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ADAPTATION PROCESS TO CLIMATE CHANGE IN AGRICULTURE- AN EMPIRICAL STUDY

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Abstract

Climatic variations affect agriculture in a process with no known end means. Adaptations help to reduce the adverse impacts of climate change. Unfortunately, adaptation has never been considered as a process. Current study empirically identified the adaptation process and its different stages. Moreover, little is known about the farm level adaptation strategies and their determinants. The study in hand found farm level adaptation strategies and determinants of these strategies. The study identified three stages of adaptation i.e. perception, intention and adaptation. It was found that 71.4% farmers perceived about climate change, 58.5% intended to adapt while 40.2% actually adapted. The study further explored that farmers do adaptations through changing crop variety (56.3%), changing planting dates (44.6%), tree plantation (37.5%), increase/conserve irrigation (39.3%) and crop diversification (49.2%). The adaptation strategies used by farmers were autonomous and mostly determined perception to climate change. It was also noted that the adaptation strategies move in a circular process and once they are adapted they remained adapted for a longer period of time. Some constraints slow the adaptation process so; we recommend farmers should be given price incentives to speed-up this process.

Keywords: *Adaptation Strategies; Climate Change; Determinants; Perception*
JEL Codes: *O13 Q12 Q15 Q16*

1. Introduction

Climate change (CC) has brought about possibly permanent alterations to our planet's ecological, biological and geological systems and impacted all economic sectors. Of all the impacts, effects of CC on agriculture are more severe. Farmers face challenges of tragic crop failures, reduced agricultural productivity, physical damages and diseases due to CC. For instance, studies found that the aggregate impact of climatic parameters affect agriculture in three ways (GOP, 2016; Raza and Ahmad, 2015 and Zaffar and Khan, 2015). First, the impact of CC varies from region to region. Second, it varies from crop to crop either positively or negatively. Third, these variations have overall negative impact on cereal crops. Hence, CC is worsening the situation which calls for farm level adaptation. Delay in adaption action can cause adaptation deficit as per IPCC and farmers face increase cost due increase risk and vulnerability (IPCC, 2012)

There are two principal ways to reduce the adverse impacts of CC: mitigation and adaptation. Mitigation efforts to reduce sources or enhance the sinks of greenhouse gases will take time. Adaptation is therefore critical and of concern in developing countries where vulnerability is high because of the low ability to adapt (IISD, 2012 and IPCC, 2012). For example, Pakistan is facing the brunt of CC at a high cost to its economy despite being a low Green House Gas (GHG) emitter (<1% of global per capita emissions) (GOP, 2016). This situation requires concerted efforts to adapt to the adverse impacts of CC and relatively fewer efforts to carry out mitigation measures.

For successful adaptation, perception about CC is necessary. Studies revealed that the probability of adaptation increases with perception. That is why researchers were on the opinion that in the process of adaptation in agriculture perceiving climatic adversary is the first step (Abid et al., 2015 and Deressa et al., 2011). It is also important to have detailed knowledge about the extent and type of adaptation measures being carried by farmers and need for further advances in existing adaptation setups. Hence, understanding how farmers perceive changes in climate, how they get information on vulnerabilities and risk and what factors shape their adaptive behavior are useful for adaptation research. Unfortunately, in developing countries like Pakistan farmers are not well aware of CCs and still practicing traditional agriculture. Farmers' long term perception about CC and hence adaptation not only depends on actual climate vagaries happened but there are other socio economic, geographical and environmental factors (Gbetibouo, 2009). However, it is important to engage stakeholders with different backgrounds, experience and knowledge in reaching and tackling a shared approach to addressing the challenges in framing an adaptation approach (Tompkins and Eakin, 2012 and Weber, 2006).

The farmers' choice of adaptation measures depends on different economic, social and environmental factors (Bryan et al., 2013 and Deressa et al., 2007). This knowledge ultimately enhances the credibility of policies and their strength to handle the serious issues being foisted by CCs on farmers (Deressa et al., 2009). Adaptation requires the involvement of multiple players from various sectors such as farmers and local communities, those in the private welfare organizations and agricultural extension services, as well as research and policy (Bryan et al., 2013).

