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Linking Climate Change Awareness, Climate Change Perceptions and Subsequent Adaptation Options among Farmers

Ghulam Mustafa ¹, Bader Alhafi Alotaibi ^{2,*} and Roshan K. Nayak ³

¹ Department of Economics, Division of Management and Administrative Science, University of Education, Lahore 54000, Pakistan

² Department Agricultural Extension and Rural Society, King Saud University, Riyadh 11451, Saudi Arabia

³ Division of Agricultural and Natural Resources, University of California, 2801 2nd Street, Davis, CA 95616, USA

* Correspondence: balhafi@ksu.edu.sa; Tel.: +966-504240201

Abstract: Several studies have reported farmers' perceptions of climate change, but there is inadequate knowledge available on the farm households' climate change awareness (CCA) in Pakistan. This study was undertaken to assess farmers' CCA. For this purpose, the study collected the data from southern and central Punjab, Pakistan, through a purposively multistage random sampling technique. Binary logit and odds ratio were used to analyse the data. The analysis of the study shows that the majority of respondents were aware of climate change but had differing perceptions of climate change. This research showed that 70.8% of farmers are aware of climate change and reported their awareness level on winter and summer rainfall and temperature, the growing season length (GSL) of crops, the sea level rise, and the causes of climate changes and conceptual understanding of it while persistently denying climate change. However, many farmers did not perceive decreasing winter (48%) and summer (31.2%) precipitation, the majority of the farmers could not perceive in the GSL of summer (63.2%) and winter (64.4%) crops, while few did not notice increased winter (36.4%) and summer (33.6%) temperature, respectively. Financial and non-financial factors such as education (1.16), experience (1.07), distance to markets (1.07), non-agricultural income (2.83), access to agricultural credit (0.29) and marketing of produce (6.10), access to extension services (3.87) and the number of adaptation strategies (1.30) were pointedly related to farm households' CCA. These odds values in the parenthesis show that the likelihood of CCA increases/decreases as these determinants increase. Moreover, the results of the study show that CCA is a significant predictor of adaptation to climate change. Main adaptation strategies opted for by farmers include changing crop variety and type, changing planting dates, tree plantation, increasing/changing fertilizer, soil and water conservation, off-farm income and diversification. Further, the study finds that some farmers did not perceive climate change as it takes time to be visible, but they are aware of climate change. Therefore, there is a need to reshape the households' perception of climate change and enhance farmers' CCA through existing extension services.

Keywords: adaptation to climate change; climate change awareness; CCA; logit model; odds ratio; perception



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1. Introduction

Climate change is a fact, and it has already left negative signs in every field of life. Observational evidence indicated variations in temperature and rainfall reliability in Southeast Asian countries, particularly Pakistan [1]. In addition to existing challenges, the impacts of climate change are making farm households more vulnerable. It can impact millions of people in the country [2]. Unfortunately, most developing and under-developing countries are still in the denial stage of climate change grief [3,4]. Farmers of such countries take

changes to the climate as the result of a natural cycle, and hence, they feel less obliged to develop any management strategies [5]. Therefore, this study aims to assess the farmers' climate change awareness (CCA).

Perception and awareness of climate change are two different terms that, unfortunately, are used interchangeably in the literature. For instance, Simpson et al. [6] reported that confusion between concepts of CCA and climate change perception has also hindered understanding of the importance of different predictors of climate change knowledge. Similarly, Madhuri and Sharma [7] are of the opinion that there is a nuanced relationship between farmers' perceptions and climate change information and their associated determinants. Awareness is something you know through knowledge or perception of a situation or fact. Climate change is a fact, and most developing countries, including Pakistan, are still in the denial stage of climate change. Therefore, awareness of climate change is a better term than climate change fact. On the other hand, perception is the way in which something is regarded, understood or interpreted through the ability to see, hear or become aware of something through the senses. Perceptions can be changed over time, while awareness about a fact does not change.

The growing impacts of extreme weather events posted by climatic variations on every field of life have generated rich contributions to the literature on the general public's CCA in the last few years [8,9]. However, the literature on farmers' CCA is rather limited and under-researched. Few efforts have been made in this area that is primarily based on farmers' perceptions of climate change [1,6,10,11]. Awareness is the first step in any perception being created [7]. The reason behind this is that sometimes farmers do not perceive climate change as it takes time to be visible. For instance, Maddison [12] finds that farmers hardly detect immediate climate changes as changes in atmospheric conditions are a long-term process. Therefore, climate change is a slow process that can only be observed with meteorological instruments, and the farmers rely on a short-term experience based on their past memories while reporting climate-related information [13]. In such circumstances, it is quite vague to find the farmers' perception of climate change, particularly in a dichotomous fashion [14]. For instance, Hasan and Kumar [15] find no evidence of whether farmers of Bangladesh perceive climate change properly. Thus, CCA can better address climate-related issues and associated adaptation practices.

There are many theories (e.g., information deficit, nudging, circuit model and binding communication theory) about why CCA does not inspire the kind of behavior changes it should [8,16–19]. Providing more or better information is necessary for communication to be effective in terms of raising awareness and promoting adaptation to climate change. The most important question pertaining to climate change perception is either do they match reality. The extent to which perceptions match the real-world data on changes in climate would lead to better communication [7]. This can be performed by combining field and laboratory research with real-world, observed data [17]. Otherwise, effective communication would fail. The perception of people is very important in behavioural changes, such as an adaptation to risk (climate change) [9]. When people have a positive attitude about the environment, coupled with strong CCA, it translates to effective adaptation strategies [20]. People's CCA becomes more salient and vivid when they perceive and experience climate-related hazards [21]. Therefore, the study in hand is designed to check the farmers' CCA, how they perceive climate change and subsequent adaption strategies.

Many farmers are aware of climate change, but the extent to which farmers are aware of climatic vagaries (unpredictable or erratic rainfall and temperature) is unclear [22]. Apparently, this is because of how farmers experience the impacts of climate change, their understanding of the reasons, how they respond, and the costs to them vary [23,24]. Conversely, climatic variations are generally perceived as being unimportant by some farmers, and hence they believe changes to the climate were not human-induced [25]. Therefore, they feel less motivated to apply coping and adaptation strategies [5]. Some farmers may not notice or care about climatic variations and perceive that changes in climate are natural processes [26,27]. For example, Hamilton and Keim [28] find an inverse

relationship between age and CCA level of respondents in nine U.S. states. Similarly, low education levels, illiteracy and lack of experience may decrease CCA [29,30]. Another study found that farm size significantly increases the CCA of farmers' and large farmers perceive more climatic shocks as compared to small farmers [31,32].

Farmers who are involved in non-farming activities may have a great deal of climatic awareness. For instance, if farmers have non-agricultural income, their awareness level may increase [31,33]. For instance, Das and Gosh [26] find that CCA knowledge significantly improves by income from non-farming activities. Many farmers take changes in climate in a religious manner, while others have a scientific perspective [34], and their CCA depends on farmers' access to climate-related information, education level and their local long-term climate change observation [35].

Climate knowledge has been considered the main factor for any adaptation and mitigation strategies, particularly in farming systems. Ng'ombe et al. [36] were of the opinion that the success of adaptation and mitigation efforts to climate change mainly depends on the farmers' CCA. Farmers' climatic information provides multiple solutions and practices that can reduce environmental risks [37,38]. For instance, raising CCA is essential for increasing environmentally-friendly farming practices [39]. It ensures that farmers undertake appropriate management strategies to mitigate the adverse impacts of climatic vagaries [37]. The CCA empowers farming communities for sustainable use of natural resources [40,41]. It helps farmers to be actively involved in agri-environmental programs [40,42]. The CCA is imperative to develop a sense of ownership among the farmers [43].

