Journal of Energy and Power Engineering 17 (2023) 136-151
doi: 10.17265/1934-8975/2023.04.003

Climate Change Perceptions, Impacts and Adaptation Strategies of Farm Households in Potohar Region of Punjab, Pakistan

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Abstract: Climate change has become a global phenomenon and is adversely affecting agricultural development across the globe. Developing countries like Pakistan where 18.9% of the GDP (gross domestic product) came from the agriculture sector and also 42% of the labor force involved in agriculture. They are directly and indirectly affected by climate change due to an increase in the frequency and intensity of climatic extreme events such as floods, droughts and extreme weather events. In this paper, we have focused on the impact of climate change on farm households and their adaptation strategies to cope up the climatic extremes. For this purpose, we have selected farm households by using multistage stratified random sampling from four districts of the Potohar region i.e. Attock, Rawalpindi, Jhelum and Chakwal. These districts were selected by dividing the Potohar region into rain-fed areas. We have employed logistic regression to assess the determinants of adaptation to climate change and its impact. We have also calculated the marginal effect of each independent variable of the logistic regression to measure the immediate rate of change in the model. In order to check the significance of our suggested model, we have used hypothesis testing.

Key words: Climate change, multistage stratified random sampling, impacts, adaptation strategies, logistic regression, marginal effect, Hypothesis testing.

1. Introduction

Climate change is real and affecting each and every sphere of the human life on this globe. Particularly, poor countries where populations are more dependent on agriculture are largely affected by climate change due to limited resources and low adaptive capacity [1]. Increase in the occurrence and intensity of climatic extreme events such as floods, droughts and heavy rainfalls are affecting the economic well-being in the developing countries.

Climate change has been caused due to increased volume of greenhouse gases in the air [2]. Industrial development is one of the possible reasons for these emissions which are caused mainly due to fossil fuel burning. The concentration and consumption of fossil fuels is likely to be doubled by year 2100 [3]. Greenhouse gases emissions could affect the ozone layer and may lead to increase in surface temperature and sea level rise. Climate change is an externality that is caused by various economic and financial activities. The geography, level of development and dependence on certain resource define countries' vulnerability and sensitivity to climate change. Agriculture, which is itself affected by climate change, is one of the main sources of greenhouse gases through formation of CO_2 and CH_4

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gases during crop production and livestock production. Further, increase in temperature and changes in rainfall distribution patterns are also responsible for decrease in crop production [4, 5]. The positive or negative impacts of climate change depend on geography and type of cropping patterns. For example, warmer regions may have negative impacts on crops production due to increase in temperature while cold regions may have positive impacts on their crop production due to increase in temperature. Extreme weather events like flood sand droughts have caused the significant reduction in crop production all over the world especially in developing countries [6].

Pakistan, where agriculture accounts for 20 percent of the total GDP (gross domestic product) and provides livelihoods to 42 percent of its labor force, is also experiencing climate change from past few decades. The GCRI (Global Climate Risk Index) ranked Pakistan at number 8 in countries most affected by climate change over the period 1995 to 2014 [7]. An adverse effect of it is seen as dry spells and surges which has negative impacts on human settlements, water management and rural livelihoods [8]. Alone 2010 floods have affected 20 million of people, destroyed 2 million of hectares of standing crops and caused a net loss of 4 billion USD losses only to agriculture sector.

The effects of climate change are more prominent on rain-fed agriculture compared to irrigated agriculture due to its direct linkages with climate. The Potohar region in Pakistan is mainly rain-fed where agriculture is the major source of livelihood for local people. The main crops grown in this area are maize, wheat, rice and groundnut but their production is decreasing from last many years due to increasing temperature and decreasing rainfall [9]. Punjab received on average less than 250 mm rainfall per year. In nutshell, climate is changing and showing its impact everywhere. Particularly, poor households have been affected adversely by climate change through negative impacts on their crops and livelihoods [10].

Climate change impacts on poor household are more due to their low adaptive capacity and existence of constraints in the adoption of tools that may save them from harmful effects of climate change. The lack of adoption of preventive measures may have negative impacts on the society and cause adverse social and economic effects [11]. Social issues related to climate change include shortfall in energy, infrastructure damages, increasing losses to industry, and food and water security, while poor economic conditions make it difficult for households to maintain their smooth and decent standard of living. Declines in agricultural production affect the income and consumption level of households and push them in poverty. The consumption pattern of end-users may be disturbed due to increase level of poverty in the society. Similarly, the net producers may also confront a decrease in their utilization because of little crop production and income [12].

Perceiving climate variability is the first step in the process of adapting agriculture to climate change [13]. A better understanding of farmers' concerns and the manner they perceive climate change is crucial to design effective policies for supporting successful adaptation of the agricultural sector. Further, it is also important to have precise knowledge about the degree and extent of adaptation methods being taken up by farmers and need for further advances in existing adaptation setups. Hence, understanding how farmers perceive changes in climate and what factors shape their adaptive behavior is desirable for adaptation research [5]. The choice of adaptation methods by farmers depends on various social, economic and environmental factors [14]. This knowledge will ultimately enhance the credibility of policies and their strength to tackle the challenges being imposed by climate change on farmers [13]. Adaptation will require the participation of multiple players from different profiles such as research, policy, extension, private welfare organizations, local communities and farmers [15].

Keeping in view the research gaps, this study examines the farm households' perceptions and vulnerability to climate change and implemented adaptation strategies to climate change. Specifically, this study has four objectives: (1) to assess the vulnerability and impacts of climate change impacts on crop production in Potohar region, (2) to identify adaptation measures adopted by farm households to protect their livelihoods from climate change, (3) to assess determinants of climate change adaptation and constraints that restrict farm level adaptation, and (4) to suggest policy options to reduce negative impacts on farm households in Potohar and other regions.