Many studies are conducted on adaptation at farm-level across various disciplines in different regions and explored farmers' adaptive behavior and its factors. Little research work is carried out in Asian countries despite internationally extensive research on adaptation to CC in the agriculture. Similarly, in Pakistan, the scope of research linking CC to agriculture is very restricted and under researched. To date, studies on agriculture and CC in Pakistan have been entirely limited to potential effects of CC on particular sectors or crops. None of the studies examined farmers' perspectives of adaptation to CC for major crops of Pakistan. Hence, this study is designed to fill the existing research gap in Pakistan with respect to adaptation to CC in the major crops. Furthermore, there are a few studies on the nature and dynamics of farm-level coping and adaptation processes and how they influence responses. Moreover, climatic variations affect agricultural system through a process which has no known ends means (Ensor, 2009). Hence, adaptation to CC should also be taken as a process to reduce the harmful effects of these vagaries. But unfortunately adaptation to CC has not considered a proper process. This study designated to fill this gap by empirically testing the adaptation process and its various stages and their factors.

2. Adaptation Process

Literature has found that perception is the preliminary step for the adaptation to climate change (Abid et al., 2015; Idrisa et al., 2012; Mtambanengwe et al., 2012; Mandleni and Anim 2011; Aydogdu and Yenigün 2016; Fosu-Mensah et al., 2012 and Mudombi et al., 2014). In Mexico, Sánchez-Cortés and Lazos-Chavero (2013) examined that the indigenous Zoque people changed their agricultural practices due to their perceptions on changes in climate variations linked to annual weather pattern and agriculture as a result of their collective and individual cultural experience. At individual and community level, researchers noted that the traditional knowledge has a critical and important role to play in the understanding of climate change in Oceania (Leonard et al., 2013 and West et al., 2008). Although it is considered as accumulated knowledge and has significant role for adaptation to climate change. Pandey and Bardsley (2013) stated that agreement exists between climate perception and climatological knowledge by a population and between traditional and scientific knowledge. In Costa Rica, Smith and Oelbermann (2010) found that community members observed changes in local weather conditions that happened ten years before in addition to changes in distribution patterns of wildlife and vegetation. The authors concluded that respondents of the study area had a good understanding of climate change and its likely effects on crop production. In Australia it was found that changes in adaptive response and skepticism level in farming community depend on the terms used to describe climate change from political and scientific discourse (Raymond and Spoehr, 2013).

The manner of perceiving the world (worldwide) and personal values are the important factors related to adaptive behaviour to climate change (Wolf et al., 2013; Rogers et al., 2012 and Kuruppu, 2009). Brondizio and Moran (2008) studied the relationship between climate change perception and memory. After three years of severe drought in Brazil, only 40% of the producers interviewed remembered it, thus, highlighting the need to consider how climate information is generated and distributed at the local level, especially with regard to agricultural producers.

Ndambiri et al. (2012) applied induced theory of adaptation to climate change. Its central concept is that the central role of climate as a motivator of the farmers to innovate and ultimately adapt to climate where climate as the motivator can be called as action against the climate change. This gave rise the action theory and applied by Mandleni and Anim (2011) who found that farmers react to climate change through adaptation by perceiving about climate change. Further this was applied by Maddison (2007) and Nhemachena and Hassan (2007) and noted that farmers act against climatic variation through getting information on climate change. They were on the opinion that farmers first perceive of climatic vagaries and their negative effect on crops and then the farmers go to adaptation to climate change if there were no financial constraints. Moreover, Abid et al. (2015) used the same theory for adaptation to climate change in agriculture in Pakistan in addition to intention to adapt to climate change. They found that farmers first perceive and get the awareness about climate change, then intended to climate change and if there were no constraint ultimately farmers adapt to climate change.

The choice of adaptation methods by farmers depends on various social, economic and environmental and institutional factors (Bryan et al., 2013 and Deressa, 2007). This knowledge will ultimately enhance the credibility of policies and their strength to tackle the challenges imposed by climate change on farmers (Deressa et al., 2009). Adaptation will require the participation of multiple players from sectors such as research and policy, those in the agricultural extension services and private welfare organizations, as well as local communities and farmers themselves (Bryan et al., 2013). The study found the factors affecting adaptation to climate change. Among all the factors in facilitating adaptation measures, institutional factors are crucial in determining adaptation (Tol et al., 2003; Bakker et al., 1999 and Adger, 2000). They further point out that institutions are the determining factors to manage climate-sensitive aspects of society and the capacity to adapt successful.
From the literature given above it can be concluded that adaptation fellows three steps such as perception to climate change, intention to adapt and actual adaptation as seen in Figure 1. These three level adaptation further empirical tested in this study.