Research reported in the empirical literature suggests a strong association between CCA and its impact on adaptation [44,45]. How farmers receive knowledge of climate change impacts how they handle it. This knowledge would ultimately lead to adaptation techniques and processes involved in it [44]. On the other hand, any misconception or poor planning about CCA and its associated risks may cause an adaptation deficit or no adaptation, thus exacerbating the inevitable impacts of climate change [46]. Therefore, knowing the extent of farmers' CCA is very important in terms of understanding their adaptation behaviours. This knowledge is also extremely important in shaping national adaptation and mitigation policies. The previous literature has determined farmers' CCA, yet most of the studies failed to consider the effects of CCA on adaptation practices [31,47]. Moreover, very little is known about the factors affecting farmers' CCA.

Pakistan is the sixth most populous country in the world and is among the top ten countries that could be severely affected by climate change [48]. The mass community of the country who are very poor is highly susceptible to the negative impacts of climatic variations. The agriculture sector of Pakistan grew by 4.4%, with a 22.7% contribution to GDP and a 37.4% share in the total labour force; thus, any adverse consequence posed by climatic variations might negatively impact the livelihoods of millions of the population [2]. For instance, crop simulation model-based studies reported 21 percent and 40 percent reductions in wheat yields in the case of RCP 8.5 for the 2020s and 2080s, respectively, in various parts of Pakistan. Till now, Pakistan has not devoted much of its efforts to curtailing the emissions from agriculture due to limited awareness and low confidence in monitoring/estimation of these emissions [2], p. 307. In the countries where rates of CCA are high, particularly the Global North, research has mainly focused on risk perception, opinion or belief, climate change perception, awareness and whether these perceptions and awareness correlate with adaptation [49–52]. In contrast, in Southeast Asian countries, studies suggest that the perception of meteorological change is high [1,53,54], but very little is known about CCA and its relation with adaptation strategies. Against this backdrop, this research was conducted to assess farmers' views of climate change and the factors affecting it in Punjab, Pakistan. It is expected that it would contribute to a deeper understanding of farmers' CCA and its consistency with adaptation. The findings of this study identify the factors that can be used by policymakers and practitioners to support climate change knowledge and agricultural adaptation to climate change.

2. Conceptual Framework

Conceptually, awareness of climate change is influenced by the number of institutional, farm and farmer-specific characteristics. The institutional factors, which comprise access to agricultural credit [32], membership in farmers' organizations (FOs) [31], access to the marketing of produce [1] and access to extension services [55], impact farmers' CCA. Congruently, farm-specific characteristics, including distance to the output market [1], landholding [56], tenancy status [33], crop income [31] and hired labour [15], also shape the farmers' awareness of climate change. Moreover, farmer-specific characteristics such as household size [57], farming experience [29], level of education [30], off-farm income [32, 56] and farmer-to-farmer cooperation or farmers group [55,58] influence farmers' CCA.

Additionally, personal adaptation factors such as the number of adaptation strategies also affect the CCA of the farmers. The CCA, in turn, determines the adaptation to climate change. For instance, Fahad et al. [56] argued that farmers who are aware of climate change become proactive in adopting farm management adaptation practices. Therefore, many farmers are likely to adopt management strategies to reduce the negative impacts of climate change [59]. The reason is that adaptation to climate change is mainly driven by the CCA [60]. Moreover, this adaptation behaviour further increases the farmers' awareness of extreme weather events. In simple wording, there is a causal relation between CCA and adaptation strategies. Building on this body of the literature, the study presented the following conceptual framework (Figure 1).

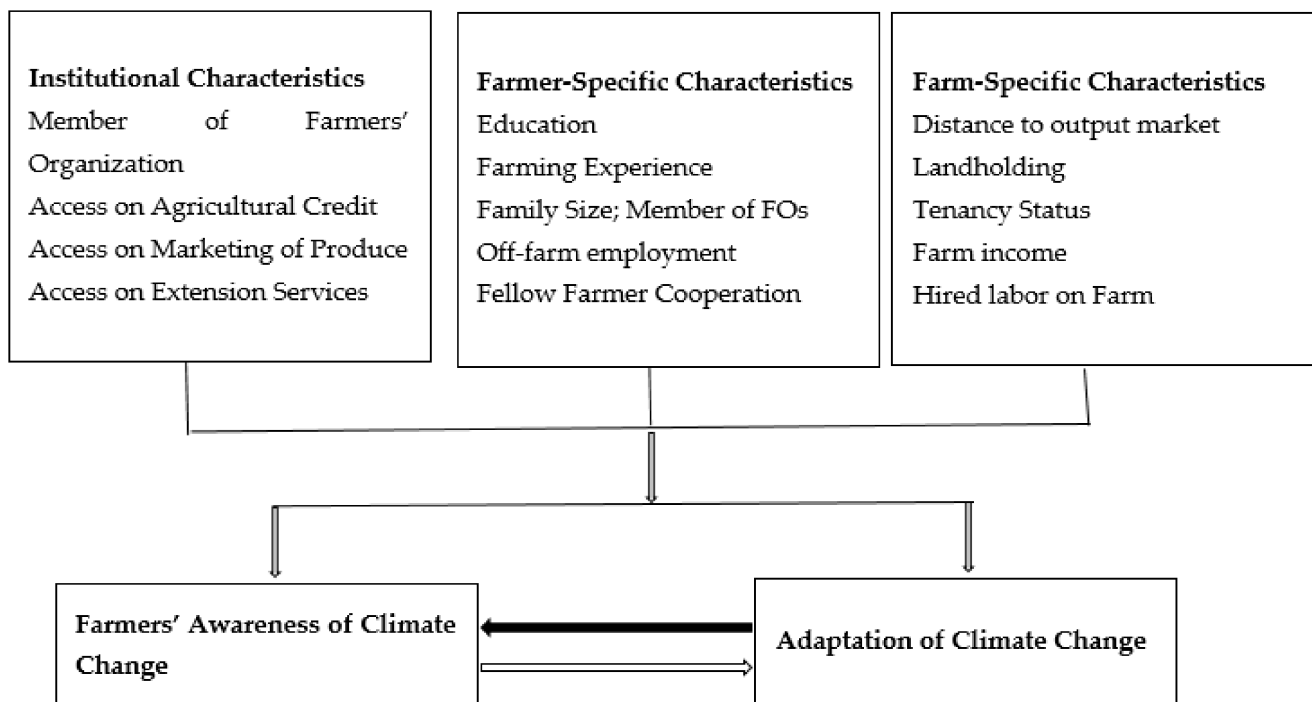


Figure 1. Conceptual framework of the study. Note: Own illustration based on past literature.

3. Materials and Methods

3.1. Research Design

A farm household survey was conducted in central and southern Punjab. In the first stage, Punjab is selected as it is the most populous province, and almost 60 percent of the population lives in this province. Punjab is a major contributor to the agriculture of Pakistan. In the second stage, central and southern Punjab was selected as these areas are most vulnerable to climate change [61,62]. In the third stage, one Tehsil from each district is selected (Figure 2). In the fourth stage, five villages from each Tehsil are randomly selected. In the fifth and last stage, one model farmer is purposively selected with the

help of agricultural officers. Thus, a multistage purposively random sampling technique is applied for data collection.