2. Methods

2.1 Study Area

The present study was conducted in Potohar region of Punjab. Total population of Potohar region of Punjab is 14,610,009 [16]. The total area of the region is 22,254 square kilometer [16]. It is situated in the east by the River Jehlum, by the Indus River in the west, the Kala Chitta Range in the North and the Margalla Hills also, and in the south by Salt Range. The Potohar region of Punjab includes the four districts of Rawalpindi, Attock, Jhelum and Chakwal. The reasons behind the selection of Potohar region as main study areas include the growing aridity and exposure of rain-fed agriculture to climate change and climatic events, which are more prominent in arid regions compared to irrigated regions. Another reason for this selection was the vulnerability of agricultural communities to climate change that is adversely affecting the socioeconomic wellbeing and livelihoods.

The on average winter minimum temperature in Potohar region of Punjab was recorded 16 ℃ to 18 ℃ and on average summer maximum temperature was recorded in Potohar region 29 ℃ to 32 ℃ over the period of 1980-2013. The distribution of rainfall in Punjab is wide-ranging, mostly linked with the monsoon winds. The rain-fed zone receives the highest quantity of rainfall followed by the wheat zone, mixed zone and peanut zone respectively [17]. The Potohar region of Punjab totally depends on rainfall which received on average annual rainfall 380-510 mm. Thus, rainfall falls in southwest and increases in the northwest.

2.2 Sampling and Data Collection

In this study 120 farm households were collected through multi-stage stratified random sampling as shown in Fig. 1. In the principal stage, for the selection of study districts, Potohar region of Punjab is divided into major Barani (rain-fed) region. In this stage we selected Potohar region of Punjab. In the second stage four districts were selected. In the third stage four tehsils were chosen from the each area. In the fourth stage we chose randomly two villages from each tehsil. In the fifth and last stage around fourteen to fifteen farm households were randomly selected from each Tesil [18]. Overall 120 and specifically thirty farm households from each district were interviewed.

On the base of research ethics all interview was conducted [19]. Before the starting of interview researchers clearly explained the reason and objective of the study. The farm households' survey question includes households' attributes, cultivating, and climate perception risk, impacts of climate change on farm households, adaptation and constraints to adaptation to climate-related risk.

Present study used both primary as well as secondary data. The primary data that consist of farm household interviews were collected from district located in Potohar region of Punjab province while secondary data on climate indicators were collected from Pakistan metrological department for selected nearest weather stations. Observed weather data of mean, minimum and maximum temperature and total rainfall were collected for the period of 1980-2013.

For primary data, a cross-sectional data collection technique is employed and semi-structured questionnaire was designed. The questionnaires were pre-tested in field before going for final survey. It was done to avoid missing any important information. Data were collected at a specific point in time from various people having similarities with others in their attributes but different from others on a means factor of interest such as income level, age and geographic location [20]. Selected villages were visited to conduct interview with farm households. Prior informal agreements were made with the farmers by stating objectives and purpose of the study and assurance of use of data only for educational purpose. Other households replaced the households who refused interviews. Average time of filling one questionnaire was 1 h approximately per sample. The reason behind too much consumption of time per sample was to convince them and to take accurate response from respondent in order to make research effective. Author completed this activity of data collection in three months.

2.3 Analytical Framework

2.3.1 Dependent and Independent Variables

This study followed the binary logistics model which was used to determine the factors influencing the choice of adaptation options adopted by poor households in the study region. The assessment to adapt requires that farm households observe changes in long-term climate such as temperature and rainfall trends [15]. Some agriculture measure to adaptation can fall losses due to fall perception and rise temperature [21].

The farm households will adapt only if they perceive fall in the risk crop production [15, 22], or an increase in expected net benefits. Consider a latent variable (Y_{ij}*) which is equal to expected benefits from the adoption of certain adaptation measures:

$$Y_{ij}^{*} = \alpha + \sum \beta_k X_k + \varepsilon_{Y_{ij}^{*}} \quad (1)$$

In this equation, Y_{ij}* is a latent binary variable with subscript *i* depicting the household who adapted to climate variability and *j* depicting different adaptation measures. X_k represents the vector of exogenous explanatory variables that influence the farmers' choice of adopting particular adaptation measures and *k* in the subscript shows the specific explanatory variable (varies from zero to 8). The symbol α denotes the model intercept, β_k the vector of binary regression coefficients and $\varepsilon_{Y_i^*} \cong N(0,\sigma^2)$ is the error term which is normally distributed and homoscedastic (zero mean and constant variance) [23].

