Journal of
Water & Climate Change

IWA PUBLISHING

Journal of Water and Climate Change Vol 15 No 9, 4699 doi: 10.2166/wcc.2024.275

Climate change awareness and adoption measurements of respondents toward food security in Khyber Pakhtunkhwa, Pakistan

Muhammad Rizwan Ullah[a], Junbo Mao[b] and Muhammad Nasrullah[b,*]

[a] School of Health Management, Shanxi Technology and Business University, Shanxi, China
[b] School of Public Administration, Xiangtan University, Xiangtan, Hunan, 411105, China
*Corresponding author. E-mail: nasrullaheconomist@hotmail.com

ABSTRACT

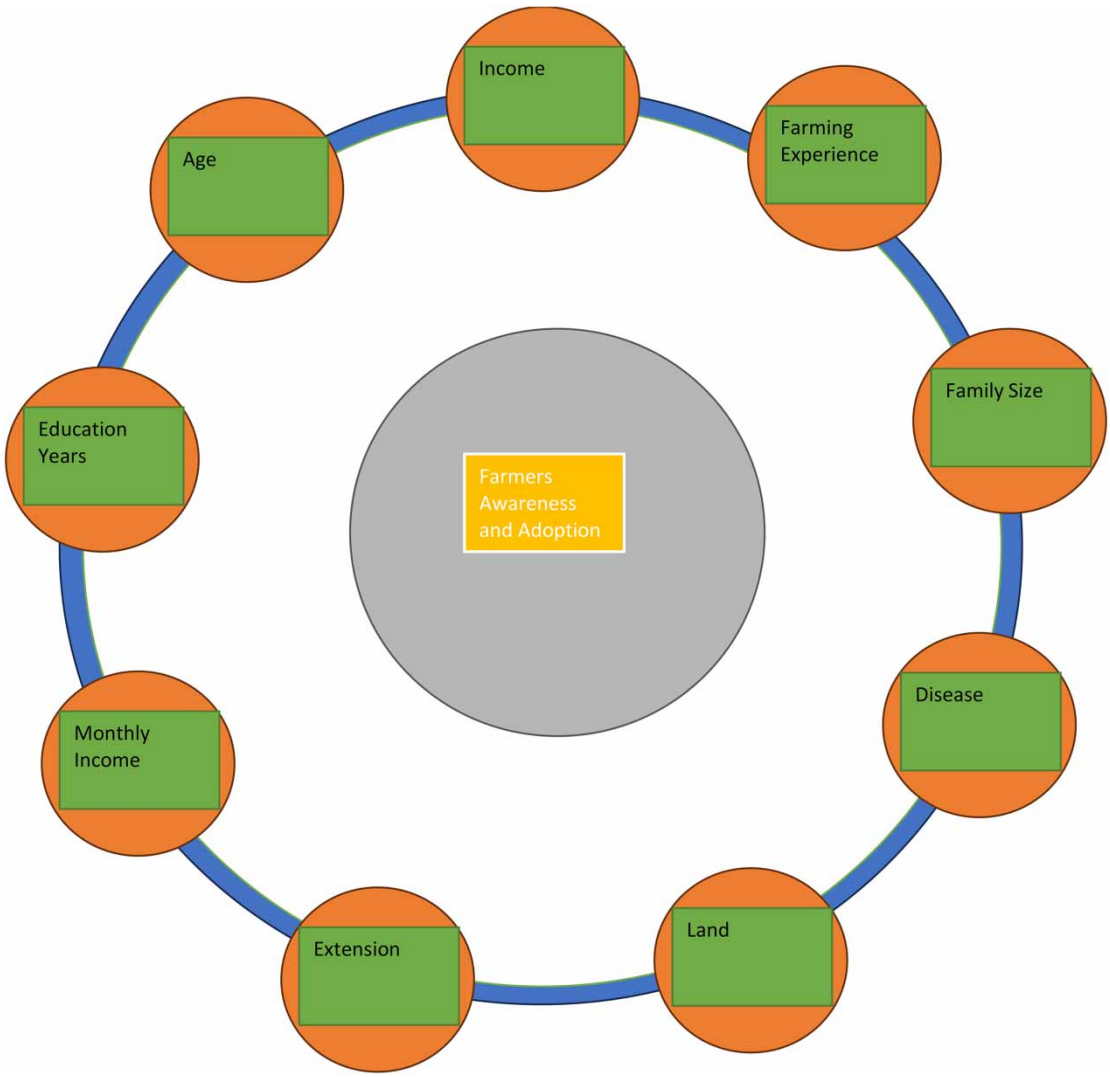
Climate change has affected all sectors of the economy, especially the agriculture sector. Pakistan is one of the developing countries in South Asia that is most vulnerable to climate change and disasters. Various studies were conducted to report on farmers' understanding of agriculture, adaptation, mitigation, and perception of climate change. Still, the literature on farmers' awareness of climate change in Pakistan is weak. To close such a research gap, the study carried out the awareness level and related issues of farm households about climate change in Pakistan. A sample of 1,123 respondents was interviewed from the four districts of Khyber Pakhtunkhwa Province, Pakistan, through a questionnaire. The logistic regression method was used to investigate the awareness level of farm households about climate change. Results of the study showed that 63.5% of respondents were aware of climatic shocks. The socioeconomic and demographic factors such as age, land ownership, education level, income, family size, and farming experience were directly related to the respondent's awareness of climate change.

Key words: climate change, farmer adaption, farmer awareness, logistic model, VIF

HIGHLIGHTS

- Climate change which is a major threat for food security especially in developing countries.
- The study evaluates the level of awareness among respondents regarding climate change.
- The study also identifies the strategies adopted by the respondents to mitigate the impact of climate change.
- The socioeconomic and demographic factors affect the level of awareness.
- Policies for enhancing climate resilience and sustainable agriculture are recommended by the research.

GRAPHICAL ABSTRACT



1. INTRODUCTION

Climate change is one of the biggest global environmental challenges facing our society (Steffen *et al.* 2015). The entire world is being impacted by climate change (Beniston & Haeberli (2001). Various sectors, such as forestry, fisheries, agriculture, water resources, and human health, are critical to survival (Beniston 2003; Pulhin *et al.* 2006). However, climate change has impacted these features and various ecosystems through rising sea levels, changing precipitation patterns, temperature increases, severe floods, and glacier melting (IPCC 2007). Globally, mean temperature increases and the frequency of risky weather events induces crop failure, posing a challenge to global food security (Liverman & Kapadia 2010). Such an event might exacerbate soil erosion and land management issues by increasing floods and drought, making agricultural production more difficult (IPCC 2014). Weather variability impacts farmers' livelihoods and poses a significant risk to global food security. Climate change raises the poverty line of the rural population, particularly farmers who rely on agricultural output (Hallegatte *et al.* 2016). Climate change information is scarce in the farming community. The absence of knowledge regarding climate change suggests that the source of information is insufficient and untrustworthy in providing farmers with scientific facts and innovations (Weber 2010). According to Bickerstaff (2004), determining whether someone is aware of climate change depends on their perceptions, which influence their behavior (Niemeyer *et al.* 2005).