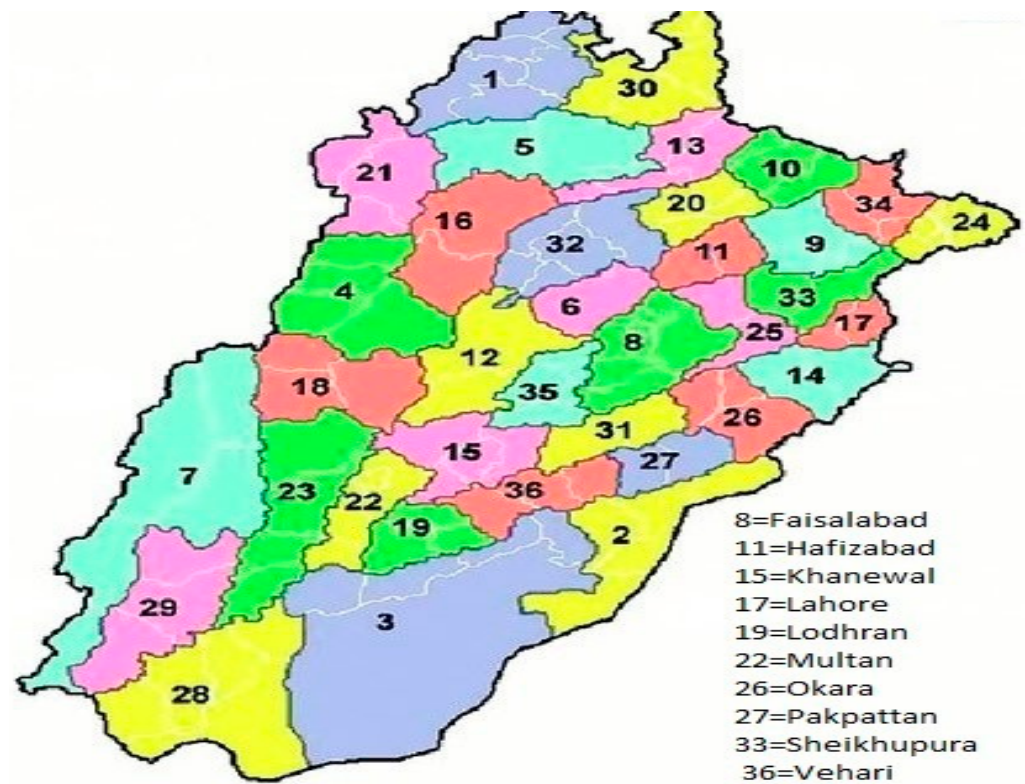


Figure 2. Map of Punjab Province.

Data were collected using a structured questionnaire that was translated into Urdu to remove communication barriers, if any. Further, a questionnaire was updated on Google form to collect the data to follow COVID-19 SOPs. However, face-to-face interviews were conducted, but the passing of questionnaire papers from hand to hand was avoided. Farmers were asked to respond about their socioeconomic status, the awareness level of climate change and adaptation strategies they were using on their farms from September 2021 to April 2022. Moreover, farmers were told that data would only be used for research purposes and that their anonymity would be maintained.

The used purposively technique in the sense we selected model farmers and climate change-affected districts of Punjab followed by a previous study [32]. Model farmers are those who received government service subsidized water-saving technologies, free water and soil-testing services, low/free interest rate credit facilities or any form of the latest knowledge and technology. These farmers were readily able to spare the lands to adapt government technologies at subsidized rates (For instance, growth of new crop variety or change of crop or application/testing of new plant medicines). The detail of the data collection procedure is given as below (Table 1).

3.2. Model Specification

The study used two models; logit and multiple regression model. The previous study used the low, medium and high awareness levels [32,54,63] and thus used Multinomial logit and probit models. Such models can be used where 100 percent of respondents know about climate change but varying degrees regarding all climate change-related variables (e.g., temperature, rainfall, GSL, causes of climate change, sea level rise, etc.). However, the dilemma is that most developing countries do not have such knowledge and do not consider climate change a factual phenomenon, hence denying climate change (3–4). In such circumstances, you know or do not know (zero/one). We provided the list of climate

change-related factors to farmers and asked them to report their awareness level on winter and summer rainfall and temperature, GSL of crops, sea level rise, causes of climate changes and conceptual understanding of farmers (such as pollution and carbon emission). We categorized farmers as those who are at least aware of one reason for climate change and the rest who are unaware or deny the climate is changing. Following previous studies, this study used a dummy nature of CCA, and thus the binary logit model is applied (26, 36, 56, 33). Moreover, the study used the multiple regression model with CCA as an independent variable (it is a dependent variable in the logit model) and found a 48% variation in CCA and adaptation strategies. The correlation matrix for the remaining variables is given in Appendix A.

Table 1. Respondents of Field Survey.

Zone	Districts	Tehsil	Villages	Farmers	Total
Central Punjab	Lahore (5)	1	5	5	25
	Sheikhupura (5)	1	5	5	25
	Okara (3)	1	5	5	25
	Faisalabad (6)	1	5	5	25
	Hafizabad (2)	1	5	5	25
Southern Punjab	Multan (4)	1	5	5	25
	Vehari (3)	1	5	5	25
	Khanewal (4)	1	5	5	25
	Lodhra (3)	1	5	5	25
	Pak Pattan (2)	1	5	5	25
Total		10	50		250

Source: Field survey (values in parenthesis are Tehsils).

By using the binary logit model, we estimated the farmers' CCA level, where awareness was taken in a dichotomous (yes/no) fashion. The respondent was probed about their awareness level of climate change. They were asked to report how they perceive the rainfall and temperature patterns of Rabbi (winter) and Kharif (summer) cropping seasons. Moreover, they also asked to report the growing season length of Rabbi and Kharif crops. Based on this information, farmers' knowledge was assessed on actual climate change knowledge, as also used in a previous study [32]. Therefore, we categorized each farmer as either those who are aware or unaware of climate change. Thus, the study made CCA a binary variable. Logistic regression uses maximum likelihood estimation. It estimates the parameters of the most likely observed data. This model considers the relationship between a dummy dependent variable and a set of explicative variables. The model is given as below:

$$\ln\left(\frac{L_i}{1-L_i}\right) = \alpha + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \dots + \beta_{16} X_{16} + \varepsilon \quad (1)$$

where $\ln\left(\frac{L_i}{1-L_i}\right)$ is the logit for farmers' CCA (e.g., L_i = probability of awareness of climate change and $1 - L_i$ is unaware of climate change), β_i s are coefficients to be estimated (it is the $K \times 1$ vector of unidentified parameters), X_i s is the $1 \times K$ vector of other determinants influencing the farmers' CCA and ε is the error term. The set of independent variables, their measurement and mean values and the studies where these instruments were adapted are given below (Table 2).

Table 2. Variables used in the study, their nature and source in the selected region of Punjab.