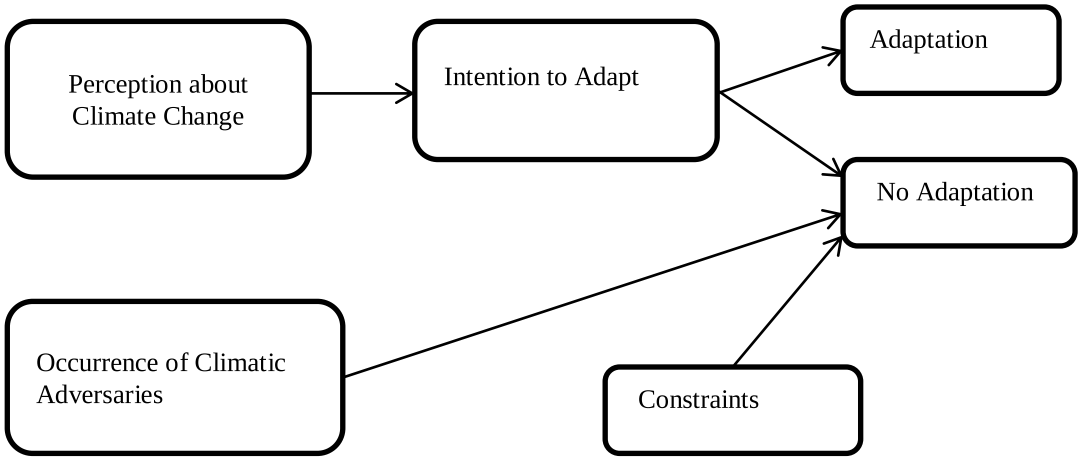


Figure 1. Adaptation Process

3. Materials and Methods

3.1. Data Collection and Sampling Technique

The study used multi stage purposively random sampling technique. At first stage, province Punjab is selected. At second stage, study purposively selected two zones of Punjab (central Punjab- semi-arid zone and Southern Punjab-arid zone). The reason of selected these two zones is that these areas are highly vulnerable to CCs. The crop simulations model suggested that yields of major crop would substantially decline in 2020s, 2050s and 2080s due to climatic variations in above mentioned areas (GOP, 2016). At third stage, four Tehsils (Sub Part of District) randomly selected (two Tehsils from each zone randomly). At fourth stage, four Union Councils (Sub-part of Tehsils) were selected randomly from each district. At fifth stage, two villages were randomly selected from each Union Council randomly. At sixth and last stage, 7 farmers were randomly interviewed. Total sample size, thus, became 224 farmers as shown in Table 1.

Table 1. Distribution of the Sample Size

Zone	Total Tehsils	Tehsils	Total Union Councils	Selected Union councils	Selected Villages	Farmers	Total
Central Zone	11	Faisalabad	52	4	2	7	56
		Sheikhupura	51	4	2	7	56
Cotton Zone	4	Shujjabad	12	4	2	7	56
		Multan	83	4	2	7	56
Total							224

Source: (Compiled by author based on Tehsils Councils Data and Malik, 2017)

3.2. Empirical model

For methodological point of view, previous studies used the Multinomial Logit Model (MNLM) that assumes the interconnectedness of adaptation strategies (Deressa et al., 2009 and Hassan and Nhemachena, 2008). However, decision of one adaptation strategy is independent of other strategy. For instance, increase/conserve irrigation water is independent of change crop variety. Therefore, Binary logit model can be best model to evaluate the determinants of adaptation.

The dependent variable is the discrete variable where farmers were asked that do you perceive about climate changes, intended and actually adapted to those changes (three stages adaptation process). In this study, a binary logistic model is used to determine the factors affecting three stages. This method is popularly used in different attitude social surveys (Abid et al., 2015; Hasan and Akhter, 2011 and Christie and Jarvis, 2001). The equation can be written as:

$$L_i = \frac{P_i}{1-P_i} = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \cdots + \beta_{12} X_{12} + \varepsilon_i \quad (1)$$

Where Li are the here stages (perception, intention and adaptation) and βs the vector of binary regression coefficients and $\varepsilon_i \cong N(0, \sigma^2)$ is the error term which is homoscedastic and normally distributed such as zero mean and constant variance and Xs are the independent variables (Schmidheiny, 2013).