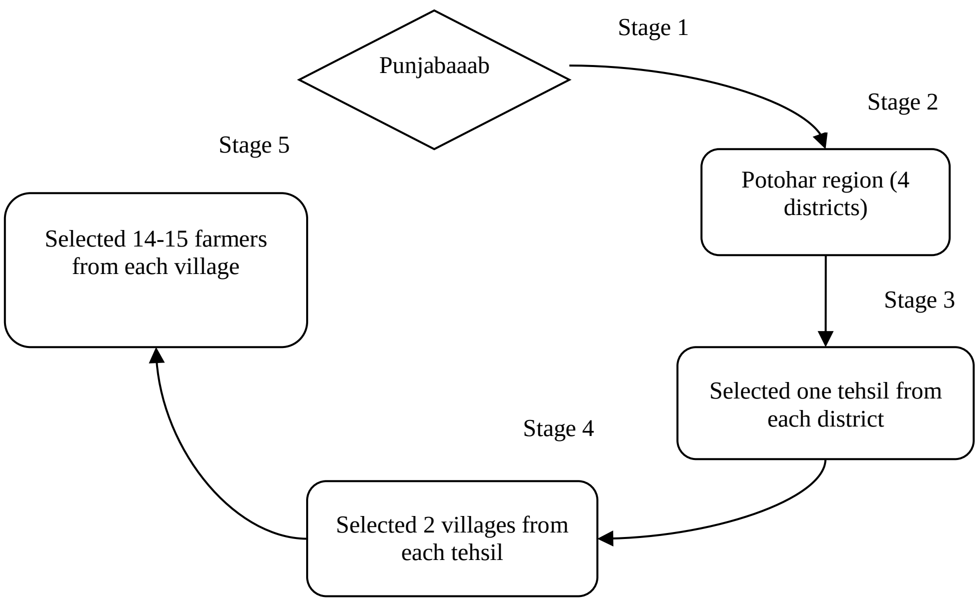

Fig. 1 Sampling stages to select surveyed sampled households in Potohar region, Punjab.

We do not observe the latent variable (Y_{ij}*) directly. All we observe is:

$$Y_{ij} = \begin{cases} 1 & if \quad Y_{ij}* > 0 \\ 0 & if \quad Y_{ij}* \leq 0 \end{cases} \tag{2}$$

where Y_{ij} is dependent variable which shows that household *i* will adopt adaptation measure ($Y_{ij} = 1$) only if her or his estimated benefits are positive ($Y_{ij}* > 0$), and otherwise household *i* will not pick adjustment measure *j* if the normal benefits are equivalent to or under zero ($Y_{ij} \leq 0$).

Hence, we can take Eq. (2) in terms of the observed binary variable (Y_{ij}) as:

$$\Pr(Y_{ij} = 1) = Y_{ij} = G(X_k\beta_k) \tag{3}$$

where *G* takes the definite binomial distribution [24].

2.3.2 Marginal Effects/Marginal Probabilities in Logistic Regression

Marginal effects are calculated in various ways for discrete and continuous variables. With binary independent variables marginal effects measure discrete change. In short, marginal affects for continuous variable measure the rate of immediate change [25]. In the existence of binary variable the situation of interpretation becomes change and no sense left to look at derivatives [26]. Marginal effects showed the change in probability when independent variables increase by one unit. Thus, to interpret and quantify the results, we need to calculate either marginal effect. Marginal effects (y_{ij}') describe the effect of a unit change in the independent variable on the probability of dependent variable, i.e. Pr ($Y_{ij} = 1$). Derivation of marginal effect is detailed below:

By applying chain rule we take partial derivative of Eq. (3) with respect to independent variables [27]. it will give us the marginal effect which becomes Eq. (4).

$$\frac{\partial Y_{ij}}{\partial X_k} = \frac{\partial G(X_k B)}{\partial X_k} = \frac{\partial G(X_k B)}{\partial X_k B} \cdot \frac{\partial X_k B}{\partial X_k} = G'(X_k\beta)\beta_k = g(X_k\beta)\beta_k \tag{4}$$

As we know that:

$$G(X_k\beta) = \frac{e^{X_k\beta}}{1+e^{X_k\beta}}$$

Therefore, by applying the quotient rule the derivative of $G(X_k\beta)$ with respect to $X_k\beta$ [27] will be followed as:

$$g(X_k\beta) = \frac{(1+e^{X_kB})e^{X_kB} - e^{X_kB}.e^{X_kB}}{(1+e^{(X_kB)})^2} = \frac{e^{(X_kB)}}{(1+e^{(X_kB)})^2} \tag{5}$$

If we put the value of $g(X_k\beta)$ from Eq. (5) into Eq. (4) then it becomes Eq. (6):

$$\frac{\partial Y_{ij}}{\partial X_k} = \frac{e^{(X_kB)}}{(1+e^{(X_kB)})^2} \cdot \beta_k \tag{6}$$

We may replace X_k with the average value of $\overline{X_k}$ because usually marginal effects were calculated at

$$= \frac{e^{(\overline{X_k}\beta)}}{1+e^{(\overline{X_k}\beta)}} \cdot \frac{1}{1+e^{(\overline{X_k}\beta)}} \cdot \beta_k$$

$$= \Pr(Y_{ij} = 1) \cdot \left(1 - \frac{e^{(\overline{X_k}\beta)}}{1+e^{(\overline{X_k}\beta)}}\right) \cdot \beta_k$$

$$= \Pr(Y_{ij} = 1) \cdot \left(1 - \Pr(Y_{ij} = 1)\right) \cdot \beta_k$$

average of explanatory variables [23]:

As $\frac{\partial G(X_k\beta)}{\partial X_k}$ is simply the marginal effect of logistic regression (see Eq. (6)), so we may write Eq. (7) as:

$$\eta_Y(X_k) = X_k.\Pr(Y_{ij} = 1).[1 - \Pr(Y_{ij} = 1)]\beta_k \tag{7}$$

The final equation of the marginal effect (y_{ij}') after derivation becomes Eq. (8) is:

$$y_{ij}' = \Pr(Y_{ij} = 1) \cdot (1 - \Pr(Y_{ij} = 1))\beta_k \tag{8}$$

2.3.3 Description of Explanatory Variables

The selection of independent (explanatory) variables used in this study is based on data availability and review of the literature. The explanatory variables include household characteristics (e.g. education, gender, households head of farming experience and household size) and production impact factors, constrains factors (e.g. financial constraint factors, information constrain), social attributes in various regions specifically and dummy utilized for Potohar region. Instead of using arid region perception factors, we used dummy variables for Potohar region of Punjab and cultural given the lack of variability in perception (e.g. temperature and rainfall) for farm households in the rest of other districts.