Variable and Measurement	Mean	Std. Dev.	Min	Max	Reference
CCA (1 = if farmer aware about CCA; 0 otherwise)	0.708	0.455594	0	1	[26,33,36,56]
Education (formal year of schooling)	6.944	5.020127	0	18	[30]
Farming experience (number of years)	21.644	12.84528	0	60	[29]
Family size (number of family members)	8.944	3.398095	4	26	[57]
Distance to output market (KMs)	13.664	8.838983	0	70	[1]
Landholding (number of acres of land)	7.02	7.67517	0.25	100	[56]
Off-farm income (1 if off-farm income; 0 otherwise)	0.24	0.42794	0	1	[32]
Tenancy Status (1 if own land; 0 otherwise)	0.808	0.394663	0	1	[33]
Farmer cooperation (1 if fellow farmers cooperate; 0 otherwise)	0.76	0.42794	0	1	[55,58]
Member organization (1 if member of any farmer organization; 0 otherwise)	0.456	0.499059	0	1	[31]
Access on agricultural credit (1 if access on credit; 0 otherwise)	0.432	0.496348	0	1	[32]
Access to marketing of produce (1 if access to marketing of produce; 0 otherwise)	0.32	0.467412	0	1	[1]
Access to extension services on crop (1 if farmer has access; 0 otherwise)	0.628	0.484308	0	1	[55]
Zone (1 = central Punjab; 0 = southern Punjab)	0.5	0.501003	0	1	[64]
Number of adaptation practices implemented by the farmers.	4.316	2.632845	0	10	[15]
Labour (number of full-time workers on farm)	2.572	1.97698	0	15	[15]
Crop income (Income in PKR from all crops)	46,583.24	15,917.07	15,000	117,000	[31]

Odds ratio $\left(\frac{L_i}{1-L_i}\right)$ represents the ratio of the likelihood of an event taking place vis-à-vis the likelihood of the event not taking place [35,65]. The exp (beta) from the odds ratio can be explained as the odds ratio of the corresponding category with respect to the reference category, ceteris paribus (e.g., keeping the impact of all other variables are held constant). Moreover, in the case of a continuous variable, the exp (beta) estimates the change in odds due to one unit change in the (independent) variable. The study in hands also quantified the marginal effects of per unit change of independent variables on the dependent variable (CCA). The model of marginal effect is given below:

$$\frac{\partial P_j}{\partial x_k} = P_j \left(\beta_{jk} - \sum_{j=1}^{j-1} P_j \beta_{jk} \right) \quad (2)$$

This equation measures the expected change in the probability of a CCA being made with respect to a unit change in an independent variable from the mean [27].

Moreover, the study used a simple regression model to estimate the impact of farmers' CCA on adaptation strategies. The model is given below:

$$Y = \alpha_0 + \alpha_1 x_1 + \alpha_2 x_2 + \dots + \alpha_9 x_9 + \mu \quad (3)$$

where Y is the number of adaptation strategies opted by farmers, such as changing crop variety, changing planting dates, changing crop type, soil conservation, water conservation, diversification, change/increase fertilizer, tree plantation, off-farm income, migration to the urban area and others, x_i s is the $1 \times K$ vector of other determinants influencing the adaptation strategies, α_1 is the coefficient of the parameters and μ is the error term. Moreover, farmers were asked to tick the adaptation strategies they used in the last five years; therefore, a continuous dependent variable was generated.

4. Results and Discussion

The study finds that 70.8% of farmers are aware of climate change. This awareness level is quite lower than in other developing countries. For instance, farmers' aware-

ness level is higher in South Africa (86%), Nigeria (75%) and Bangladesh (85%) than in Pakistan [58,66–68]. Pakistani farmers' awareness level is higher than in other developing countries, such as Kenya, where Ajuang et al. [69] found that 52.2% of farm households observed climate changes regarding erratic rainfall. CCA level is typically lower in developing countries as compared to wealthier nations, although the former considers climate change to be a serious issue compared to the latter [70]. Moreover, awareness level among the farmer communities also varies from region to region and within the same region. For instance, the awareness level of farmers is lower in Punjab as compared to the Khyber Pakhtunkhwa province of Pakistan. Fahad et al. [56] found that 73% farmers were aware of and had noticed climate change in Khyber Pakhtunkhwa.

4.1. Climate Change: Actual and Perceived

4.1.1. Farmers' Perception of Winter and Summer Rainfall

Many (52%) of the sampled respondents supported the view that winter precipitation has decreased over the past 10 years, while the rest declined the view. Of these, many (34%) reported a significant decrease, some (11.6%) perceived a slight decrease, and very few (6.4%) observed a reduced number of rainy days in winter rainfall, respectively. The farmers who did not indicate decreasing precipitation were 49%. Out of these, many (29.2%) perceived no change in the winter precipitation, some (14.4%) told a slight increase in winter rainfall, few (2.4%) reported that winter precipitation significantly increased and only two percent were of the opinion that the number of rainy days has increased.

The farmers who agreed that there was decreased summer rainfall accounted for 68.8%, and the rest of the farmers were unsure of the overall summer rainfall change. Figure 3 provides a further breakdown of the aware farmers. For instance, 41.6% of respondents reported a significantly decreased in summer rainfall, 21.2% of the farmers observed a slight decrease in precipitation and only 6% said that number of rainy days has decreased, respectively. Out of 31.2% unaware farmers, 22.4% of the sampled respondents contended no change in summer rainfall, 5.6% perceived a slight increase in summer precipitation and only 2% said that number of rainy days has increased, respectively.

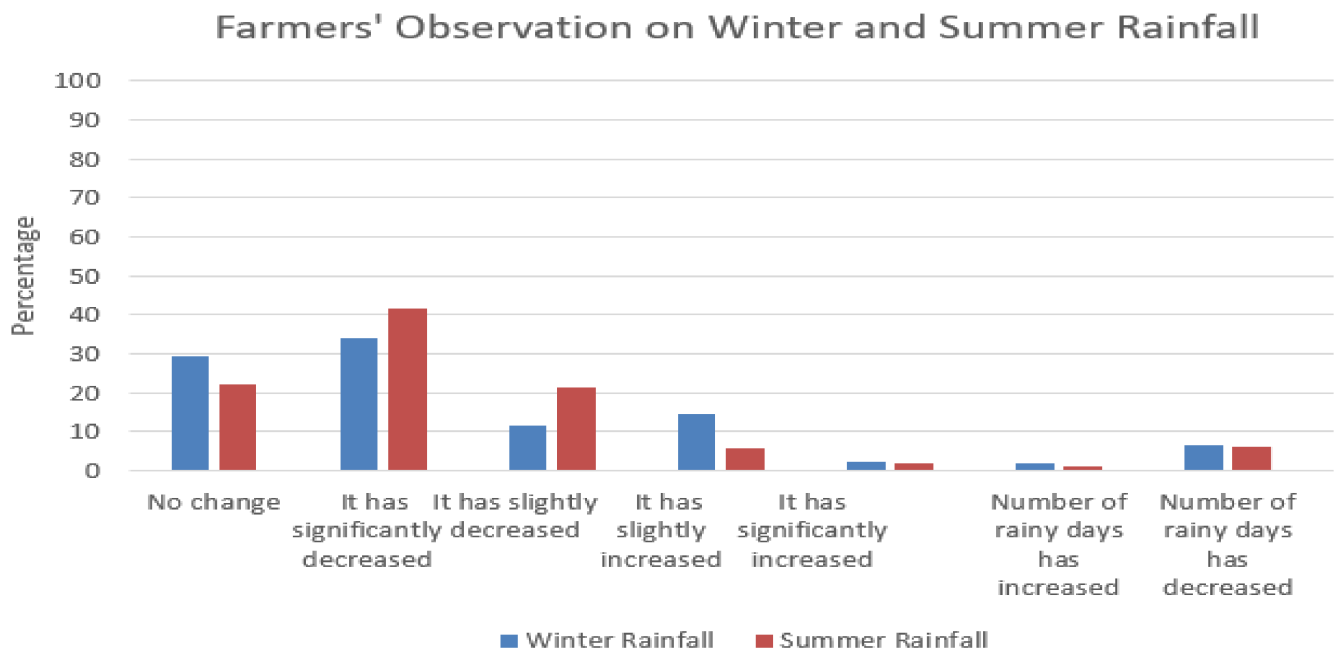


Figure 3. Farmers' view on winter and summer rainfall.