The estimated parameters (β_k) of the binary logistic model only give the direction of the effect of the independent variables on the binary dependent variable and statistical significance associated with the effect of increasing an independent variable just like ordinary least square (OLS) coefficients (Peng et al., 2002). Hence, the positive coefficients β_k show that the independent variables X_k increase the likelihood that $Y_{ij} = 1$. But these coefficients cannot explain how much the probability of household i about getting climatic information ($Y_{ij} = 1$) will change when there is change of X_k, i.e., the coefficient (β_k) does not show the magnitude of the effect of a change in explanatory variable X_k on $\Pr(Y_{ij} = 1)$. Thus, to interpret and quantify the results, there is need to calculate marginal effect. Marginal effect (Y'_{ij}) describes the effect of a margin change in the independent variable on the probability of a dependent variable, i.e., $\Pr(Y_{i\,j} = 1)$. The final equation of the marginal effect ($Y'_{i\,j}$) after derivation becomes;

$$Y'_{i\,j} = Pr(Y_{i\,j} = 1)\,(1 - Pr(Y_{i\,j} = 1))\beta_k \tag{2}$$

For first and second stage only directions are found using logistic model while for third stage logistic regression in addition to marginal effects is also calculated to quantify the adaptation strategies in relation to independent variables.

4 Results and Discussion

4.1 Determinants of Three Stages (Perception, Intention and Adaptation)

Before explaining the determinants of three stages, the study first found the goodness of fit-GOF-models. For this purpose, R^2 measures for binary logit model, which is one approach to assessing model GOF. It can predict the dependent variables (adaptation strategies) based on independent variables (Table 2) and hence R^2 is a measure of predictive power. That may be an important concern, but it does not really address the question of whether the model is consistent with the data. By contrast, GOF tests help you to decide whether your model is correctly specified. They produce a p-value—if it's low (say, below .05), you reject the model. If it is high, then your model passes the test. In all cases GOF tests in Table 2 pass the models and showed that models are good fitted for factors of three stages of adaptation.

Additionally, LR chi squares and their probabilities values are highly significant at 1% level of significant and reject the null hypothesis of "no goodness of fit model". Pseudo R^2 also reasonably high and shows that adaptations are explained reasonably due to independent variables that enters into the model. The current study also found that models correctedness based on classification tables as shown in the Table 2. Therefore, we can explain binary logistic models' coefficient of determinants for three stages as shown in Table 3.

Table 2. Goodness of Fit Models

	Perception	Intention	CV	Pdate	Tree	Irri	Diversify
LR Chi2	137.51	119.92	114.78	111.50	141.34	82.52	131.26
Prob>Chi2	0.00	0.00	0.00	0.00	0.00	0.00	0.00
DF	13	13	13	13	13	13	13
Log Likelihood	-65.26	-91.35	-96.12	-98.23	-77.52	-109.25	-89.60
Pseudo R2	0.5130	0.3963	0.3739	0.3621	0.4769	0.2741	0.4228
Corrected	89.7%	79.9%	77.7%	77.7%	86.6%	75.9%	83.5%

Note: CV=Change Crop Variety; Pdate=Change Planting Dates; Tree=Tree Plantation; Irri=Increase/Conserve Irrigation Water and Deverify=Diversification of Crop

Education

Education is considered as a global determinant for perception about CC and hence, intention and adaptation. It has significant and positive impact for all three stages of adaptation except one strategy-diversification. Positive coefficient values can be seen in Tables 3 that indicate the direction of education in relation to perception, intention and adaptation. This can be observed from marginal effects given in the Table 4 that due to the unit change in education the probability changing crop variety by increase 4.9% while keeping the influence of other variables same. Similarly, marginal effects for change planting dates, tree plantation, increase/conserve irrigation water and diversification depicted that probabilities increase by 2.7%, 4.5%, 2.4% and 1.4%, respectively. The results for three adaptation stages are in line with past studies (Hassan and Nhemachena, 2008; Deressa et al., 2008; Ajuang, 2016; Maddison, 2006; Bryan et al., 2011; Gunamantha et al., 2016; Olarinde et al., 2016).