Pakistan is a developing country and has been highly affected by climate changes in recent decades due to floods, snowfalls, landslide droughts, and heat stress, as evidenced by the devastating floods that struck the nation in 2010, 2011, and 2014. These floods significantly impacted agriculture, water resources, and public health (Ahmed *et al.* 2016). Alone, the 2010 floods claimed the lives of over 20.2 million people, flooded almost one-fifth of the nation's geographical area, and resulted in economic losses estimated at $43 billion (Shabir 2013). The devastation of crops and livestock by these floods threatened food security and the livelihoods of farmers (Atanga & Tankpa 2021). Long-term problems with water scarcity were worsened by the disruption of water supplies caused by the flooding of fields and the collapse of irrigation systems (Ingrao *et al.* 2023). Due to the government effort and hard work of the farming community, it takes almost 2 years to recover the affected agricultural land. The devastating effects of these floods on human health also included widespread displacement, a rise in the incidence of waterborne illnesses, and a shortage of medical facilities (Du *et al.* 2010).

The frequency with which these extreme weather events occur highlights the pressing need for awareness-raising campaigns and efficient adaptation strategies, such as strengthened flood defenses and sustainable farming methods, to increase resilience against future climate-related disasters. Hence, this study was carried out to measure the farmers' awareness and adoption strategies in the area already affected by these heavy disasters. The study will contribute to a deeper understanding of the farmers' perception of climate change and its consistency with scientific innovation and information (Weber 2010). Globally, climate change has a negative impact. Still, the farmers in developing countries are expected to suffer more due to the following reasons: insufficient awareness, infrastructure, skills, illiteracy, financial capacity, and low adaptive capacity – the ability to diversify and incompetence to forecast extreme hydrological and atmospheric events (Kurukulasuriya & Mendelsohn 2008).

Climate change is a big challenge for developing countries, where most of the population is combating poverty. Pakistan is also one of them, which is not only facing the poverty challenge but is also hugely vulnerable and affected by climatic events. Most of the population depends on agriculture, and such climatic challenges threaten food security and affect social well-being. Several parts of Pakistan are under different climatic pressures, like droughts, floods, snowfalls, landslides, and avalanches. The agriculture sector in Pakistan contributes 18.5% to the gross domestic product (GDP) and engages 38.5% of the total labor force in Pakistan, which is nearly 55% of the population; therefore, any adverse repercussion of climatic shock can affect the everyday activities of the population (GOP 2013). Recently, natural disasters underwent three floods in 2014, 2011, and 2010 that critically impacted the farming community, and the economic activities of the area were highly damaged in various sectors such as livestock, forestry, fisheries, tube wells, seed stocks, animal sheds, houses, fertilizers, infrastructure, and other agricultural equipment. Furthermore, around 1 million acres of cultivated land and nearly 250,000 farm households were affected (Fahad & Jing 2018; Shahid *et al.* 2018; Shahid & Rahman 2021).

Several studies highlighted the farm households' climate change vulnerability, adaptation, awareness level, and adverse shocks among the regions. Still, the selected research considers Pakistan the most susceptible to climate risks. Climate changes, perceptions, and awareness of climate change vary from region to region (Mandleni & Anim 2011). An enormous gap in the literature does not connect climate change awareness with food security or measure the adoption of smart agriculture practices. Hence, the existing literature fails to provide the succession of climate change awareness campaign and their policies.

Additionally, the existing literature has not fully explored the changes in the awareness level due to demographic and socio-economic factors, and institutions are not fully recovering from the gap. It is important to figure out how farmers are aware of and using climate-smart practices, which are essential to creating efficient solutions that lessen the effects of climate change on agriculture. Without this information, programs and policies might not adequately address the needs and difficulties unique to this area. By identifying obstacles to adopting adaptive techniques, evaluating the efficacy of current awareness efforts and policies, and performing a thorough analysis of the current level of climate change awareness among farmers in Khyber Pakhtunkhwa (KP), the study aims to close this knowledge gap. It hopes to achieve this by offering practical ideas to enhance food security and climate change resilience.

To fully cover the existing gap, this study was conducted with the main objectives: 1) to investigate farmers' awareness of climate change and its impacts, 2) to check that farmers are aware of climate issues and have sufficient knowledge and resources to adopt them, and 3) to check farmers' adoption measures toward climate change in KP, Pakistan. By offering a thorough grasp of farmers' awareness, knowledge, and adaptive activities in response to climate change in KP, these objectives seek to close research gaps. By focusing on these areas, the study hopes to provide information for more focused actions and policies that would help farmers become more resilient to difficulties brought on by climate change.

2. METHODOLOGY

2.1. Data collection and sampling

KP is a province of Pakistan that is situated in the north-west. The primary source of earnings in KP is agriculture, which contributes 22% to the provincial GDP and employs 44% of the labor in the province. The total area covered by agriculture in KP is 1.9×106 ha. This province has experienced significant damage due to climate change over the last two decades. Hence, this province was selected purposively due to the high damage and continuous flood experience in the previous two decades. The study used a stratified sampling technique to collect data to measure the awareness level and adoption strategies about climate change. KP has been classified into four agroecological zones, i.e., A, B, C, and D. In the first stratum, the study purposively selected three districts from Northern Mountainous Zone A (District Upper Dir, District Lower Dir, and District Malakand) and one district from Central Plain Valley Zone C (District Charsadda). The land use for agriculture in District Upper Dir, District Lower Dir, District Malakand, and District Charsadda is 3.2×104, 4.2×104, 4.6×104, and 7.3×104 ha (https://kp.gov.pk/uploads/2023/10/Land_Use_Statistics_(2019-20).pdf). The respondent districts were selected due to their vulnerability and regular climatic events, floods, and droughts from 2010 to 2014 (Fahad *et al.* 2018). Initially, District Malakand, District Charsadda, District Upper Dir, and District Lower Dir were purposely selected due to their flooding history, agricultural importance, and the severity of flood damages. In the second stratum, three tehsils were selected purposely from District Upper Dir, three tehsils from District Lower Dir, two tehsils from District Malakand, and three tehsils from District Charsadda. In the third stratum, a proportional allocation sampling technique was used to find the desired number of respondents from each tehsil using the following equation:

$$n_r = (N_r/N) * n \tag{1}$$

where n_r is the number of respondent farmers from rth tehsil, N_r is the total number of respondent farmers in the rth tehsil, N is the total number of farmers in the area, and n is the total sample size. The estimated results of the proportional allocation sampling technique are shown in Table 1.

In the last stratum, the study utilized a random sampling technique to collect data through a well-designed questionnaire. A household survey was conducted in the selected districts (District Upper Dir, District Lower Dir, District Malakand, and District Charsadda) of the KP Province of Pakistan. A household survey was conducted using face-to-face interviews, which was suitable for the socio-economic nature of the respondents in the study area. The survey team consists of three PhD students, one lecturer, and one research assistant to collect data from the household. The questionnaire consisted of several questions, and the respondents were asked about their awareness level toward climate change, demographic and socioeconomic information, adaptation measures, and sources of information. The farmers were informed that these data were purely for research purposes and that their information would not be exposed publicly. Due to language barriers, the designed questionnaire in English was translated into the local language (Pashto) for the respondent's convenience. Finally, the data were collected from March to June 2021.