4.1.2. Farmers' Perception of Winter and Summer Temperature

Among the respondents, 63.6% of the farmers in the study area perceived increased winter temperature. Out of these, 45.2% believed winter temperature is slightly increasing

over the years, while 18.4% reported that winter temperature is significantly increasing. The rest of them were unaware of the winter temperature (36.4%). Among the unaware respondents, some farmers (21.6%) reported that there had been no change in winter temperature over the years, while 10.8% and 4% perceived slightly and significantly cooler winters, respectively.

About two-thirds (66.4%) of the sampled respondents were of the opinion that summer temperature has been increasing over the past ten years, while the rest declined the view. Many respondents perceived a slight warming summer temperature (36%) and 30.4% perceived a significantly warmer summer. Out of unaware farmers (33.6%), 24% of the respondent in the study area reported that there has been no change in summer temperature. Only a few perceived slightly cooler (6.8%) and significantly cooler (2.8%) summer temperatures, respectively (Figure 4).

Farmers' Perception on Winter and Summer Temperature

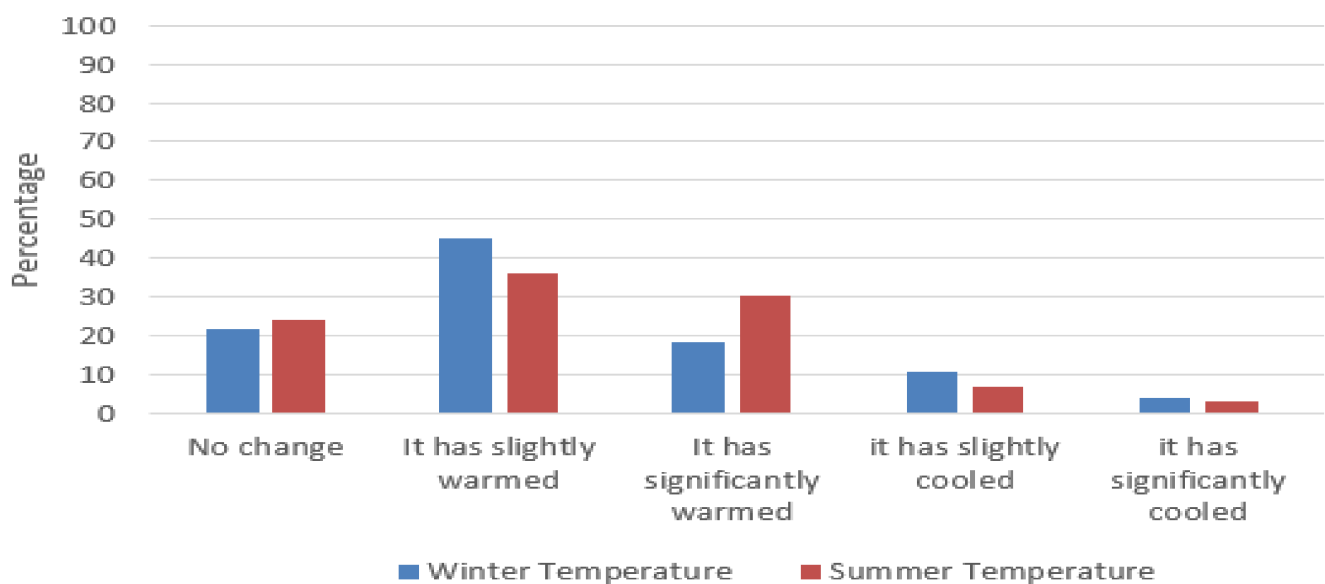


Figure 4. Farmers' observation on winter and summer temperature.

To verify the farmers' perception with the actual past records, Abid et al. [1] regressed annual temperature and rainfall for 30 years (1990–2010) in Punjab, Pakistan. They exhibited an increasing summer and winter temperature by nearly 0.0917 °C and 0.0478 °C, respectively. Their findings are thus compatible with the average global warming of 0.6 °C for the century [71]. The annual national mean temperature for 2022, for Pakistan as a whole, was 0.84 °C above average, placing it as the fifth-warmest year on record (average annual mean temperature = 23.64 °C, normal temperature = 22.80 °C) [72]. Punjab's annual mean temperature for 2022 was recorded at 0.88 °C above average (average temperature = 25.43 °C, normal temperature = 24.55 °C). Similarly, at the national level, the 2022 mean annual maximum temperature at the country level was 30.65 °C, 0.95 °C warmer than the average of 29.69 °C, and this was so in all regions of the country. The mean annual minimum temperature was 16.63 °C, 1.29 °C warmer than the country average of 15.36 °C, being the warmest on record, surpassing the previous record of +1.04 in 2006. This was so on a sub-regional basis as well, with GB and Punjab being first and AJK and KP the second all-time warmest minimum on record. Further breaking down to the district level, it has been observed by the Pakistan Metrological Department that temperature has increased [72]. For instance, from the previous 69 years, the new highest

maximum temperature of 40.2 °C was recorded in Multan during 2022 as compared to the mean temperature of 39.5 °C in 2010. Similarly, from the previous 107 years, the new highest maximum temperature of 38.5 °C was recorded in Faisalabad (192 KM away from Lahore) in 2022 as compared to the mean temperature of 38 °C in 2018 [72]. Comparing these results with previous studies and Pakistan Metrological Department, it is clear that there is a need to reshape the perception of farmers, although the majority perceived climate change. Moreover, the fact of winter temperatures is that they are increasing; however, an increase in the winter temperatures perception tends to be less as compared to summer temperatures.

As for as winter and summer rainfall is concerned, recorded data showed that both seasons' precipitation decreased. For instance, Abid et al. [1] exhibited decreasing precipitation as shown in linear regression trend lines for winter ($y = -0.7104x + 1531.8$) and summer ($y = -0.0057x + 353.72$) rainfalls, respectively. In 2022, the winter rainfall for the country as a whole was near average (−2%), followed by Punjab, which received normal rainfall of 387.0 mm as compared to an average rainfall of 560.9 mm, while the wettest period was in 2015 with an average rainfall of 642.3 mm [72]. Further breakdown to division level, central Punjab (Lahore, Sheikhpura, Faisalabad, Okara, Haifizabad) receives more than 70% monsoon rainfall [73–75]. Low pressure is formulated at the Pamir region due to high temperatures that transfer moisture from the Bay of Bengal toward central Punjab [73,74]. Moreover, winter rainfall occurred due to the returning monsoon, western disturbances and the presence of jet streams in central Punjab [73]. Ullah et al. [73] reported declined seasonal rainfall before 2000; however, a slight increase was observed after that in the 53 stations of central and southern Punjab. Our results are compatible with the previous study as the majority of the respondents reported that more decrease in summer rainfall as compared to winter rainfall. It means the weather of Punjab in summer is extremely hot, and in winter, extremely cold. However, the availability of station-based is very limited in Punjab [76–78]. Therefore, the study compared the farmers' perception of central Punjab with overall Punjab, while station-based data in central Punjab exactly matched with those farmers who reported decreasing rainfall patterns. Hence, future studies can compare the farmers' climate change perceptions of those regions where station-based (at the Tehsil level) data are available.