Experience

Experience has significant effect on first stage-perception, insignificant but positive impact on second stage-intention and significant effects on majority of adaptation strategies. Through learning and experiencing from the past vagaries farmers observe CC and hence adapt against these variations. For instance, marginal effects calculations in Table 4 show that one percent increase in the years of experience increases the probability of choosing new crops variety (0.7%), plant shaded trees (0.9%) and increase/conserve irrigation water (0.6%) as adaptation options. These results are supported by previous studies (Abid et al., 2015; Gunamantha et al., 2016; Olarinde et al., 2016).

Family Size

Family size shows that the probability of adaptation to CC increases with increases household size. This illustration is also true for perception and intension stages although insignificant whereas it has significant and positive impact for all adaptation strategies (third stage) except increase/conserve irrigation water that is insignificant. For instance, household size influences the adaptation measures by availability of more members for working on farms. This can be seen from Table 3 where increasing household is associated positively with adoption measures. Whereas the marginal effects show that increase in the household size is associated by 4.4% increase in the probability of change crop variety, 3.2% increase in the probability of change planting dates, 4.3% increase in the probability of plant shaded trees and 3.9% probability of diversification while keeping the effects other variable controlled in each case. These results are supported by Olarinde et al. (2016) who found that family size is positively associated with numbers of adaptation strategies. However, results also contradict to the previous studies (Hassan R and Nhemachena, 2008; Bryan et al., 2011 and Uddin et al., 2014).

Table 3. Coefficients of Determinants of Adaptation Strategies to Climate Change

Factors	Perception	Intention	Crop Variety	Planting Dates	Tree	Irrigation	Diversify
Education (years)	0.138 (0.058) *	0.179 (0.051) *	0.209 (0.047)*	0.113 (0.043)*	0.223 (0.055)*	0.105 (0.043)*	0.057 (0.049)
Experience (Years)	0.030 (0.018) ***	0.014 (0.015)	0.028 (0.016)***	0.022 (0.016)	0.046 (0.019)*	0.026 (0.015)***	-0.015 (0.017)
Family size (Numbers)	0.075 (0.081)	0.037 (0.051)	0.189 (0.077)*	0.133 (0.070) **	0.211 (0.079)*	0.053 (0.063)	0.157 (0.076)**
Landholding (Acres)	0.018 (0.046)	-0.027 (0.025)	0.061 (0.056)	0.139 (0.056)*	0.151 (0.062)*	0.091 (0.050)***	0.047 (0.057)
Farmer to farmer extension	0.364 (0.840)	0.973 (0.566) ***	0.800 (0.557)	0.842 (0.531)***	0.871 (0.574)***	1.012 (0.516)**	-2.031 (0.665)*
Animal Holding (1=owned, 0=otherwise)	0.990 (0.611) ***	0.776 (0.475) ***	0.168 (0.496)	-0.431 (0.479)	-0.347 (0.540)	-0.801 (0.465)***	1.595 (0.559)*
Tube-well ownership (1=owned, 0=otherwise)	-1.522* (0.620)	-2.253 (0.547) *	-0.569 (0.493)	-0.506 (0.487)	0.475 (0.557)	0.953 (0.456)**	-0.840 (0.517)***
Member organization (1=member, 0=otherwise)	1.093 (0.592) ***	0.848 (0.441) **	0.764 (0.407)***	0.668 (0.410)***	-0.369 (0.485)	0.001 (0.399)	0.098 (0.483)
Agri credit (1=access, 0=otherwise)	-0.524 (0.625)	0.430 (0.469)	0.938 (0.443)**	-0.762 (0.455)***	-0.669 (0.530)	0.599 (0.400)	0.181 (0.517)
Access on marketing of produce (1=access, 0=otherwise)	-0.544 (0.768)	0.103 (0.530)	0.826 (0.515)***	0.924 (0.462)**	1.386 (0.500)*	0.579 (0.443)	0.457 (0.489)
Access on extension (1=access, 0=otherwise)	1.066 (0.484) **	1.228 (0.414) *	-0.657 (0.470)	0.866 (0.465)***	-0.012 (0.550)	0.326 (0.423)	0.128 (0.494)
Zone (1=Arid Zone, 0=otherwise	3.805 (1.099) *	0.320 (0.593)	-0.106 (0.595)	0.308 (0.548)	1.256 (0.584)**	0.164 (0.494)	2.844 (0.558)*
Income (crop income per acre per season)	0.0002 (0.000) *	0.001 (0.000) *	-	-	-	-	-
Perception	-	-	0.858 (0.503)***	1.090 (0.566)**	1.090 (0.689)***	-0.287 (0.503)	0.105 (0.573)
Constant	-11.269 (2.190) *	-4.666 (1.096) *	-5.113 (1.007)*	-5.525 (0.981)*	-8.292 (1.285)*	-4.176 (0.833)*	-2.766 (0.871)*