Table 1 | Sample size of the respondent area

Districts	Tehsil	$(N_r/N) * n$	Sample size (n_r)	Total sample size
District Upper Dir	Barawal	(1,422/21,537) * 1,123	74	1,123
	Kalkot	(1,767/21,537) * 1,123	92	
	Wari	(1,114/21,537) * 1,123	58	
District Lower Dir	Timergara	(1,460/21,537) * 1,123	76	
	Munda	(826/21,537) * 1,123	43	
	Samar Bagh	(1,095/21,537) * 1,123	57	
District Malakand	Batkhela	(3,112/21,537) * 1,123	162	
	Dargai	(3,765/21,537) * 1,123	196	
District Charsadda	Charsadda	(1,959/21,537) * 1,123	102	
	Shabqadar	(2,382/21,537) * 1,123	124	
	Tangi	(2,670/21,537) * 1,123	139	

2.2. Socioeconomics factors

Based on the existing literature, adoption and awareness of climate change are determined by many socioeconomic issues, such as geographic characteristics, farming area, and institutional services (Bayard *et al.* 2007; Oduniyi 2013; Huong *et al.* 2018). Farming areas increase climate change awareness by participating in farming activities. Correspondingly, the existing literature elaborates that institutional determinants (extension agents or agricultural organizations) are also linked with climate change awareness and the adoption level of farming communities (Luseno *et al.* 2003; Bayard *et al.* 2007; Maddison 2007). It is essential to identify the awareness factors and step forward to adopt measures such as crop diversification, crop rotation, and other steps for livelihood (Deressa *et al.* 2011). The awareness and adoption strategies about climate change vary due to the different services provided by various organizations. Regular contact with an extension service agent significantly increases awareness among the respondents. A logistic regression model was utilized to measure the dependency of the awareness factor on various independent variables.

2.3. Model specification

Logistic regression was proposed by statistician David Cox in 1958. Gujarati & Porter (2003) suggested that the logistic model is important in binary data estimation. Hence, they used logistic regression for the model specification to estimate farmers' climate change adoption strategies. Agresti (2013) suggested a logit model for estimating the categorical data. The logistic model for the study can be specified as follows:

$$\text{logit}\,(p) = \log\left(\frac{P}{1-P}\right)$$

$$\text{let } P_i = P_{\text{r}}\left(\frac{Y=1}{X=x_i}\right)$$

Then, the model should be specified as

$$P_{\text{r}}\left(y=\frac{1}{x}\right) = \frac{\exp^{x'b}}{1+e^{x'b}} = \log\left(\frac{P}{1-P}\right) = \text{logit}\,(P_i) = \beta_0 + \beta_1 x_i$$

P_i shows the awareness and adoption strategies about climate change, while X_i shows the various factors that can affect the farmer's awareness level and adoption strategies in the respondent area, β_0 is the intercept and β_1 are the parameters to be estimated.

3. RESULTS AND DISCUSSION

3.1. Respondent awareness and adoption level about climate change

The respondents were interviewed about the changes in climate and their awareness level. The result demonstrates that 69.9% of the respondent participants are aware of the variation in climate, and the remaining (30.4%) are unaware of the District Upper Dir. Similarly, in the District Lower Dir, 66.5% of the respondents are aware of climate change, and 33.4% are unaware. The estimated frequency of District Malakand shows that 62.8% of the households know about climate change, while the remaining 37.2% do not. Likewise, in District Charsadda, the awareness level of the respondents was 59.2% about climate change among 365 respondents. The pooled data show that the awareness level in all four districts is 63.5% about climate change, and the remaining is 36.4% unaware, as shown in Figure 1. Most participants have noticed variations in the mean temperature during summer and winter. The findings, as well as the official statistics of Pakistan 2015, coincide with the fact that the majority of the area in KP is facing a dry climate. The estimated result also revealed that, as compared to other developing countries (Nigeria 75% awareness level and South Africa 86%), the awareness level of Pakistan is still lower (Mandleni & Anim 2011; Huong *et al.* 2017). In Bangladesh, 85% of the farm households were aware of climate change (Hasan & Akhter 2011). In comparing climate change variation with other developing countries such as Kenya, 52.2% (Ajuang *et al.* 2016) of the respondents were aware of the climate change, so our study area is pretty much higher.

The adoption level of the farmer respondents is shown in Figure 2. The estimated finding shows that fewer respondents in the selected area are adopting the new technique to tackle climatic shock. The study observed that 37.5% of people are

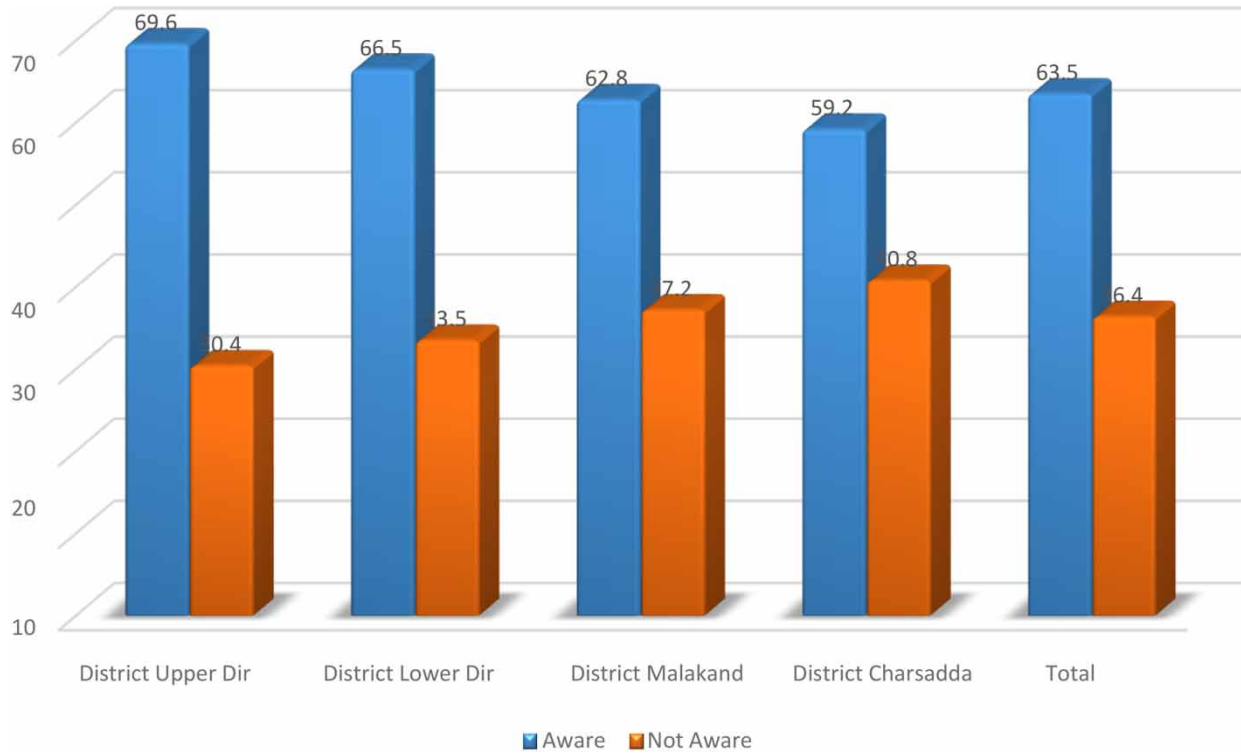


Figure 1 | Climate change awareness level of farmers.