4.1.3. Farmers' Perception of Growing Season Length (GSL) of Crops

From the group of 250 interviewed farmers, 35.6% felt changes in the GSL of winter crops and 36.8% reported that the GSL of summer crops decreased, respectively, over the 10 years (Figure 5). Conversely, the majority of the sampled respondents reported either no change or increased GSL of both Rabi and Kharif crops. However, crop simulation models have revealed that the GSL of crops has reduced due to increasing temperature [61,62]. For instance, in Pakistan, the GSL of wheat, cotton and rice has reduced with severe adverse impact on wheat and rice. At the same time, there are positive and negative impacts on cotton according to its life cycle and geographic location. Further, it was found that wheat yields would be reduced by 3.4 to 12.5% in the semi-arid irrigated areas (Sheikhpura and Faisalabad) and 3.8–14% in arid (Badin, Hyderabad, Multan and Bahawalpur) areas under both A2 and B2 scenarios towards the end of 21st century [62]. Therefore, it is crucial to create climate change awareness among the farmers so that they can shift their crops to a suitable climate.

4.2. Determinants of Farmers' Climate Change Awareness (CCA)

The results of the logit model are given in Table 3. Among independent variables, the education of the farmers showed a positive and significant impact on the farmers' awareness level (coefficient = 0.1446; standard error = 0.0640). The odds ratio shows that as farmers receive one more year of education, they are 1.16 times more likely to be aware of climate change as compared to lesser-educated or uneducated farmers. Marginal effects show educated farmers were 1.5 percent more likely to be aware of climate change. This

finding appears to be in line with some of the existing literature, which has shown that education is an important factor in shaping environmental education among farming communities [56,79]. In other words, education is the global determinant of climate change awareness. Education is not only determining the CCA but is also significantly related to adaptation to climate change. Table 3 further provides information that education is positively associated with adoption measures through regression analysis. The previous literature also found a positive link between adaptation strategies and education that further improves household welfare [80]. Therefore, education should be increased to raise CCA among farmers.

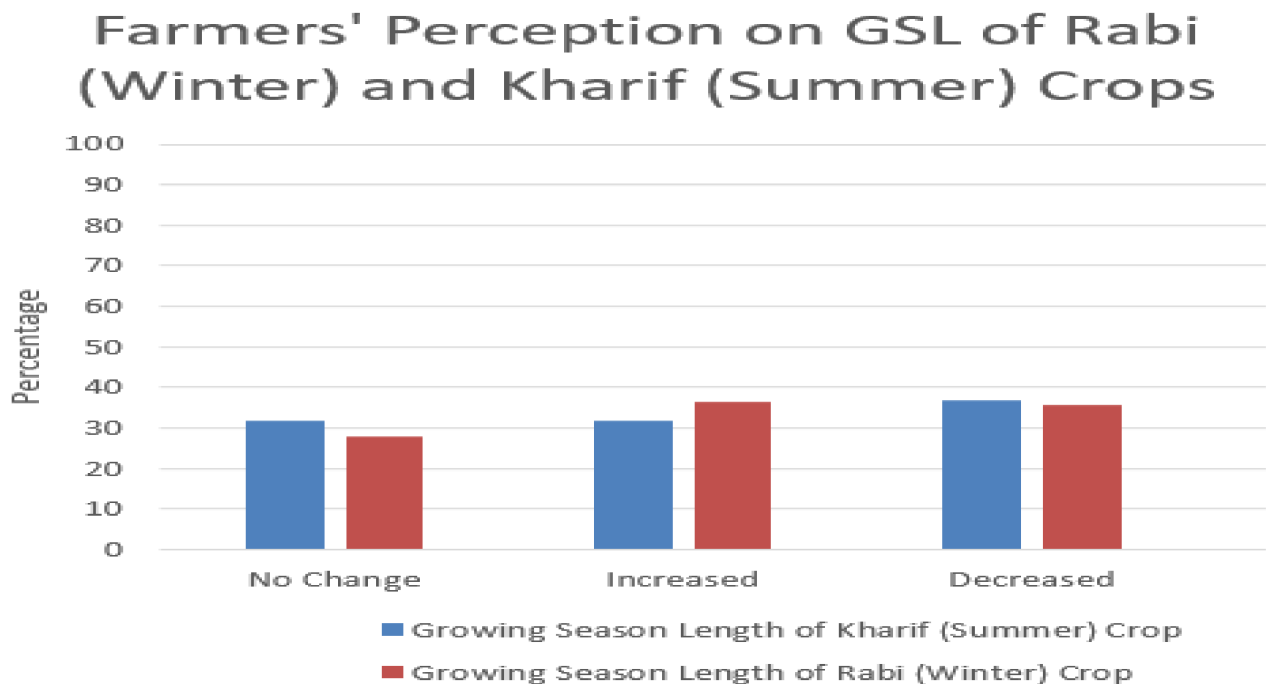


Figure 5. Farmers' perception of GSL of Rabi and Kharif crops.

Our results demonstrated that farmers in Punjab exhibited a significantly higher awareness level related to experience than less or no experienced farmers (coefficient = 0.0715; standard error = 0.0248; odds ratio = 1.07). This indicates that farmers having farming experience appeared to have a higher probability of CCA than farmers with less or without experience. Marginal effects show that the probability of CCA increases by 0.73 percent as there is a unit increase in farming experience. This is due to the fact that farming experience increases knowledge and enhances farmers' awareness level of the changing temperature and rainfall patterns. This result is consistent with the findings of Ndambiri et al. [64], who found a significant influence of farming experience on the probability of farmers perceiving climate change in Kenya. Similarly, Huong et al. [58] corroborated that experienced farmers perceived long-term changes in drought and abnormal temperatures. However, the findings of this study contradict the previous literature, which found that farming experiences were negatively and significantly correlated with the farmers' CCA [26,81]. This implies that farming experience is among the major sources of CCA, particularly in the regions where there is a gap between environmental information provided by researchers and scientists and the actual experiences and understanding of climate change by farmers at the ground level. Farming experience is part of the living record of short- as well as long-term changes in the climate because farmers are inhibited in the same rural area where they were born. For example, if there is no scientific information available on climate change in a particular region, farmers' experience can be utilized. Thus, policymakers should use farmers' local observation of climate change in local places with no or limited instrumental climate data.

Table 3. Coefficient estimates of the binary logistic, odds ratio model (DV = Awareness of Climate Change) and regression model (DV = Adaptation Strategies).

Explanatory Variables	Binary Logistic Model	Marginal Effects	Odds Ratio	Regression Analysis
Education	0.1446 (0.0640) **	0.0150 (0.0064) **	1.16 (0.0739) **	0.1515 (0.0263) *
Farming experience	0.0715 (0.0248) *	0.0073 (0.0023) *	1.07 (0.0266) *	-
Family size	0.0205 (0.0807)	0.0021 (0.0082)	1.02 (0.0824)	0.1048 (0.0360) *
Distance to output market (KMs)	0.0577 (0.0320) ***	0.0060 (0.0031) ***	1.06 (0.0339) ***	−0.0358 (0.0121) *
Landholding	0.0040 (0.0175)	0.0004 (0.0018)	1.00 (0.0176)	−0.0035 (0.0173)
Off-farm income	1.0392 (0.6475) ***	0.0886 (0.0472) ***	2.83 (1.8303) ***	-
Tenancy Status	−0.2311 (0.6760)	−0.0226 (0.0629)	0.79 (0.5365)	-
Farmer cooperation	0.4525 (0.7587)	0.0512 (0.0924)	1.57 (1.1929)	-
Member organization	0.0676 (0.5897)	0.0070 (0.0608)	1.07 (0.6310)	-
Access to agricultural credit	−1.2345 (0.5739) **	−0.1388 (0.0617) **	0.29 (0.1670) **	0.6672 (0.2578) *
Access to marketing of produce	1.8084 (0.7957) **	0.1539 (0.052) *	6.10 (4.8546) **	1.0080 (0.2954) *
Access to extension services on crop	1.3541 (0.4481) *	0.1627 (0.0684) **	3.87 (1.7355) *	0.2745 (0.2643)
Zone (1 = central Punjab; 0 = southern Punjab)	1.4682 (0.6747) **	0.1566 (0.0749) **	4.34 (2.9292) **	1.1151 (0.2715) *
Number of adaptation practices implemented by the farmers.	0.2625 (0.1281) **	0.0271 (0.0123) **	1.30 (0.1665) **	-
Awareness of Climate change	-	-	-	0.6984 (0.3173) **
Labour	0.5676 (0.1558) *	0.0587 (0.0206) *	1.76 (0.2748) *	0.2279 (0.0761) *
Crop income	0.000024 (0.000081)		1.00 (0.000081)	-
Constant	−7.3061 (2.0849) *	0.000003 (0.0000)		0.4190 (0.4265)
Number of Observation		250		250
Wald Chi ² (16)/F(10,239)		53.47		59.64
Prob > Chi ² /Prob > F		0.0000		0.0000
Pseudo R ² /R ²		0.4833		0.6078
Log Likelihood/Root MSE		−78.01		1.6829