Note: * significant at 1%, ** significant at 5% and *** significant at 10%, respectively.

Land Holdings

For whole adaptation process the sign of farm size is positive according to priori expectations (Table 3) and can be interpret as adaptation to CC increase with increase agricultural land size. However, it has significant effect on majority of adaptation strategies. For instance, current study found that the probability of adopting planting dates (3.3%), plant shaded trees (3.0%) and increase/conserve irrigation water (2.1%) all increases as farm size increases as evident from the marginal effects into the brackets. Farm size is frequently used in the literature and our results can be seen compatible to the past studies (Bryan et al., 2011; Gunamantha et al., 2016; Nabikolo et al., 2012).

Farmer-to-Farmer Extension

Farmer-to-farmer extension (exchange of information and agricultural inputs) has important role to play for adaptation process through share of information. For instance, due to unit change in farm-to-farm cooperation the probabilities of adoption measures such as change planting dates, tree plantation and increase/conserve irrigation water increases by 20.0%, 17.6% and 23.1%, respectively. These results are compatible with Tessema et al. (2013) However, it may negatively influence farmers who performs poorly and doing traditional practices as can be seen in case of diversification (Table 3) although relationship is insignificant. The results can be compensated by Deressa et al. (2011) who found that adaptation strategies negatively and significantly affected by farmer-to-farmer extension.

Perception about Climate Change

Perception on CC has a key role for adaptation. Farmers perceive about climatic variations and hence react to these vagaries through suitable adoption techniques. This study found that perception positively and significantly affect majority of adaptation techniques and even very influential in most of strategies as can be seen from Table 3. Furthermore, results are elaborated by marginal effects and show that due to marginal increases in the perception the probability of choosing new crop variety would increase by 20.1%, change planting dates by 25.9% and plant shaded tress by 22.0%, respectively. Results are in agreement with previous studies for majority of adaptation measures (Deressa et al., 2009; Gunamantha et al., 2016 and Komba and Muchapondwa, 2012). Although diversification is insignificant (Table 4) but negatively related with perception to CC as found by Mandleni and Anim (2011) where they found awareness about CC negatively related to adaptation strategies.

Animal Holdings

Animal holding has two compensations. First, as the farmers own the animals they may grow more crops like fodders to feed their animals. Consequently, farmers’ perception about CC increases due adverse impact on crops that lead to intention and adaptation. This also justified by marginal effect showing that the probability of choosing diversification increases by 39.9% due to increase in the animal holdings as compared to farmers with no animals. Almost similar results are found by Deressa et al. (2009). Secondly, farmers rear animals as full time business while crops are grown as fodder only to feed animals and hence their perception about CC would reduce that would lead to decrease in adaptation. Mandleni and Anim (2011) found almost same results. Moreover, the marginal effect shows that probability of adaptation (increasing/conserve irrigation water) reduces by 18.2% for animal holders as compared to non-holders while keeping the effects of other variables held constant. These results can be justified by previous studies (Nabikolo et al., 2012 and Tessema et al., 2013).

Table 4. Determinants of Adaptation Strategies to Climate Change-Marginal Effects