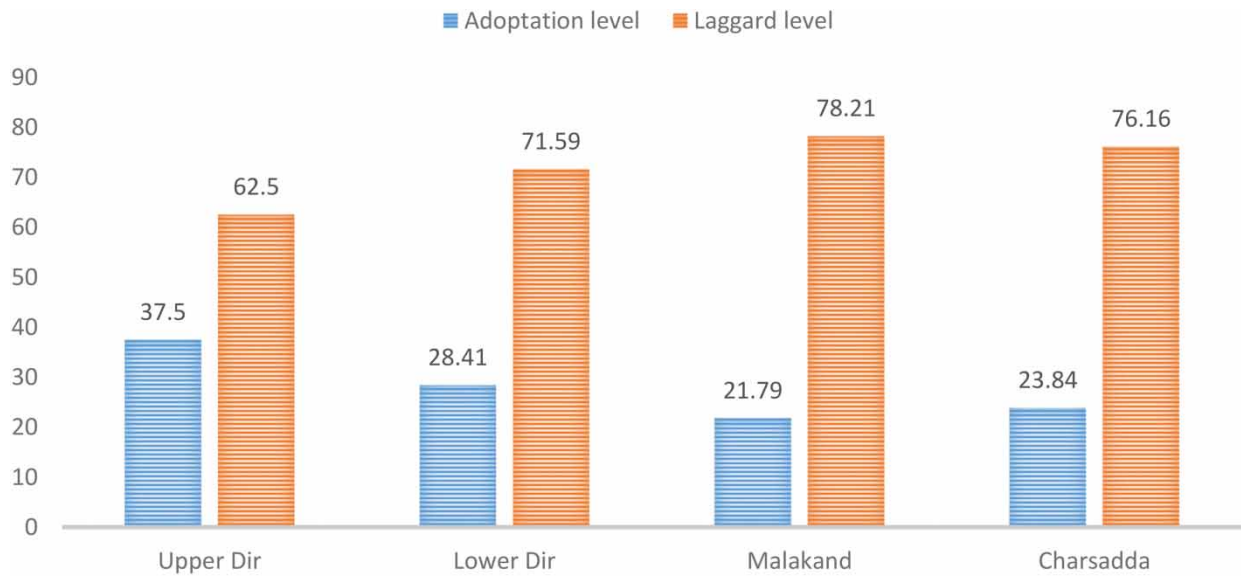


Figure 2 | Climate change adoption level of farmers.

adopting new technology to tackle the climate shock in District Upper Dir. The adoption level of the respondents is worse in Malakand (21.79%), followed by District Charsadda (23.84%) and Lower in Dir (28.41%).

3.2. Perception of climate change

To cover the various climate change factors and their response toward climate change, it is important to know the awareness level of households about climate change, their perception of extreme climatic events (precipitation, temperature, flood, and

drought), and the importance of understanding the present and future adoption measures that are important for decision-making (Esham & Garforth 2012). The results of the study reveal that the study participants strongly observed climate change variability, as shown in Figure 3. Many of the study participants perceived high temperatures (50.7% in District Charsadda, 21.3% in District Upper Dir, 42.1% in District Lower Dir, and 50.7% in District Malakand) and rainfall (26.8% in District Charsadda, 52% in District Upper Dir, 35.4% in District Lower Dir, and 26.8% in District Malakand), and responded to increasing flooding (38.4% in District Charsadda, 7.1% in District Upper Dir, 57.9% in District Lower Dir, and 38.4% in District Malakand). Likewise, the study participants indicated droughts (26.8% in District Charsadda, 7.1% in District Upper Dir, 42.1% in District Lower Dir, and 26.8% in District Malakand) that adversely impact agricultural production.

3.3. Logistic regression model (farmer's awareness)

Before logistic regression, the data were checked for the problem of multicollinearity, which is one of the basic assumptions of the classical linear model. The data were pre-tested on various inflation factors (VIFs) for the multicollinearity problem. The estimated results of the VIF show that the value of the VIF for all variables is less than five, which indicates that the data are free from the problem of multicollinearity, as shown in Table 2.

The estimated logistic regression, as shown in Table 3, indicates that in the District Upper Dir, the age of the respondent, education, monthly income, farming experience, any disease, farmland, and extension visits are statistically significant at 1, 1, 1, 1, 1, 1, and 10% with a positive coefficient of 3.303, 2.552, 3.944, 2.969, 3.397, 3.355, and 0.903. The estimated coefficient implies that an increase of 1% in the age of the respondent, education, monthly income, farming experience, any disease, farmland, and extension visits can increase the probability of awareness by 3.303, 2.552, 3.944, 2.969, 3.397, 3.355, and 0.903%. While the off-farm income is significant with a negative coefficient at a 1% level, it shows that respondents' awareness decreases by 2.508% with a 1% increase in off-farm income. The estimated results of marginal effects for District Upper Dir show that the marginal effect of monthly income is higher than other factors, which implies that respondents whose monthly income is greater than others have more awareness.

Similarly, in District Lower Dir, the age of respondent, education, monthly income, farming experience, any disease, extension visit, and family size are statistically significant at 1, 1, 1, 5, 1, 1, and 5% with a positive coefficient of 1.373, 1.462, 2.449, 0.863, 4.790, 1.372, and 1.013. The result shows that a 1% increase in the age of respondent, education, monthly income, farming experience, any disease, extension visit, and family size can increase awareness by 1.373, 1.462, 2.449, 0.863,

