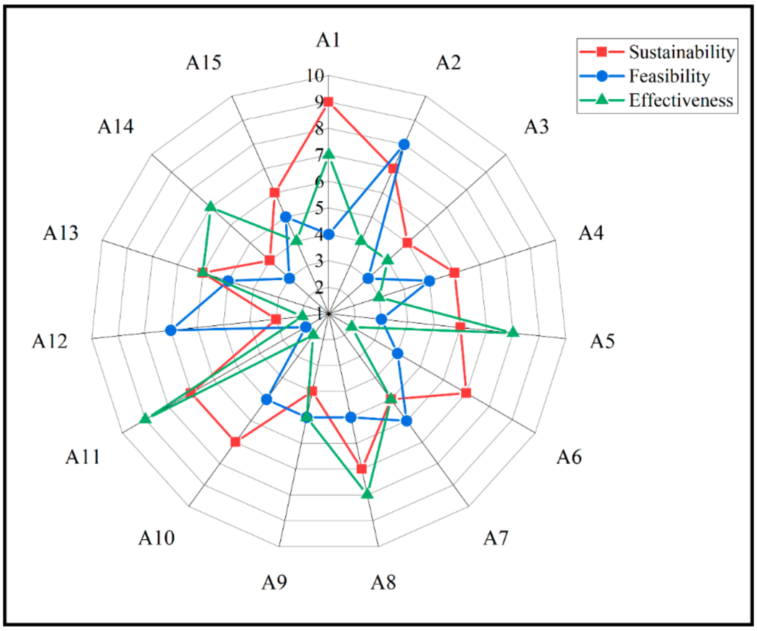

Figure 6. Weights assigned to various adaptation strategies on the basis of their sustainability, feasibility, and effectiveness.

3.5. Results of BLR Model

To determine the influence of the 26 variables mentioned in Table 4, the BLR model was run in two rounds. All 26 factors passed the correlation test as a pre-requisite of BLR analysis. The results of the first-round model showed that farmers' adaptive behavior was significantly predicted by 10 factors (Table 6), as the significance level of these factors was lower than 0.1, showing the significant impact of these factors at a 90% confidence interval. The results of the first-round BLR model with all 26 factors are shown in Table 6. The significant factors having positive influence on farmers' adaptive behavior include the gender of farmer, non-agricultural income, training, credit access, perceived changes in temperature, precipitation, rainfall, and flood; while the factors having negative influence include age and the demand of any type of training, guidance, and/or awareness program from government regarding climate change and possible adaptations. Out of these 10 factors, the highest odd ratios were found for age of farmers (3.946) and policy demand by the farmer (3.184), indicative of a higher possibility of the negative effect of farmers' age and policy demands on their adaptation behavior.

The age of farmer is considered as an important factor in determining adaptive behavior [12]. The coefficient of age is negative, showing that as the age of farmer increases, their adaptive attitude declines. For farm-level adaptations, gender has been considered an important determinant of adaptive behavior [67]. The coefficient of gender in our study is significant and positive, indicating that farmers' adaptive behavior is different for male and female farmers. This is in line with the extant literature, as gender differences have been proven to affect adoption of adaptations differently—the likelihood of adopting adaptations is greater for male farmers than females [32]. The coefficient of non-agricultural income of farmer affects farmers adaptation behaviors positively, which is not surprising as Deressa et al. [68] suggested that wealthier farmers pose a higher capacity to buy and plant new varieties as well as have better planning horizons. The coefficients of farmers' training and their access to credit are positive, which is also in line with the extant literature [23,38,69]. The perceived changes in temperature, precipitation, rainfall, and flooding are also significantly affecting the farmers' adaptive behavior in a positive manner, suggesting that if the farmers are aware of climate change threats, it would be important determinant of taking agricultural adaptation measures [13,70]. The theory of protection motivation also supports the findings, as farmers' adaptive behavior is linked to intention to adapt, based on their perceptions [22]. Furthermore, the theory of planned behavior also supports the findings, as there exists a strong relationship between people's perception of risk and adaptive attitudes [20].