In most of the previous studies farmers are restricted to select only one adaptation measure, thus analyzed before studies adaptation to climate change engaged in machine learning approach [14, 21, 28]. However, in this study we commonly found that farmers have more than one adaptation measure. A possible preparation would be to merge alike measures into single categories [15]. However, such federation into self-defined categories may lead to misunderstanding [15]. Thus, MNL modeling approach was proposed for this study. We used different adaptation measures and also employed the logistic regression method to observe the factors that cause the choice of adaptation measures.

2.3.4 Hypothesis Testing for Model Significance

In order to test the significance of the model and accuracy of prediction power of the model, we used different measures. First of all, a classification table is computed to assess the accuracy of model to predict dependence of outcome variable on various explanatory variables. Following Hosmer and Lameshow [29], the classification table compares the predicted scores of observations on basis of independent variables of the model with their actual responses given in the data. In next step, to test the overall significance of the model we established a global null hypothesis by assuming all coefficients of logistic regression equal to zero, while the alternative hypothesis was that at least one of the regression coefficients would be non-zero [30]:

H_0: $\beta_k = 0$

H_1: $\beta_k \neq 0$

Similar to F-test approach used for model testing in Ordinary Least Square (OLS) regression, this approach checks whether the model with predicators (alternative hypothesis: H_1) is significantly better than intercept-only model (null hypothesis H_0).

$$Y_{ij}^{*} = \alpha \quad (9)$$

Further, the test statistic is computed by subtracting the residual deviance for the model with predictors from the null deviance of intercept-only model. The test statistic uses chi-square with degree of freedom equal to the difference between the number of variables used in the model with predictor and intercept [31].

Hence, based on the statistics, the null hypothesis will be accepted or rejected. If the null hypothesis is rejected then the alternative hypothesis should be accepted implying that at least one of the regression coefficients (β_k) is not zero.

Further, we test the goodness-of-fit of our model by estimating R-square. The estimation of R^2 filled in as a standard for such measure. Estimation of conventional R^2 lies between 0 and 1. The closer the estimation of R^2 to 1, the more great fitted model and near 0 showed no predictive estimation of model or model is not good [32]. Conventional R^2 is not a significant measure of goodness of fit when dependent variable is a definite variable. The reason is that the predicted values of explained variables are probabilities while actual values in dependent variables are in form of either 1 or 0. When dependent variable is a qualitative then Pseudo R^2 is used to check the goodness of fit instead of R^2 [33]. It is defined as the percentage of the variance of the latent variable that is explained by using covariates [34].

$$pseudoR^2 = \frac{L_{UR}^{2/n} - L_R^{2/n}}{(1 - L^2/N_R)L_{UR}^{2/n}}$$

Based on the results from the classification table, global null hypothesis and Pseudo-R^2 it is said that the models of the current study are fit and can accurately estimate the factors affecting the adoption of different adaptation methods.

3. Results and Discussion

3.1 Descriptive Statistics

The description and summary statistics of the socio-economic variables i.e. age, size, education and experience were used in this study as shown in Table 1. Hence, respondents were asked about the socio-economics characteristics while on average age of respondents was 47 years because age of respondents plays a significant role in any study. Most of farm household's families in our country are having large family size. In current study most of our respondents have 10 members in their family. Investment in education sector, ensures quality education and equal access to education contributes in economic growth of country by providing more employment opportunities [35]. Unfortunately, farmers in our country are uneducated and they are not aware of the benefits of education in their own life and keep their children ignorant. In current study, most of respondents are poorly educated and respondent's education lies between middle to metric. In Pakistan, if father is farmer then he engages his son at very young age in farming. On this basis, they have a lot of farming experience. Most of respondents are having experience between 15 years to 25 years, while on average 20 years of experience. Same is the case of all districts. These results are found in the studies of [18, 36, 37]. These results also compared across the districts.

3.2 Climate Change Perceptions

As discussed farmers' short- and long-term climate change perceptions in climate are essential pre-indicators in the process of adaptation [38]. Hence, it is asked by respondents how they perceive changes in climate indicators in their region.

Thus, study results (Fig. 2a) indicate that larger number of farmers perceived an increase in temperature for both summer (87.6%) and winter season (40.5%). In perceiving the perception patterns, the percentage of farmers who reported a slight decrease in precipitation in both summer (84.3%) and winter (69.42%) seasons is more than the farmers who perceived significant or no change in both summer and winter season (Fig. 2c).

Farm-level perceptions of the majority of famers about climate indicators in both summer and winter seasons are in accordance with actual trends presented in Figs. 2b and 2d. According to Fig 2b, the mean temperature in winter and summer seasons shows a significant slight increase over the period of 1980-2013, while Fig. 2d indicates a slight decrease in winter and summer precipitation over the same period.

Temperature is one of the most important climatic variables that effect production cycle. At a certain limit of temperature crop production grows. Average maximum temperature and increasing temperature will affect the production [39]. The negative effect on production of crop confirmed that temperature increase will reduce crop yield [40]. Rainfall is another most important factor that affects annual production all over the world. In time or effective rainfall i.e. before sowing and shooting to grain information is greatly beneficial.

Table 1 Socio economic characteristics of households in the study regions.