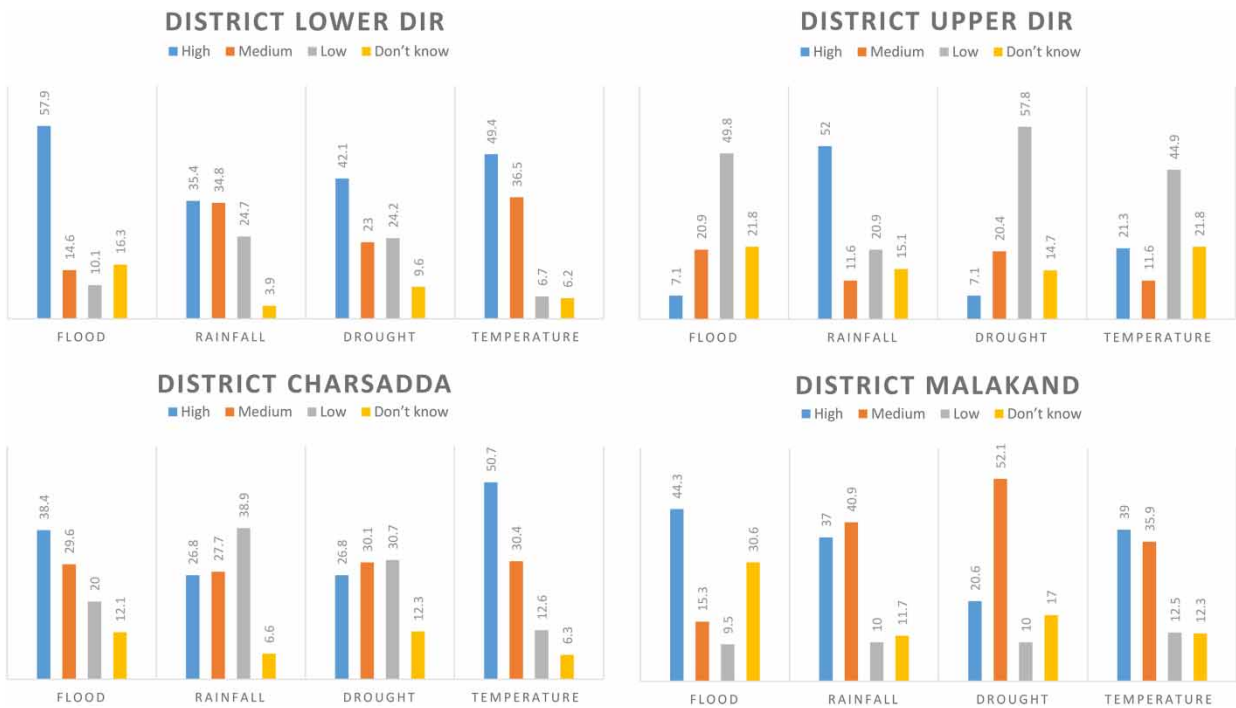


Figure 3 | Climate change perception in the surveyed area (district-wise).

Table 2 | Various inflation factors for the multicollinearity check

	Upper Dir	Lower Dir	Malakand	Charsadda	Total
Variables	VIF				
Age	1.61	1.28	1.49	1.58	1.45
Education years	1.19	1.14	1.30	1.26	1.21
Total monthly income	1.20	1.23	1.17	1.18	1.17
Other sources of income	1.35	1.42	1.25	1.32	1.17
Farming experience	1.35	1.19	1.28	1.35	1.28
Family size	1.27	1.32	1.26	1.16	1.18
Do you, or any of your family members, have any disease?	1.42	1.33	1.30	1.35	1.32
Land (Kanal)	1.27	1.18	1.32	1.17	1.19
Extension	1.06	1.15	1.21	1.05	1.07
Mean VIF	1.30	1.25	1.29	1.27	1.24

4.790, 1.372, and 1.013%. The marginal effect shows that in District Upper Dir, the respondents are more aware when there is any disease in their family. In the District Lower Dir, the farming land and other sources of income have no impact on the respondents' awareness level. Likewise, in District Malakand, all the variables are statistically significant with a positive coefficient except other sources of income, which have a negative coefficient. This result implies that all the variables have a direct relation with awareness level, while another source of income has an indirect relation with respondent awareness. The estimated marginal effect of any disease in the family has the highest effect on awareness. The estimated results of District Charsadda are like the results of District Malakand, but farming land alone does not affect awareness.

By combining all four district respondents, the pooled data show that the marginal effect of the respondents with any disease in their family is more aware of climate change. Similarly, the estimated results of the respondents who are engaged in other professions along with agriculture are less aware of climate change. The estimated logistic regression shows that a 1% increase in respondents' engagement in other professions can decrease awareness by 0.683% in KP. It is likely the estimated results of the respondent's age, education, monthly income, farming experience, family size, any disease, farming land, and extension visit are significant at a 1% level. The results imply that respondent awareness increases by 1.157, 0.836, 0.901, 0.888, 0.522, 1.994, 0.459, and 0.947% with a 1% increase in the age of respondent, education, monthly income, farming experience, family size, any disease, farming land, and extension visit.

3.4. Adaptation measurements

In these four districts, the participants used the main adaptation techniques mentioned in the questionnaire about the measurement of climate change adaptation. The estimated result shows that 11.2, 9.1, 24.7, and 36.4% of respondents changed their irrigation patterns in Districts Upper Dir, Lower Dir, Malakand, and Charsadda, while 54.0, 53.4, 44.5, and 27.9% of respondents diversify their crops. Likewise, 36.6, 58, 45.7, and 35.7% of householders change crop verity in Upper Dir, Lower Dir, Malakand, and Charsadda. The predicted result shows that 36.6, 41.5, 55.7, and 51.2% of respondents changed their seed quality in Districts Upper Dir, Lower Dir, Malakand, and Charsadda. Similarly, 26.8, 26.7, 31.0, and 69.0% of respondents adopted water and soil management in Upper Dir, Lower Dir, Malakand, and Charsadda. Meanwhile, the farmers' adopted crop rotation was 26.3, 63.6, 31.3, and 65.5% in Districts Upper Dir, Lower Dir, Malakand, and Charsadda. The results show that the water storage in Districts Upper Dir, Lower Dir, Malakand, and Charsadda was 9.8, 15.9, 14.9, and 24.1%, and deep ploughing was observed at 58.0, 51.1, 48.3, and 39.5% (Figure 4).

3.5. Source of information about climate change

The closed-ended questions were put to the selected respondents about their sources of information related to climate change. The estimated results show that 19.6, 8.0, 8.1, 24.7, and 15.8% of the respondents are updated about climate via newspapers in Districts Upper Dir, Lower Dir, Malakand, Charsadda, and total. The predicted result shows that 63.4, 64.8, 19.0, 51.8, and 45.7% of people get information via radio, and 5.8, 14.2, 23.5, 14.8, and 15.7% of people get

Table 3 | Major factors responsible for climate change awareness

Variable s	District Upper Dir Coefficient (SE)	*dy/dx* (SE)	District Lower Dir Coefficient (SE)	*dy/dx* (SE)	District Malakand Coef ficient (SE)	*dy/dx* (SE)	District Charsadda Coefficient (SE)	*dy/dx* (SE)	Total Coefficient (SE)	*dy/dx* (SE)
Age	3.303* (1.103)	0.137* (0.039)	1.373* (0.465)	0.107* (0.033)	1.165* (0.310)	0.112* (0.028)	1.076* (0.271)	0.136* (0.032)	1.152* (0.165)	0.121* (0.016)
Education years	2.552* (0.691)	0.106* (0.020)	1.462* (0.455)	0.114* (0.031)	0.697* (0.239)	0.067* (0.022)	0.760* (0.214)	0.096* (0.026)	0.836* (0.131)	0.088* (0.013)
Total monthly income	3.944* (0.964)	0.163* (0.027)	2.449* (0.718)	0.191* (0.049)	0.772* (0.253)	0.074* (0.023)	0.458** (0.209)	0.058** (0.026)	0.901* (0.144)	0.095* (0.0143)
Other sources of income	−2.508** (1.116)	−0.104* (0.043)	0.399 (0.794)	0.031 (0.062)	−0.946** (0.431)	−0.091** (0.040)	−0.715** (0.370)	−0.090** (0.046)	−0.683* (0.234)	−0.072* (0.024)
Farming experience	2.969* (0.838)	0.123* (0.028)	0.863** (0.452)	0.067** (0.034)	0.857* (0.267)	0.082* (0.025)	0.903* (0.233)	0.114* (0.028)	0.888* (0.145)	0.093* (0.0145)
Family size	0.380 (0.591)	0.016 (0.024)	1.013** (0.523)	0.079** (0.040)	0.633* (0.244)	0.060* (0.023)	0.760* (0.214)	0.096* (0.026)	0.522* (0.133)	0.05 5* (0.014)
Do you, or any of your family members, have any disease?	3.397* (1.004)	0.141* (0.032)	4.790* (1.003)	0.373* (0.054)	1.905* (0.4000)	0.183* (0.033)	1.328* (0.348)	0.168* (0.040)	1.994* (0.217)	0.209* (0.019)
Land (Kanal)	3.355* (0.907)	0.139* (0.026)	−0.467 (0.453)	−0.036 (0.035)	0.781* (0.253)	0.075* (0.023)	0.115 (0.212)	0.015 (0.027)	0.459* (0.135)	0.04 8* (0.014)
Extension	0.907*** (0.693)	0.050*** (0.027)	1.372* (0.586)	0.107* (0.042)	1.164* (0.348)	0.112* (0.031)	0.680** (0.299)	0.086** (0.037)	0.947* (0.186)	0.099* (0.019)
_cons	−26.263* (5.842)		−15.106* (4.112)		−8.955* (1.387)		−7.674* (1.077)		−8.935* (0.771)	
Observations	224	224	176	176	358	358	365	365	1,123	1,123
X^2 (9)	214.93		135.17		249.12		200.53		712.44	
R^2	0.78		0.60		0.53		0.41		0.48	
Log-likelihood	−30.041		−44.670		−111.633		−146.550		−380.240	
% Correct prediction	93.30		90.91		88.83		82.47		87.18	