Note: values in parenthesis () are robust standard errors while *, ** and *** are significance levels at 0.01, 0.05 and 0.10, respectively.

Distance to the output market is a significant predictor of farmers' awareness of climate change. The previous literature indicated that farmers residing nearest to the input/output markets were more likely to perceive that the climate was changing than farmers residing further away from the markets [64]. This hypothesis is rejected by the current study (coefficient = 0.0577; standard error = 0.0320). The odds ratio indicates that farmers who lived away from markets were 1.06 times more likely to be aware as compared to farmers who lived nearest to input and output markets. The marginal effect shows that as distance increases by one more kilometre from input/output markets, the probability of CCA increases by 0.60 percent. This might be the reason that Lahore and Multan are major markets, and these are distant for select respondents. These mega-cities (about 13 million

population) are major absorbers of farmers' agricultural production and hence the source of climate change information. This result agreed with the finding of Opiyo et al. [82].

The off-farm income shows a direct relationship with farmers' CCA; for instance, farm household's family members engaged in off-farm jobs other than farming, the more the probability of farm household is aware of climate change (coefficient = 1.0392; standard error = 0.6475; odds ratio = 2.83). It means that for the households who have non-agriculture income, their probability of CCA increases by 2.83, which makes it more likely as compared to counterfactual. These findings are also in consonance with the studies of the previous literature [26,31].

This study revealed that access to agricultural credit significantly decreases the likelihood of the farmers' climate change awareness (coefficient = -1.2345 ; standard error = 0.5739; odds ratio = 0.29). A negative sign of the coefficient implies that high values of the variables will decrease the likelihood of CCA. This indicates that agricultural credit users tend to have 0.29 times less awareness level as compared to non-credit users. Marginal effects results show that a unit increase in agricultural credit availability decreases the probability of CCA by 13.88 percent. This might be the reason for the non-productive use of agricultural credit. A previous study also found a negative association between farmers' CCA and credit availability [63]. This implies that insufficient credit availability means that farmers do not have the financial standing to access information on climate change. However, access to credit significantly increases the probability of adaptation to climate change. It can help farmers to purchase new climate change resilient crops and their new varieties, farmers can use credit for soil and water conservation, and it can be useful for the diversification of farms and enterprises through having more investment through credit availability. The results are supported by previous where Huong et al. [58] found that there is a positive association between credit availability and adoption measures.

Landholding did not significantly impact the CCA. Similar results are found that land areas do not associate with awareness of climate change [32]. However, Ado et al. [31] found that land area significantly reduces CCA, and large farmers perceive fewer climate changes and their associated losses as compared to small farmers. In contrast to landholding, hired labour directly affected climate change awareness. This means that when the number of labour increases, climate change awareness increases by 1.76 times (coefficient = 0.5676; standard error = 0.1558; odds ratio = 1.76).

Access to the marketing of produce enhances the farmers' ability to increase their capacity to buy more farm tools, the availability of capital for the next crop, the avenues to learn new agricultural skills or market their products, and hence the surety of higher profits. The findings in this paper provide evidence that farmers who have access to the marketing of produce are more likely to be aware of climate change than otherwise (coefficient = 1.8084; standard error = 0.7957; odds ratio = 6.10). The odds ratio implies that those farmers who have access to the marketing of produce are 6.10 times more aware of climate change than those farmers who do not have access to the marketing of their agricultural produces. Marginal effects show that as unit increase in the access on the marketing of produce, the probability of CCA increase by 15.39 percent. Farmers in Punjab usually receive access to the marketing of produce (a local term for this is baradana) for wheat. The government provides jute bags to farmers to fill the wheat and to sell at specific nearby government grain stores at supported prices. Most of the time, this is provided on a political basis. Usually, ten bags per acre are provided, and the rest of the outputs farmers had to sell in local markets or to middlemen for low prices. Therefore, it is necessary to increase baradana access to farmers.

Farmers must have sufficient financial support for sustainable farming operations. It includes access to the marketing of produce, agricultural credit and non-agricultural income. The financial support enhances the adaptive capacity of farmers through an increase in agricultural income or output. Financial support increases CCA while this support, such as access to the marketing of produce and credit availability, also leads farmers to adopt more adaptation strategies to climate change. Such support helps farmers

to have the capital for the next production seasons, conserve water and soil, purchase new crop varieties, change/increase fertilizer and crop and enterprise diversification. These are autonomous adaptations where farmers' own economic interests are involved. Table 3 (column 5) indicates that as farmers who have access to the marketing of produce and agricultural credit, their probability of taking adaptation strategies increases. These results can be supported by previous studies [83,84].

The results of the study revealed that extension service was statistically significant, with a positive association, and it increased the likelihood of climate change awareness (coefficient = 1.3541; standard error = 0.4481; odds ratio = 3.87). The odd ratio shows that extension service recipients are 3.87 times more aware of climate change as compared to counterfactual, non-recipients of extension services. Marginal effects depict that probability of 16.27 percent increases due to a unit increase in extension services on crops. The results can be supported by the previous literature [33,56]. In the previous section, we addressed that many farmers did not perceive erratic summer and winter rainfall and temperature. The majority of farmers (63.2%) did not perceive a reduction in GSL of summer crops, and about two-thirds (64.4%) of farmers indicated no change or increase of GSL of winter crops (Figure 5) against the scientific facts [61,62]. In this regard, the extension system of the countries can effectively reshape the perceptions of farmers. Punjab has a well-established extension department with vast public infrastructure. It used top-down institutional hierarchy to provide extensions on crops and livestock at the grassroots level. It is present at the federal, province, district and even at the union council (UC) levels. Agricultural extension officers, along with team field assistants at the UC level, provide free-of-cost services to farmers to increase their crop production. These entities sometimes provide low-cost services to the farmers. These services include low-interest or interest-free credit facilities, weather and marketing information, free water and soil testing, subsidized water-saving, ploughing and harvesting technologies, farm advisory services and access to the marketing of produce (baradana). These farmers then become model or leading farmers who ultimately prove helpful in farmer-to-farmer extension, and other farmers can improve farming through this community knowledge. There are also parallel bodies of private (e.g., seed and pesticide) companies and NGOs that exist and have been providing more advanced information on climate change over the last few years. Therefore, extension educators play an important role in helping farmers to reshape their climate change perception, and the government can increase CCA through its existing extended extension system.