Characteristics	Study districts				Average
	Attock	Chakwal	Jhelum	Rawalpindi	
Age (years)	46.2	44.7	47.2	48.2	46.6
Household size (numbers)	9.5	10.4	10.0	10.2	10.1
Education (years)	7.8	8.0	8.5	6.1	7.6
Experience of respondent	15.2	20.1	19.3	23.4	19.5
N	30	30	30	30	120

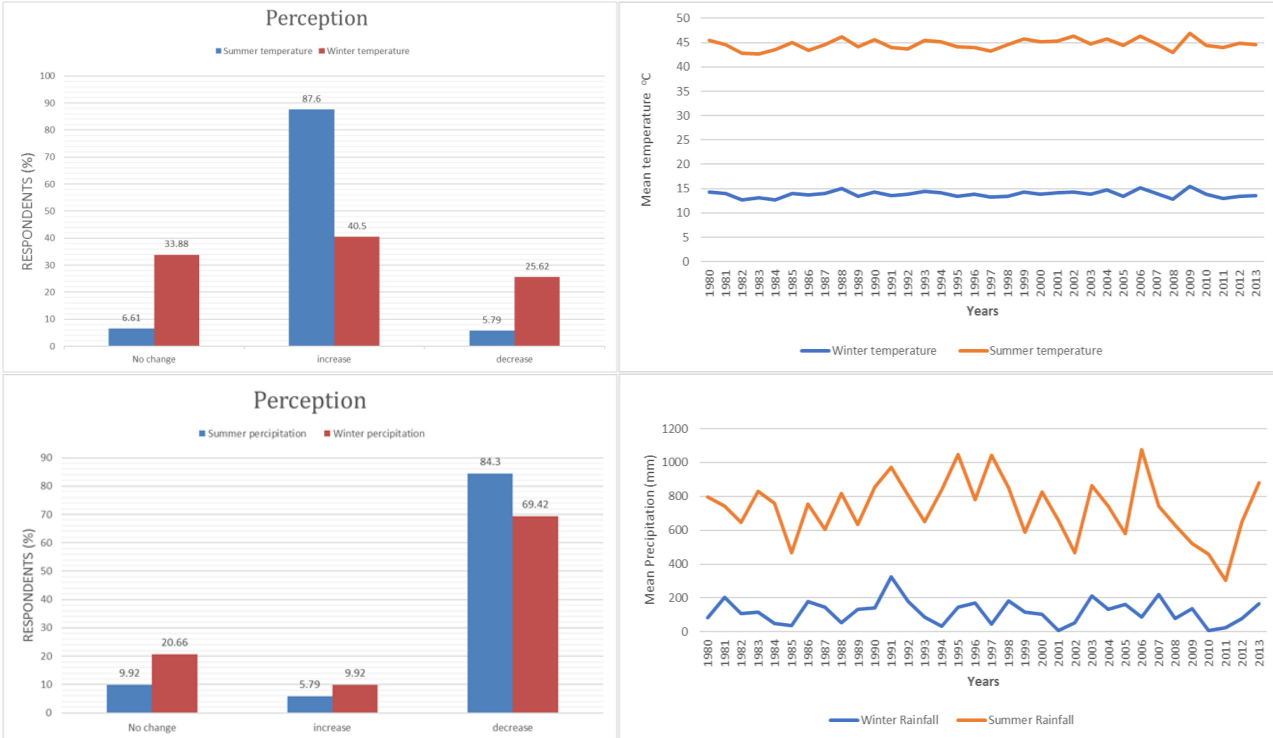

Fig. 2 Farmers' perceptions of changes in seasonal climate vs. observed changes in the study area.

In the same way at the time of maturity negatively Climate change affects crop growth and ultimately reduce the yield of production.

3.3 Climate-Related Risk Perceptions

Farmer's recognition of different risks disclosed the importance of climate-related condition at their farm level process. The distribution of different climate-related risks across study districts is summarized in Fig. 3. In Potohar region of Punjab the six most important climate-related risks identified by farmers were changes in crop production, changes in water availability, human diseases, crop pests and diseases, household income and cost of living.

Farmers reported that changes in crop production were mainly negative. The rainfall in Potohar region of Punjab shows more doubt and follows a decreasing pattern over the period of 1980-2013, which ultimately disturbs the current crop production and creates water shortage especially in the regions where poor farmers are totally dependent on rainfall. Many farmers totally depend on agriculture income in Potohar region of Punjab. Changes in climate condition year by year production show decline in trend due to extreme temperature and heavy rainfall in arid region presenting that increasing temperature will affect crop productivity negatively [41]. Thus, that reduction in production ultimately affects farmer household's income and cost of living. The farmers reported huge increase for water requirements (61%) showing the huge changes in water requirements for crops production. One of the important resources in Pakistan at farm level is water. According to World Bank and ADB (Asian Development Bank), Pakistan has been listed as water strained country due to the expected acute water shortage over the next five years and is placed in the red zone [42]. Continuously decreasing both rainfall and ground water availability put agriculture and livelihood of rural and urban population at risk. Concerns over human diseases, crop and pests' diseases are also important to consider as they directly or indirectly (negatively) affect the productivity of agriculture commodity, and also negatively affect household income and cost of living.

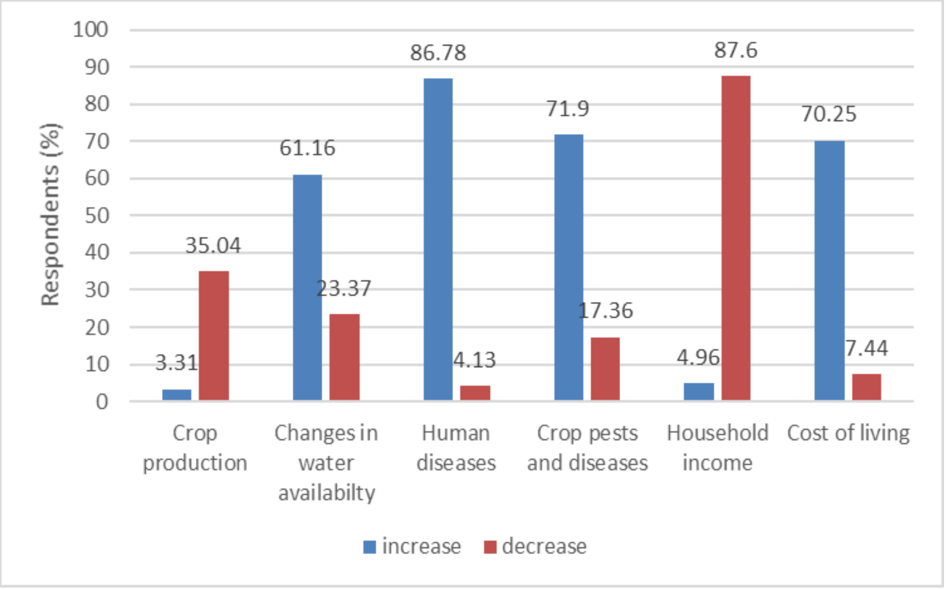

Fig. 3 Perceived climate-related events during last 10 years.