Note: Coefficient and (SE) show logistic regression's coefficient and standard error, while *dy/dx* shows the marginal effect. *, **, and *** show the significance level at 1, 5, and 10%.

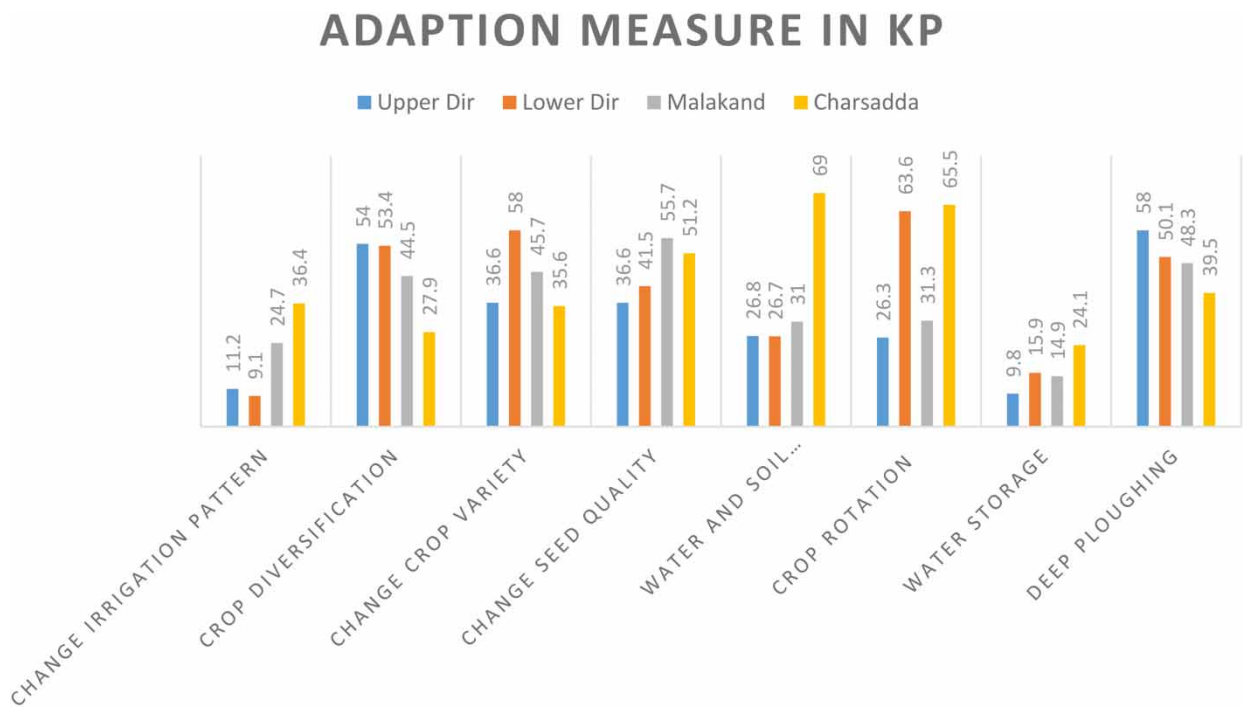


Figure 4 | Adaptation measurement of the respondent in a percent.

information via television in the Districts Upper Dir, Lower Dir, Malakand, Charsadda, and total. Similarly, through direct contact with a concerned organization, the respondents are aware of 27.2, 17.6, 36.0, 35.6, and 31.3%, while through the Internet, 5.4, 6.2, 10.1, 3.6, and 6.4% of interviewers in Districts Upper Dir, Lower Dir, Malakand, Charsadda, and total. Awareness through mobile is 54.0, 66.5, 53.1, 27.1, and 46.9%, while discussions with a local farming expert are 62.5, 40.9, 29.3, 55.6, and 46.3% of households that identify climate change in the Districts Upper Dir, Lower Dir, Malakand, Charsadda, and total. Meanwhile, the information via farmers' discussion is 53.6, 52.8, 39.7, 79.5, and 57.4% of respondents in the Districts Upper Dir, Lower Dir, Malakand, Charsadda, and the information was obtained from the agriculture seminar with 21.1, 15.3, 9.8, 20.0, and 14.4% of respondents. These are the sources from which farmers can get information in the concerned districts as shown in Table 4.

Table 4 | Description of the major source of information in the study area

	Upper Dir (%)	Lower Dir (%)	Malakand (%)	Charsadda (%)	Total (%)
Newspaper	19.6	8.0	8.1	24.7	15.8
Radio	63.4	64.8	19.0	51.8	45.7
Television	5.8	14.2	23.5	14.8	15.7
Direct contact with the concerned organization	27.2	17.6	36.0	35.6	31.3
Internet	5.4	6.2	10.1	3.6	6.4
Mobile	54.0	66.5	53.1	27.1	46.9
Discussions with local farming experts	62.5	40.9	29.3	55.6	46.3
Farmers' discussion	53.6	52.8	39.7	79.5	57.4
Agricultural seminar	12.1	15.3	9.8	20.0	14.4

3.6. Logistic regression model (farmer adoption)

The estimated logistic regression shown in Table 5 indicates that in the District Upper Dir, the age of the respondent, education, monthly income, other source of income, farming experience, family size, farmland, and extension visits are statistically significant at 1, 2, 1, 3, 1, 1, 2, and 3% with a positive coefficient of 1.065, 1.073, 1.071, 1.899, 1.105, 1.566, 1.324, and 1.868. The estimated coefficient implies that an increase of 1% in the age of the respondent, education, monthly income, other source of income, farming experience, family size, farmland, and extension visits can increase the probability of the adoption strategy by 1.065, 1.073, 1.071, 1.899, 1.105, 1.566, 1.324, and 1.868%. Any disease in the family member is insignificant, showing no effect on adoption measures. The estimated results of marginal effects for District Upper Dir show that the marginal effect of other sources of income is higher than other factors, which implies that respondents who earn income from other sources have greater adoption measures than others.