Factors	Crop Variety	Planting Dates	Tree	Irrigation	Diversify
Education	0.049 (0.011)	0.027 (0.010)	0.045 (0.011)	0.024 (0.010)	0.014 (0.012)
Experience	0.007 (0.004)	0.005 (0.004)	0.009 (0.004)	0.006 (0.003)	-0.004 (0.004)
Family size	0.044 (0.018)	0.032 (0.017)	0.043 (0.016)	0.012 (0.014)	0.039 (0.019)
Landholding	0.014 (0.013)	0.033 (0.013)	0.030 (0.013)	0.021 (0.011)	0.012 (0.014)
Farmer to farmer extension	0.187 (0.130)	0.200 (0.127)	0.176 (0.117)	0.231 (0.118)	-0.508 (0.166)
Perception	0.201 (0.119)	0.259 (0.132)	0.220 (0.133)	-0.065 (0.115)	0.026 (0.143)
Animal Holding	0.039 (0.116)	-0.103 (0.114)	-0.070 (0.109)	-0.182 (0.106)	0.399 (0.140)
Tube-well ownership	-0.133 (0.114)	-0.121 (0.116)	0.096 (0.112)	0.217 (0.103)	-0.210 (0.129)
Member organization	0.179 (0.095)	0.159 (0.098)	-0.075 (0.097)	0.0001 (0.091)	0.025 (0.121)
Agri credit	0.220 (0.103)	-0.181 (0.108)	-0.135 (0.107)	0.137 (0.091)	0.045 (0.129)
Access on marketing of produce	0.193 (0.120)	0.220 (0.111)	0.279 (0.103)	0.132 (0.101)	0.114 (0.122)
Access on extension	-0.154 (0.109)	0.206 (0.109)	-0.002 (0.111)	0.074 (0.096)	0.032 (0.124)
Zone	-0.025 (0.140)	0.073 (0.130)	0.253 (0.121)	0.037 (0.113)	0.711 (0.140)

Tube-Well Holding

Asset such as tube-well ownership has a significant relationship with perception to CC. Tube-well is important part of farming in Pakistan where availability of water can be ensured in case of canal-irrigation water shortage. This may be the reason that farmer avail water during water shortage and less rainfall due to CC and leaving him unaware about climatic vagaries. For instance, as the farmers own tube-well the probability of perception and hence intention to adapt decreases as can be seen in Table 3. Abid et al. (2015) found similar results regarding asset ownership but they found the asset ownership affect insignificantly. Tube-well ownership does negatively affect majority of adaptation strategies such change crop variety, change planting dates and diversification (Table 3) and even can be seen from a previous study (Ndambiri et al., 2012). For instance, marginal effect shows that the probability of diversification decreases by 21% for farmers who own the tube-well as compared to non-holders of it while keeping the effects of other variables held constant. Tube-well sometimes also considered as heavy machinery and Hassan and Nhemachena (2008) found that it is negatively and significantly associated with adaptation strategies.

On the other hand, tube-well ownership can have significant effect on the adaptation to CC through proper and timely availability of water in case of canal irrigation shortage and during less rainfall. This is the case for tree plantation and increase/conserve irrigation water where tube-well ownership has positive and significant relationship with coping strategies

(Table 3). For instance, marginal effect shows that the probabilities of adaptation increase by 21.7% due to having tube-well ownership. Results are compatible with Abid et al. (2015) but they found significant relationship between tube-well ownership and adaptation strategies.

Membership of Farm Organization

According to priori expectation participation in the farmer organizations (FOs) has significant and positive relationship with the perception and intention to adapt. With these kinds of participation farmers' perception can be increased due to discussion with members of organization. Membership of any FO positively affects the coping with climatic variations. This also refers to the social capital in the literature. Through information and innovation farmers' membership helps farmers to adapt as it does contribute in the perception to CC. Majority of adaptation strategies have positive and significant association with the membership of FOs. For instance, marginal effects reveal that due to unit increase in the FOs membership the probabilities of changing crop variety increases by 17.9% while keeping the effect of other variables are held constant. Literature frequently used this factor affecting adaptation and supported current results (Bryan et al., 2011 & Gunamantha et al., 2016).

Access to Agricultural Credit

Access to credit that increases financial resources of farmers and enable farmers to have more access to information sources. This could lead the farmers to be perceived about CC (Abid et al., 2015). However, study found negative and insignificant relationship whereas intention to adapt has positive but insignificant association with availability of credit. Access to agricultural credit in relation to adaptation can be seen from two angles. Firstly, with increasing access to agricultural credit adaptation increases by building financial capacity and well-being of the farmers. Although only change crop variety has significant association with access to agricultural credit (Table 3). For instance, marginal effects elaborate the situations where adopting new crop variety increases by 22.0%% with marginal increase in the access to agricultural credit as evident from past studies (Deressa et al., 2009; Hassan and Nhemachena, 2008; Gunamantha et al., 2016; Nabikolo et al., 2012 and Bryan et al., 2009). Secondly, by having agricultural credit farmers may use it for other non-farm activities and/or household consumption and hence adaptation (change planting dates and tree plantation) decreases by increasing access to credits. However, only change planting dates significantly affected by access to agricultural credit. For instance, the probability of change planting dates decreases by 18.1% with increasing access to credit while citrus paribus assumption is hold in each case (Table 4). The results are justified from previous studies (Ndambiri et al., 2012; Olarinde et al., 2014 and Tessema et al., 2013).