These finding results from previous work carried out in different regions of Pakistan particularly in Punjab, which identified an increase in the extent and occurrence of climate-related events. For instance, Sheikh and Manzoor [43], Zahid and Rasul [44] also observed most pronounced changes in the mean temperature over the period of 1951-2000 and the frequency of extreme maximum temperatures over the period of 1965-2009 in central and southern Punjab respectively. Various other studies [45, 46] reported an increase in the frequency of human diseases, crop and pests diseases in Pakistan due to excessive rains and floods. Further, studies show that increasing incidents of extreme minimum or maximum temperature in Punjab have affected the soil fertility by increasing water stress and changing maturity and harvest dates [47].

3.4 Adaptation Strategies to Climate Change

We here divided various adaptation options into four major categories: (1) Changing cropping practices which include the choice of new varieties, changing crop type, changing planting dates; (2) Changing farm management practices, i.e. changing input such as fertilizer/pesticides, changing irrigation practices; (3) Advanced land management measures i.e. soil conservation, tree plantation; (4) Changing livelihood options which include crop diversification, migration from rural to urban areas, income diversification, and changed job.

When cropping practices are changed, which were employed by farm households at level of farm, cropping practices could be short term as well as long term depending on the nature of problem and risk. Particularly a changing crop variety was pursued by farmers in the reaction to more crop pest attack on old, affecting the growth of old varieties. For example, farmers in Potohar region of Punjab reported wheat and peanut crop in response to an increase in the frequency of harsh maximum temperature. Changing crop type was garnered by farmers against happenings of heavy pest attack, soil problem and extreme temperature conditions. For instance, in Chakwal, a reasonable number of farmers reported that they have not grown peanut since 2012 due to its exposure to heavy pest and changing weather condition. The majority of adapters use weather forecasting information from different sources to adjust management options, particularly the wheat planting dates.

For instance, farmers in Barani (rain-fed) region used this techniques more often due to their higher dependence on rainfall for wheat sowing. The measure of planting dates was adopted by farm poor households in response to variability in daily weather condition. In finding of study around 82% of respondents adopted changing crop type and changing planting dates as shows in Fig. 4. These results also found in the study [48, 49] reported an increasing water shortage in rain-fed region due to ongoing climate change.

At the farm level, different farm management practices include changing fertilizer and pesticides, as well as irrigation and changing farming techniques. For a moment, in case of droughts or harsh maximum temperature, farmers established crops to use more irrigation for their crops especially at sowing stage. In case of more crop insects, due to heavy rainfall in the monsoon season, farm poor households reported an increase in use of pesticides in to order to protect their crops from pests. Similarly farmers also reported soil problem. For instance, farmers observed significant reduction in crop productivity due to loss of fertilizers by heavy rainfall in the moon soon and slightly decrease rainfall in winter since 2012. In response, they used fertilizer to protect the crops. They increased irrigation (62%) adaptation measures mainly used in Potohar region of Punjab who reported a decrease in overall rainfall last decades. Mostly famers they do not have enough knowledge on changing fertilizer so only 24% of the study respondents change fertilizer as shown in Fig. 4.

Advanced land management measures were also adopted at farm level in order to protect livelihoods against different climate-related risk as shown in Fig. 4. Farmers who reported an increase in the frequency of extreme temperature and concerns about the soil fertility used soil conservation and tree plantation methods in order to protect and maintain their land fertility and crop productivity.

For instance, farmers in Potohar region of Punjab reported as soil conservation (51%), higher use of organic matter as soil conservation techniques in order to preserve soil quality which has reduced due to heavy runoff of the fertile layer by heavy rainfall since 2012. Tree plantation (41%) was also used as another adaptation by farmers in Potohar region of Punjab in order to protect crops from increased temperature.

Changed livelihood options were mainly adopted at household level against great loss due to climate-related risk, for instance, poor farm household income