Similarly, in District Lower Dir, the age of respondent, education, monthly income, farming experience, family size, any disease, farmland, and extension visit are statistically significant at 1, 2, 2, 3, 2, 1, 2, and 2% with a positive coefficient of 1.052, 1.109, 0.937, 1.053, 1.434, 3.041, 1.482, and 2.557. The result shows that a 1% increase in the age of respondent, education, monthly income, farming experience, family size, any disease, farmland, and extension visit can increase the adoption measure by 1.052, 1.109, 0.937, 1.053, 1.434, 3.041, 1.482, and 2.557%. The marginal effect shows that in District Lower Dir, the respondents use adaptive measures when there is any disease in their family. In the District Lower Dir, the other sources of income have no impact on the adoption level of the respondents. Likewise, in District Malakand, all the variables are statistically significant with a positive coefficient except other sources of income and family size, which does not affect the adoption measure. This result implies that all the variables directly relate to adoption measures. The estimated marginal effect of disease in family members shows that disease in family members has the highest effect on adoption measures. The estimated results of District Charsadda show that all the variables significantly positively influence the farmers' adoption level, except family size.

By combing all four district respondents, the pooled data show that the marginal effect of the respondents with any disease in their family and contact with an extension agent has applied more adoption measures.

4. CONCLUSION

Various factors can be responsible for affecting the farm household's awareness and adoption level, such as demographic and socio-economic factors. A sample of 1,123 farm households was used in the study in the KP Province of Pakistan. The result of the study revealed that most farm households in the surveying districts were aware of climate change. However, it was observed that most of them were laggards and not ready to adopt the new technology to handle climatic shock. The result shows that the farmers more affected by climate change were more aware of it, but their adoption level was still lower. The key factors that significantly affected farmers' awareness level and adoption strategies related to climate change were education, age, family size, farming experience, other sources of income, extension service, and family diseases.

Furthermore, the study examines the respondent's adaptation behavior to climate change. The adaptation measurement in the study shows that changes in irrigation patterns, crop diversification, crop verity, seed quality, water and soil management, and deep ploughing were highly linked to the awareness of climate change. The study's findings also revealed that the farmers are already involved with active adaptation approaches, but their levels are still lower. Moreover, the study's findings can help the government and agriculture extension to enlarge their awareness of climatic variation in the study area, which is unprotected from climatic risk. The current study was limited to the KP Province of Pakistan. However, the findings of this study can also be implemented in regions where climate change adaptations are still ineffective. The study's recommendation is helpful for government policymakers and researchers to develop strategies and carry various features to farm households to cope with various climatic hazards. It is suggested that the necessary action should be taken to increase the awareness of climate change. The study shows that most people are aware of climate change via radio, so the government needs to make a proper plan and broadcast a special program in which experts can discuss the various issues regarding farmer awareness and climate change and give valuable suggestions. Further study should be undertaken to explore the various factors that are the key issues in adopting new technology in the farming community. Further research should also be undertaken in developing countries regarding climate change awareness and the role of advanced technology.

Table 5 | Major factors responsible for adoption measure

Variables	District Upper Dir Coefficient (SE)	*dy/dx* (SE)	District Lower Dir Coefficient (SE)	*dy/dx* (SE)	District Malakand Coefficient (SE)	*dy/dx* (SE)	District Charsadda Coefficient (SE)	*dy/dx* (SE)	Total Coefficient (SE)	*dy/dx* (SE)
Age	1.065* (0.017)	0.014* (0.003)	1.052* (0.021)	0.008* (0.003)	1.112*(0.026)	0.008* (0.002)	1.254* (0.045)	0.112* (0.002)	1.077* (0.009)	0.011* (0.001)
Education years	1.073** (0.038)	0.015** (0.008)	1.109** (0.052)	0.017** (0.008)	1.147* (0.048)	0.010* (0.003)	1.124* (0.045)	0.006* (0.002)	1.083* (0.019)	0.012* (0.003)
Total monthly income	1.071* (0.027)	0.015* (0.005)	0.937** (0.027)	0.011** (0.005)	1.100* (0.024)	0.007* (0.002)	1.126* (0.030)	0.006* (0.002)	1.052* (0.011)	0.007* (0.001)
Other sources of income	1.899*** (0.662)	0.140*** (0.076)	1.500 (0.624)	0.067 (0.068)	0.864 (0.344)	−0.010 (0.029)	2.166** (0.806)	0.040*** (0.023)	1.567* (0.267)	0.066* (0.025)
Farming experience	1.105* (0.028)	0.022* (0.005)	1.053*** (0.032)	0.009*** (0.005)	1.116* (0.034)	0.008* (0.003)	1.077* (0.032)	0.004** (0.001)	1.092* (0.013)	0.013* (0.002)
Family size	1.566* (0.251)	0.098* (0.035)	1.434** (0.255)	0.060** (0.030)	1.232 (0.175)	0.015 (0.010)	1.043 (0.171)	0.002 (0.008)	1.152* (0.078)	0.021** (0.010)
Do you, or any of your family members, have any disease?	1.460 (0.506)	0.083 (0.076)	3.041* (1.269)	0.185* (0.068)	2.833* (1.197)	0.075* (0.031)	2.834* (1.165)	0.053** (0.026)	2.191* (0.377)	0.115* (0.025)
Land (Kanal)	1.324** (0.185)	0.061** (0.030)	1.482** (0.250)	0.065* (0.027)	1.513* (0.231)	0.030* (0.012)	1.461* (0.206)	0.019** (0.009)	1.350* (0.089)	0.044* (0.010)
Extension	1.868*** (0.662)	0.136*** (0.077)	2.557** (1.063)	0.156** (0.069)	2.076** (0.801)	0.052* (0.029)	2.727* (1.055)	0.051** (0.023)	2.113* (0.360)	0.110* (0.025)
_cons	−4.261* (1.482)		−0.002* (0.001)		3.741* (1.002)		5.932* (1.762)		7.208* (2.430)	
Observations	224	224	176	176	358	358	365	365	1,123	1,123
X^2 (9)	80.47		53.59		185.23		203.97		408.49	
R^2	0.28		0.25		0.49		0.50		0.31	
Log-likelihood	−107.955		−78.24		−95.05		−98.46		−446.53	
% Correct prediction	77.68		80.68		89.11		87.40		82.99	

Note: Coefficient and (SE) show logistic regression's coefficient and standard error, while *dy/dx* shows the marginal effect. *, **, and *** show the significance level at 1, 5, and 10%.

AUTHOR CONTRIBUTION

M.R.U. conceptualized the work, did the formal analysis, investigated the study, wrote the original draft, and collected the data, software, and methodology. J.M. and M.N. did the formal analysis, wrote the review, investigated the work, and collected software and methodology.

DATA AVAILABILITY STATEMENT

Data cannot be made publicly available; readers should contact the corresponding author for details.

CONFLICT OF INTEREST

The authors declare there is no conflict.

REFERENCES

Agresti, A. 2013 *Categorical Data Analysis*. 3rd Edition. John Wiley & Sons Inc., Hoboken.

Ahmed, T., Scholz, M., Al-Faraj, F. & Niaz, W. 2016 Water-related impacts of climate change on agriculture and subsequently on public health: A review for generalists with particular reference to Pakistan. *Int. J. Environ. Res. Public Health* **13**, 1051. https://doi.org/10.3390/ijerph13111051.

Ajuang, C. O., Abuom, P. O., Bosire, E. K., Dida, G. O. & Anyona, D. N. 2016 Determinants of climate change awareness level in upper Nyakach Division, Kisumu County, Kenya. *Springer Plus* **5** (1), 1–20. https://doi.org/10.1186/s40064-016-2699-y.