Table 6. Results of first-round BLR model for farmer's adaptations.

Factor	Coefficient	Sign.	Odd Ratio	Factor	Coefficient	Sign.	Odd Ratio
X_1 ***	−0.021	0.007	3.946	X_{14}	−0.084	0.034	1.865
X_2 **	2.417	0.041	1.348	X_{15} **	2.045	0.008	3.184
X_3	−0.204	0.637	1.946	X_{16} ***	1.741	0.043	2.548
X_4	−0.108	0.749	1.114	X_{17} **	1.159	0.692	1.054
X_5	0.093	0.384	2.078	X_{18}	0.496	0.367	1.927
X_6	0.093	0.784	1.068	X_{19}	0.948	0.873	3.064
X_7	−0.059	0.213	1.347	X_{20}	0.504	0.003	2.514
X_8	1.974	0.124	2.495	X_{21} ***	0.9483	0.094	2.167
X_9	0.485	0.231	1.582	X_{22} *	−0.347	0.497	0.945
X_{10}	−0.614	0.945	1.548	X_{23}	0.194	0.003	2.594
X_{11} **	2.043	0.028	1.994	X_{24} ***	0.097	0.946	1.594
X_{12}	0.0549	0.548	1.853	X_{25}	0.764	0.005	2.634
X_{13}	−0.1796	0.191	1.946	X_{26} ***	0.184	0.154	2.046
B_0	−2.437	0.648	0.649				

Note: Factors with ***, **, and * indicate the 1%, 5%, and 10% level of significance, respectively.

On the basis of first-round analysis, a second-round model was also run by omitting the non-significant factors (with a significance level of less than 0.1). The results of the second-round BLR model are presented in Table 7. On the basis of these results, the final BLR model for estimating the probability of adaptation behavior of farmers is established as follows:

$$p = \frac{e^{-2.904-0.047X_1+2.318X_2+2.138X_{11}-0.062X_{15}+1.994X_{16}+1.684X_{17}+0.498X_{21}+0.875X_{22}+0.201X_{23}+0.8X_{26}}}{1+e^{-2.904-0.047X_1+2.318X_2+2.138X_{11}-0.062X_{15}+1.994X_{16}+1.684X_{17}+0.498X_{21}+0.875X_{22}+0.201X_{23}+0.8X_{26}}} \quad (4)$$

Table 7. Variables for the final BLR model for farmers' adaptations.

	Coefficient	Sign.	Odd Ratio	SE	WS
X_1	−0.047	0.052	3.674	0.191	5.214
X_2	2.318	0.068	1.218	0.143	6.118
X_{11}	2.138	0.043	2.548	0.384	4.061
X_{15}	−0.062	0.084	1.945	0.316	5.826
X_{16}	1.994	0.018	3.067	0.259	4.397
X_{17}	1.684	0.064	2.615	0.192	6.357
X_{21}	0.498	0.009	2.554	0.246	6.089
X_{22}	0.875	0.007	2.254	0.183	3.064
X_{23}	0.201	0.068	2.621	0.301	4.857
X_{26}	0.8	0.009	2.694	0.251	5.082
B_0	−2.904	0.006	1.119	0.748	9.584

Note: SE indicates standard error, and WS represents Wals stat.

The predicted probability of adaptation behavior of farmers is represented by p.

3.6. Percentage of Consistency

For testing the applicability of our BLR model for predicting the probability of adaptation behavior of farmers, the percentage of consistency (POC) is calculated. The results of

POC analysis are presented in Table 8. The POC for farmers with adaptations are lower (41.9%) than for farmers with no adaptations (72.7%), suggesting that our BLR model is capable of classifying 41.9% respondents taking various adaptive measures. The value of T_{POC} is 60.7%, which is considered acceptable [1].

Table 8. Prediction consistency of BLR model for farmers' adaptation behavior.