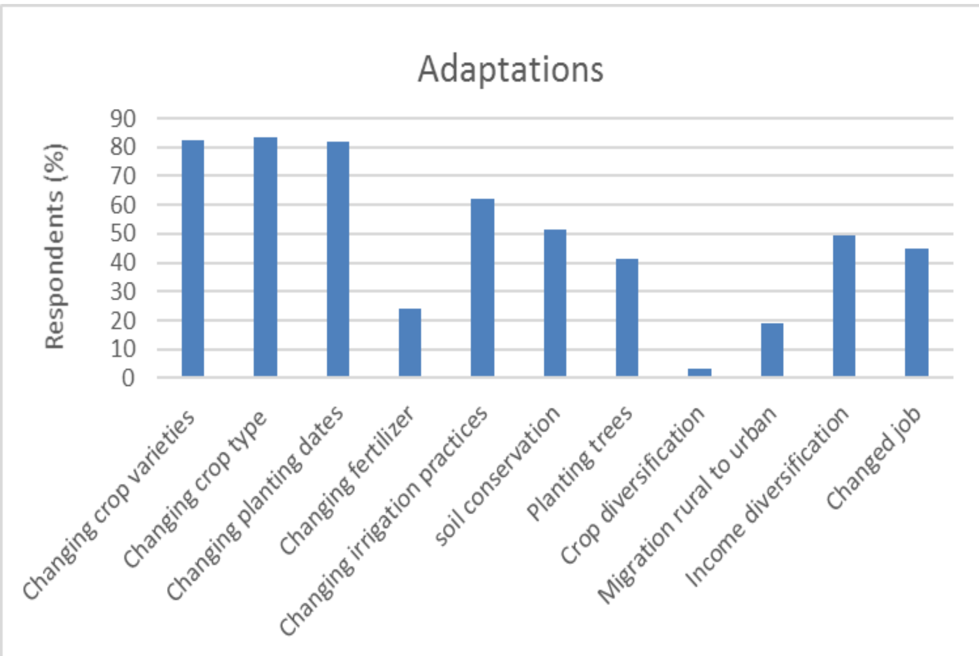

Fig. 4 Adaptation measures adopted by farm households in Potohar region of Punjab, Pakistan.

diversification (50%) as an adaptation strategy in response to loss in agriculture income due to drought like conditions attributed to less rainfall. Similarly, only 3% poor households adopt a crop diversification adaptation strategy.

Last but not least farm households' important adaptation strategy was adopted when they did not meet the minimum expenditure. One is the partial migration from rural to urban areas (19%) and second is the changed job strategy (45%) in response to loss in agriculture income due to changing climate conditions.

3.5 Determinants of Adaptation to Climate Change

To quantify the impact of various independent factors affecting poor farmer's adaptation factors, we used logistic regression models. Model is good fit according to performed tests. For instance, the Pseudo R^2 value (0.26) shows that 26% variation in the model is explained through explanatory variables used in the model. Similarly, the value of Pearson Chi square test statistic (101.80) and Lemeshow test statistic (5.99) shows model significance in determining the factors influencing adaptation to climate change. Further, Likelihood ratio (43.13), another reliable measure of goodness of fit in case of logistic regression, is highly significant at probability value less than zero, which implies that at least one of the coefficients of an independent variable is non-zero and overall model is good fitted. Furthermore, specificity for logistic distribution is 81.25% and sensitivity is 71.43%. High value of both estimates is preferable and gives correct prediction about events and non-events [50]. These two measures collectively give the value of Return on capital (ROC) (0.818) that shows that logistic model is excellent and rising ROC curve also indicates good predictive accuracy of the logistic regression.

Table 2 describes the results of logistic regression, where the logistic coefficient describes the direction of effect of explanatory variable on the dependent variable, while the marginal effects actually describe the quantifiable impact of a unit change in independent variable on the dependent adaptation variable.

Education is assumed to be an important factor in increasing advanced information and increased agriculture productivity [51, 52]. Variable of education is a positive and significant coefficient which implies a positive relationship between education and adaptation decision making. For instance, increase of one year of schooling may lead to 3.1% increase in adaptation to climate change; a positive relationship between farmer's education and adaptation to climate change is also found [13, 15, 53].

Experience has a positive and significant coefficient which shows that increase in experience may enhance adaptation to climate change. Particularly, one unit increase in years of experience may increase the probability of adapting to climate change by 1.3%. Another study also found a positive relationship between farming experience and adaptation to climate change [53, 54].

A positive coefficient of household size indicates a positive relationship among household size and probability of adaptation to climate change. Mainly, one unit increase in household size may increase the probability of adapting to climate change by 2.0%. Similar positive association of adaptation to climate change with household size was reported by [14, 55].

Temperature is also assumed to be one important factor for enhancing the crop productivity level but extreme temperature reduces the crop productivity level. Variable of temperature is a positive but significant coefficient which implies a positive relationship between temperature and adaptation decision making. For instance, increase of one unit in temperature may lead to 40.7% increase in adaptation to climate change.

Rainfall is one of the major factors contributing to the sustainability of the crop production in rain-fed regions where crop growth is mainly dependent on rainfall distribution [56]. Particularly one unit increase in rainfall may increase the probability of adaptation to climate change by 32.5%.

The result of logistic regression shows positive associations between production impact and adaptation to climate change thought the coefficients are significant. One unit increase in production impact may increase the probability of adaptation to climate change by 40%.

Access to financial constraints has a highly significant effect on the adaptation to climate change but shows on adverse impact between financial constraints and adaptation to climate change. The one unit increase in financial constraints may decrease the probability adaptation to climate change by 42.5%.

Information constraints on seasonal and daily weather forecasting (temperature and rainfall) have a negative and insignificant effect on the probability of adaptation to climate change alike. One unit increase in information constraints may decrease the probability adaptation to climate change by 24.3%.

3.6 Constraints to Adaptation

Under the purview of qualitative field research and literature review, the study identified four major constraints to adaptation and adaptive capacity in the study areas which may exist in the other region of Pakistan with similar social and geographical conditions as shown in Fig. 5, which includes: (1) limited institutional support and access, (2) lack of financial resources, (3) lack of physical resources, (4) lack of information.

Here, limited institutional support and access implies that absence of proper support and access is from local institution such as public agriculture department and local private input providers and NGOs (non-government organization). Farm households in all four districts reported that they do not have proper public institutional support and access such as information on water delivers, farm advisory and market price. According to finding of study 94% of respondents reported that they have limited institutional support and access in the field. These results are also in line with the findings of other studies [57, 58] conducted at different levels in Punjab and Pakistan.

Lack of financial resources (89%) was identified by responding of farmers as on other key constraint for adaptation, even if they plan to adapt to climate variability. Use of farm credit in the study sites limited,

Table 2 Determinants of adaptation to climate change: maximum likelihood estimates.