Atanga, R. A. & Tankpa, V. 2021 Climate change, flood disaster risk and food security nexus in northern Ghana. *Front. Sustain. Food Syst.* **5**, 706721. doi: 10.3389/fsufs.2021.706721.

Bayard, B., Jolly, C. M. & Shannon, D. A. 2007 The economics of adoption and management of alley cropping in Haiti. *J. Environ. Manage.* **84**, 62–70.

Beniston, M. 2003 Climatic change in mountain regions: A review of possible impacts. *Clim. Change* **59**, 5–31.

Beniston, M. & Haeberli, W. 2001 *Sensitivity of Mountain Regions to Climatic Change, Climate of the 21st Century: Changes and Risks*. pp. 237–244.

Bickerstaff, K. 2004 Risk perception research: Socio-cultural perspectives on the public experience of air pollution. *Environ. Int.* **30**, 827–840.

Deressa, T. T., Hassan, R. M. & Ringler, C. 2011 Perception of and adaptation to climate change by farmers in the Nile basin of Ethiopia. *J. Agric. Sci.* **149** (1), 23–31. doi:10.1017/s0021859610000687.

Du, W., FitzGerald, G. J., Clark, M. & Hou, X.-Y. 2010 Health impacts of floods. *Prehosp. Disaster Med.* **25** (3), 265–272. doi:10.1017/S1049023X00008141.

Esham, M. & Garforth, C. 2013 Agricultural adaptation to climate change: insights from a farming community in Sri Lanka. *Mitig. Adapt. Strateg. Glob. Change* **18**, 535–549.

Fahad, S. & Jing, W. 2018 Evaluation of Pakistani farmers' willingness to pay for crop insurance using contingent valuation method: The case of Khyber Pakhtunkhwa province. *Land Use Policy* **72**, 570–577.

Fahad, S., Wang, J., Khan, A. A., ullah, A., Ali, U., Hossain, M. S. & Bilal, A. 2018 Evaluation of farmers' attitude and perception toward production risk: Lessons from Khyber Pakhtunkhwa Province, Pakistan. *Hum. Ecol. Risk Assess.* **24** (6), 1710–1722.

GOP 2013 *Economic Survey of Pakistan. Economic Affairs Division*. Ministry of Finance, Islamabad, Pakistan.

Gujarati, D. & Porter, D. 2003 Multicollinearity: what happens if the regressors are correlated? In: *Basic Econometrics,* 4th Edition (Gujarati, D. N., ed.) McGraw-Hill, Boston, MA

Hallegatte, S., Bangalore, M. & Bonzanigo, L. 2016 *Shock Waves: Managing the Impacts of Climate Change on Poverty*. World Bank Group, Washington. https://doi.org/10.1017/S0022112081001535.

Hasan, Z. & Akhter, S. 2011 Determinants of public awareness and attitudes on climate change in urban Bangladesh: Dhaka as a case. *Eur. J. Soc. Sci.* **21** (1), 154–162.

Huong, N. T. L., Yao, S. B. & Fahad, S. 2017 Farmers' perception, awareness and adaptation to climate change: Evidence from Northwest Vietnam. *Int. J. Clim. Change Strateg. Manage.* **9**, 555–576. https://doi.org/10.1108/IJCCSM-02-2017-0032.

Huong, N. T. L., Bo, Y. S. & Fahad, S. 2018 Economic impact of climate change on agriculture using Ricardian approach: A case of northwest Vietnam. *J. Saudi Soc. Agric. Sci.* https://doi.org/10.1016/j.

Ingrao, C., Strippoli, R., Lagioia, G. & Huisingh, D. 2023 Water scarcity in agriculture: An overview of causes, impacts, and approaches for reducing the risks. *Heliyon* **9** (8), e18507.

IPCC 2007 *Synthesis Report. Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*. IPCC, Geneva, Switzerland.

IPCC 2014 *Climate Change 2014: Synthesis Report Summary Chapter for Policymakers*. IPCC, Geneva, Switzerland.

Kurukulasuriya, P. & Mendelsohn, R. 2008 A Ricardian analysis of the impact of climate change on African cropland. *AfJARE* 2 (1), 1–23.

Liverman, D. M. & Kapadia, K. 2010 Food systems and the global environment: An overview. In: *Food Security and Global Environmental Change* (Liverman, D. M. & Kapadia, K., eds.). Earthscan, London, pp. 3–25.

Luseno, W. K., McPeak, J. G., Barrett, C. B., Little, P. D. & Gebru, G. 2003 Assessing the value of climate forecast information for pastoralists: Evidence from Southern Ethiopia and Northern Kenya. *World Dev.* **31** (9), 1477–1494.

Maddison, D. 2007 *The Perception of and Adaptation to Climate Change in Africa*, Vol. 4308. World Bank Publications, Chicago, IL.

Mandleni, B. & Anim, F. D. K. 2011 Climate change awareness and decision on adaptation measures by livestock farmers in South Africa. *J. Agric. Sci.* **3** (3), 258.

Niemeyer, S., Petts, J. & Hobson, K. 2005 Rapid climate change and society: Assessing responses and thresholds. *Risk Anal.* **25**, 1443–1456.

Oduniyi, O. S. 2013 *Climate Change Awareness: A Case Study of Small Scale Maize Farmers in Mpumalanga Province, South Africa*. *Doctoral Dissertation*, University of South Africa.

Pulhin, J. M., Peras, R. J. J., Lasco, R. D., Cruz, R. V. O. & Pulhin, F. B. 2006 *Vulnerability of Communities to Climate Variability and Extremes: the Pantabangan-Carranglan Watershed in the Philippines*. AIACC Working Paper No. 44.

Shabir, O. 2013 A summary case report on the health impacts and response to the Pakistan floods of 2010. *PLoS Curr.* **5**, 1–47.

Shahid, M. & Rahman, K. U. 2021 Identifying the annual and seasonal trends of hydrological and climatic variables in the Indus Basin Pakistan. *Asia-Pac. J. Atmos. Sci.* **57**, 191–205.

Shahid, M., Cong, Z. & Zhang, D. 2018 Understanding the impacts of climate change and human activities on streamflow: A case study of the Soan River basin, Pakistan. *Theor. Appl. Climatol.* **134**, 205–219.

Sofoluwe, N., Tijani, A. & Baruwa, O. 2011 Farmers' perception and adaptations to climate change in Osun Satte, Nigeria. *Afr. J. Agric. Res.* **6** (20), 4789–4794.

Steffen, W., Richardson, K., Rockström, J., Cornell, S. E., Fetzer, I., Bennett, E. M., Biggs, R., Carpenter, S. R., Vries, W. D., Wit, C. A. D., Folke, C., Gerten, D., Heinke, J., Mace, G. M., Persson, L. M., Ramanathan, V., Reyers, B. & Sörlin, S. 2015 Planetary boundaries: Guiding human development on a changing planet. *Science* **347** (6223), 1259855. https://doi.org/10.1126/science.1259855.

Weber, E. U. 2010 What shapes perceptions of climate change? *WIREs Clim. Change* **1**, 332–342.

First received 29 March 2024; accepted in revised form 22 July 2024. Available online 7 August 2024