Recipients of extension services can enhance farming community knowledge through social networking. However, few farmers receive extension services despite well-established extension systems in the country. A previous study found that a very low percentage of farmers in Punjab actually have access to public or private extension services, while about half of the farmers rely on their fellow farmers and community [85]. This social networking includes a farmer-to-farmer extension through cooperation with fellow farmers in exchange for input, ideas and irrigation or canal water sharing. Social networking, such as farmers' memberships and farmers' cooperation among each other, positively but insignificantly impact the CCA (Table 3). This implies that village-level cooperation among the farmers is insufficient for raising awareness about climate change. Therefore, the government should increase the extension services to all farmers who get the government in-kind or cash services stated earlier. It would not only increase farmers' CCA but will also enhance farmers' adaptive capacity. For example, contrary to our results, Abid et al. [84] found that farmers' social networking can significantly increase adaptation strategies to climate change.

Previous studies have shown that awareness and perception positively and significantly impact adaptation strategies [15,86]. However, the current study found the impact of adaptation strategies on CCA. The results find that as the number of adaptation strategies increases, the probability of the CCA increases. (coefficient = 0.2625; standard error = 0.1281; odds ratio = 1.30). It means that as the number of adaptation strate-

gies increases, the probability of farmers being aware of climate change increases by 1.30 times as compared to these farmers who use fewer adaptation techniques. Additionally, marginal effects show that a per unit increase in adaptation strategies increases the CCA by 2.7 percent. For instance, Hasan and Kumar [15] found that the number of adopted strategies was related to all the components of the perception of climate change and vulnerability. Therefore, among climate change adaptive factors, the results of this study suggest that the number of adaptation techniques meaningfully affect the expression of climate change awareness. The result is in line with previous studies [36,87]. These studies found that farmers who adopt more adaptation practices are more likely to perceive climate change.

The level of farmer vulnerability to climate change varies by area and agroecological setting. Therefore, farmers' awareness of climate change differs by region. The current study found that farmers in central Punjab tend to have more climatic awareness as compared to southern Punjab (coefficient = 1.4564; standard error = 0.6771; odds ratio). Although southern Punjab is more vulnerable to climate change, farmers of central Punjab are more aware of climate change. The probability of climate change awareness increases by 4.29. The findings harmonized with the previous studies [58,88], which also found that the awareness level of farmers varies from region to region and even changes within the same region.

4.3. Impact of CCA on Adaptation to Climate Change

Using the simple linear regression model, the study found the impact of CCA on adaptation to climate change. If farmers' are aware of climate change, their probability of adaptation strategies increases (Table 3). These findings mean that the CCA builds the capacity of farmers to undertake more relevant, effective and efficient interventions through enhanced knowledge of climate change. Thus, the CCA significantly influences the adaptation to climate change in the agriculture sector in Pakistan. This finding is supported by recent research by Abbasi and Nawaz [37] in the context of Pakistan, (Ado et al. [31] in Niger and Chakraborty and Mukerji [89] in India). This, therefore, validates the concept that the higher the CCA level, the higher the propensity of farmers to take management options against climatic variations. The results also show that there is a causal relationship between CCA and adaptation strategies.

5. Conclusions

The study found that farmers' awareness level in Punjab is less as compared to other developed and developing countries, even less than other regions within the country. Therefore, the proportion of farmers that do not recognize climate change underscores the need for redesigning local climate change communication strategies. The majority of farmers did not perceive changes in climate change such as GSL of crops, erratic winter and summer rainfalls and temperatures against the scientific facts. Therefore, farmers' awareness levels can be enhanced through existing agriculture extension services in the country. The extended extension system can further reshape the perception of climate change vagaries through awareness programs.

The study found that the majority of farmers (70.8%) were aware of climate change, although many did not perceive climate change. The study found the determinants of climate change awareness (CCA) of the farmers in the study region and estimated that education, experience, distance to markets, off-farm income, access to agricultural credit and marketing of produce, access to extension services and the number of adaptation strategies were significantly impacted farmers' CCA. The study found important implications of financial factors on climate change awareness. For instance, contradicting the previous literature, the availability of agricultural credit decreased CCA because of less credit availability and hence the non-productive use of it. However, as another financial factor, access to the marketing of produce and off-farm income has a significant and positive impact on the CCA of farmers. Therefore, there is a need to increase the credit amount and access to the marketing of products to all the farmers. Regarding non-financial factors, the government

should increase the extension services to all farmers as it has been found that the recipient of extension services can raise CCA, and their adaptive capacity could be increased through a farmer-to-farmer extension such as farmer cooperation and membership of FOs.

In a nutshell, the study found the number of adaptation strategies increases the farmers' CCA level, which, in turn, helps more adaptation to climate change. For instance, if farmers are aware of climate change, they opt for more management strategies. Financial support, such as access to the marketing of produce and credit availability, significantly increases the probability of farmers' to increase adaptation strategies to climate change. This makes the farmers more proactive in adopting farm management strategies. The current study found the causal relationship between CCA and adaptation strategies and their associated factors; however, a future study can check the impact of these on farm productivity and income. Moreover, the current study compared farmers' CCA with meteorological results at the Punjab level; however, future research can compare farmers' knowledge with local (district) level scientific data.

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Data Availability Statement: Data supporting reported results will be made available to the interested researchers upon request.

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Appendix A. Correlation Matrix of the Selected Variables

	Perception	Adapt	Edu	Exp	FZ	DOM	Land	Offfarm	Tenancy	FFC	FOs	AC	MP	Ext	Zone	Labour	Income
perception	1																
Adapt	0.4857	1															
Edu	0.3809	0.5586	1														
Exp	0.2299	0.1257	−0.0516	1													
FS	0.2514	0.4096	0.1964	0.2454	1												
DOM	−0.1282	−0.3578	−0.2478	−0.0723	−0.1753	1											
Land	0.1183	0.1715	0.1702	0.1024	0.1918	−0.0871	1										
Offfarm	−0.0511	−0.0605	−0.0835	−0.4922	−0.3221	0.1138	−0.1234	1									
tenancy	0.089	0.1321	0.2013	0.3778	0.1537	−0.1441	0.0974	−0.5821	1								
FFC	0.1335	0.1175	0.2237	0.2547	0.1896	−0.0745	0.1176	−0.5175	0.5108	1							
FOs	0.323	0.3667	0.2395	0.2059	0.3348	−0.058	0.0202	−0.176	0.222	0.2888	1						
AC	0.1161	0.4053	0.2483	0.1804	0.2978	−0.2167	0.1487	−0.2821	0.2406	0.2254	0.3527	1					
MP	0.384	0.5343	0.3602	0.0639	0.3122	−0.1829	0.1331	−0.0442	0.0731	0.0843	0.4049	0.3538	1				
Ext	0.4158	0.3067	0.2491	0.08	0.2289	−0.0378	0.0396	−0.0713	0.2131	0.207	0.3557	0.1867	0.2973	1			
Zone	0.2023	0.3608	0.1485	−0.0496	0.1864	−0.2712	0.1063	0.1873	−0.2234	−0.4308	0	0.1615	0.2229	−0.0414	1		
Labour	0.3467	0.3062	0.1708	0.2688	0.1381	−0.048	0.0855	−0.1392	0.1876	0.348	0.3044	0.1278	0.2053	0.1812	−0.1967	1	
Income	0.1168	0.1698	0.2997	−0.0523	0.0674	−0.1919	0.2472	−0.142	0.0921	0.3481	0.0834	0.0113	0.0757	0.0842	−0.2563	0.218	1

Adapt = number of adaptation strategies, Edu = Education, Exp = Experience, FS = Family size, DOM = Distance to output market, Land = landholding, Offfarm = Off-farm income, FFC = farmer-to-farmer cooperation, AC = agri credity, MP = access to marketing of produce, Ext = access to extension services.

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