Observed	Predicted			
	Farmer Adaptation with High Probability ($p > 0.5$)	**Farmer Adaptation with Low Probability ($p \leq 0.5$)**	**Sum**	**POC (%)**
Farmer with adaptation	47	65	112	41.9
Farmers with no adaptation	24	64	88	72.7
G_{POC} (%)				60.7

4. Conclusions and Policy Implications

China's agricultural output is predicted to be significantly impacted by climate change. As a result, local producers need to take the necessary steps to mitigate the adverse impacts of climate change. For achieving the target of food security, it is essential to understand the perception and attitude of farmers and their adaptive behaviors under changing climate conditions as a basic decision-making unit. The current study sought to propose a conceptual framework of farmers' perceptions of and reactive adaptations to the climate change threat in the Hainan province of China. The findings revealed that the gap between farmers' perceptions and adaptive behavior was very low. An overwhelming majority of farmers perceived changing climatic patterns as well as adversities of climate change for agriculture. As far as their reactive adaptation measures are analyzed, the majority of farmers tended to adopt many practices, such as following up on weather forecasts, changing crop varieties, conserving agriculture through soil conservation and/or agroforestry, modifying different farm operations, increasing investment in infrastructure, increasing non-agricultural income of household, switching to new genetically modified cultivars, and engaging in water conservation methods. The adaptation strategies perceived to be highly effective, feasible, and sustainable by the farmers include adjustment in farming time, change in crop varieties, and switching to new cultivars. Based on the BLR analysis, the factors having significant impact on farmers' adaptive behavior include age and gender of farmer, non-agricultural income, training, credit access, policy demand, and perceived changes in temperature, precipitation, rainfall, and flood.

For improving the adaptive behavior of farmers and ensuring food security, feasible and effective policymaking is crucial. Supportive policies for farmers regarding adaptation to climate change at the farm level need to be properly designed as soon as possible, given the mounting evidence of climate change across the globe, especially in coastal areas such as Hainan Island. Through a deep investigation of the factors affecting farmers' adaptive behavior, the following suggestions are made for policymakers:

(1) According to the theory of protection motivation, the development of high protection capacity (i.e., adaptive behavior) is dependent on several factors affecting the motivation and competence of developing decisions. Thus, for the promotion of the effective and protective capacity of farmers, it is critical to address various significant factors at the same time.

(2) One important facet of planning adaptation strategies is to account for gender differences. Decision-making units and local governments should interact with rural communities, particularly women, while designing policies and adaptations for the climate change threat.

(3) Agricultural training related to climate change implications, as well as the benefit of adaptations, should be arranged as a supplement to policymaking. If farmers' knowl-

edge is improved via training programs, it would ultimately lead to better adaptive behavior, as farmers' actions are based on their own perceptions and interests.

(4) Farmers should be encouraged to modify their planting and harvesting time accordingly. The majority of farmers have not changed their planting and harvesting times in order to adapt to climate change, which is a negative finding. Farmers should be guided to alter planting and harvesting times based on weather changes, soil moisture, and crop development, as government weather monitoring, long-term forecasting, and guidance are all intensified throughout the planting and harvesting seasons.

(5) Finally, it would be beneficial to raise the amount farmers receive in the form of subsidies. Insuring crops against climate change is a solution, but only 41% of farmers have done so. As per the affected region, the government should relieve farmers substantially, reduce the barrier to acquiring agricultural insurance, and improve monitoring to assure that the insurance is delivered to farmers on time. To encourage farmers who have already taken successful steps to act as role models, the government may grant subsidies.

Supplementary Materials: The following are available online at https://www.mdpi.com/article/10.3390/atmos13060955/s1, Table S1: Farmers' Household Survey Questionnaire.

Author Contributions: Conceptualization, R.S. and S.L.; Methodology, R.S. and S.L.; Data Collection, R.S. and X.J.; Software and Validation, R.S.; Formal Analysis, R.S.; Writing Original Draft, R.S.; Review and Editing, S.L. and J.G.; Supervision, S.L.; Funding and Acquisition, S.L. All authors have read and agreed to the published version of manuscript.

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