Covariate	Coefficient	Marginal effects	Standard error	*Z*-value	*p*-value
Constant	-5.518		0.007	-2.78	0.000
Education	0.126	0.031	0.051	2.77	0.006
Experience	0.0529	0.013	0.029	1.91	0.056
Household size	0.0845	0.020	0.070	1.30	0.194
Temperature	2.353	0.407	14.027	1.76	0.001
Rain	1.409	0.325	2.261	2.55	0.004
Production impact	2.245	0.400	11.549	1.84	0.001
Financial constraints	-1.919	-0.425	0.104	-2.69	0.000
Information constraints	-0.992	-0.243	0.205	-1.79	0.062
Pseudo R^2			0.2601		
Likelihood ratio			43.13 (0.0000)		
Pearson goodness of fit test			19.75 (0.9006)		
Hosmer-Lemeshow goodness of fit test			5.99 (0.6488)		
Sensitivity value			71.43%		
Specificity value			81.25%		
Correctly specified			76%		
Area under ROC curve			0.8185		

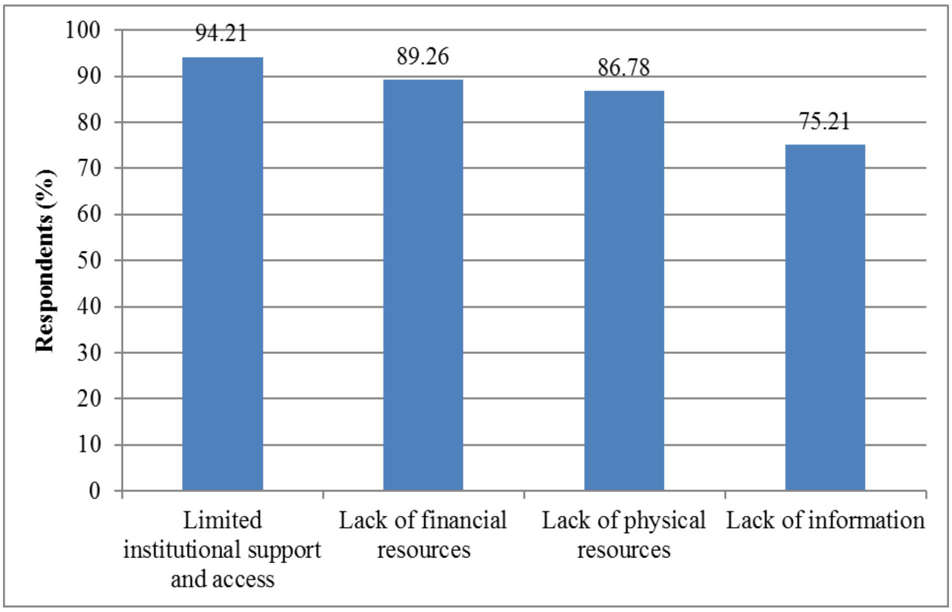

Fig. 5 Constraints of adaptation to climate change.

access to microcredit facilities available at the town level. High credit interest rate is one of the reasons for minimal attraction of farmers to credit institutions. Less access to financial resources or availability of financial resources at farm level constraints the capability to adapt to climate change [59]. Hence, proper monitoring with improved credit facilities provides low interest rate to poor farmers.

Lack of physical resources (87%) may include farm inputs (improved seed, fertilizer), farm implements (tools for soil conservation, cultivators, harvesters, etc.) and institution sources (water and soil testing laboratories). These mentioned resources are physical resources a poor farmer was constraint to adopt.

Further, we asked about lack of information (75%) deals, either from private and public sources to the farmer, about how to reinvigorate agriculture in the case of extreme weather events, including high rainfall, water stress at sowing stage, harshly high and low temperature indicators of climate change. Farmers showed their willingness to adopt particular adaptation measures but did not manage to adopt due to improper information either about the adaptation method and usefulness of certain adaptation for their crop.

4. Conclusion

The research on climate change impacts, vulnerabilities, and adaptation aspects is still limited in developing countries, compared to abundant research in developed countries. However, such assessments are crucial for the countries such as Pakistan where livelihood and economic development rely heavily on the climate sensitive agriculture sector. Researching the social dimensions of climate change in local contexts is useful to understand the current level of vulnerabilities and adaptive capacity in agricultural communities and to find possible adaptation options. The adverse impact of climate change on rural livelihood and agriculture in developing countries such as Pakistan, adaptation of the current farming and livelihood systems is a mean to lessen damages. However, effective adaptation requires sufficient information on risks and vulnerabilities and current adaptation capacities. This information should be used to design appropriate adaptation policies and build additional local adaptive capacity if necessary.

Small farmers have reported different types of climatic risk such as extreme temperature and heavy rainfall events, human diseases, crop pest and soil problem to their farming and livelihoods. Farmers take thought uncertainty and changes in crop and changes in cropping calendars and water shortage due to observed climate change-related risk. Additionally, the study's findings vary between regions based on how vulnerable they are to the effects of climate change. For instance, uncertainty in crop yield, changing cropping calendars and also changing crop varieties are reported in the rain-fed region (Potohar region of Punjab) where farming is more sensitive to climate change. Challenges of decreasing water availability at initial stage and weakness of local institutions in the process of adaptation make poor farm households more susceptible to climate-related risks. The quality of irrigation water is found declining in most of the regions while poverty is found higher in the rain-fed region. Poor farmers adopted various measures to adapt their farming to climate change such as changing cropping practices, changing farm management options and advanced land management measures. Moreover, using logistic regression analysis the role of different poor household in choice of adaptation measure can be limited due to lack of information, lack of financial resources, lack of physical resources and limited institutional support and access.

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