Access to Marketing of Produce

Access to marketing of produce insures the financial availability timely for next production cycle (in this case government purchase the output particularly wheat in Pakistan). This also helps the farmer to adjust timing of crops due to CC through information on growing season length of crops. However, the results are similar as in case of access to agricultural credit both for perception and intention to adapt. The current results are evident from Abid et al. (2015) however, our results found no significant relationship.

Access on marketing of produce positively affects all of the adaptation strategies as can be seen from Table 3 with positive coefficients of adaptation measures. All these strategies show that adaptations increase with increasing access to marketing of produce. It has significant effect on majority of adaptation techniques. For instance, the marginal effects show that due to marginal increase in the access to marketing of produce would increase change crop variety (19.3%), change planting dates (22.0%) and tree plantation (27.9%). These can also be justified as by having access on marketing of produce where farmers can sell their produce to government and can get support price timely. This ultimately would be helpful for next production period through adaptation strategies.

Access to Extension Services

Perception about CC has strong relationship with access to agricultural extension services and evident from vast literature (Deressa et al., 2011; Mandleni B and Anim., 2011 and Mudombi et al., 2014). Compatible to previous literature and according to priori expectation study found that there is probability that perception and intention increase with having access to agricultural extension services as is evident by positive coefficient values (Table 3). In two ways, access to extension services can be interpreted. First, extension services provide information on new technologies and farming advices that lead farmers to adapt. For instance, marginal effect shows that the probability of change planting dates (20.6%) increases with having access on extension services. Secondly, access to extension services may negatively affect adaptation strategies due to poor knowledge of extension agents. However, climatic variations are changing rapidly and hence adaptation techniques vary accordingly. But, extension agent cannot keep themselves abreast with new knowledge and information to provide to farmers except same past knowledge. This is even common in developing countries like Pakistan where extension agents not provided with training and development regarding latest information. This situation is shown for changing crop variety (-0.154) and tree plantation (-0.002) although the relationships are insignificant.

Locational Factors

Information varies from person to person and region to region and hence study incorporated location factor to see the relationship between geographical location and adaptation process. Current study found a significant relationship between these two and found that perception increases from central Punjab (semi-arid zone) to southern Punjab (arid zone). However, no significant relationship is found between location and intention to adapt. This is may be the reason climatic vagaries such as droughts and floods are common in former area and have been severely affected floods from 2009 to 2014. Literature frequently used different cropping and environmental zone for adaptation and concluded that adaptation methods vary from one region to another (Gunamantha et al., 2016; Komba and Muchapondwa, 2012 and Bryan et al., 2009). For instance, this study found that moving from central Punjab to southern Punjab majority of adaptation strategies increase except change cropping type (Table 3). However, only tree plantation and diversification are positively and significantly influenced by locational dummy. This may be due the fact that majority of farmers in southern Punjab diversify wheat, cotton and fodders with mango (Rehman et al., 2014). For instance, moving from central to southern Punjab the probability of adaptations increase i.e. tree plantation (25.3%) and diversification (71.1%) as can be seen in Table 4.

Crop Income

Crop income positively and significantly affects first and second stage at one percent level of significance (Table 3). Crop income effect on decision was not quantified due to high collinearity. Past studies also found that income also contributes the perception (Hasan and Akhter, 2011; Van et al., 2015 and Acquah, 2011). Therefore, we conclude that crop income helps adaptation indirectly through perception and intention stages.

4.2 Adaptation to Climate Change Process

This study found that 71.4% of the respondents perceive about climatic variations and they have observed at least one of climatic variation (summer and winter rainfall and temperature). Whereas 58.5% farmers intended to adapt. However, 40.2% actually adapted as can be seen in Figure 2.

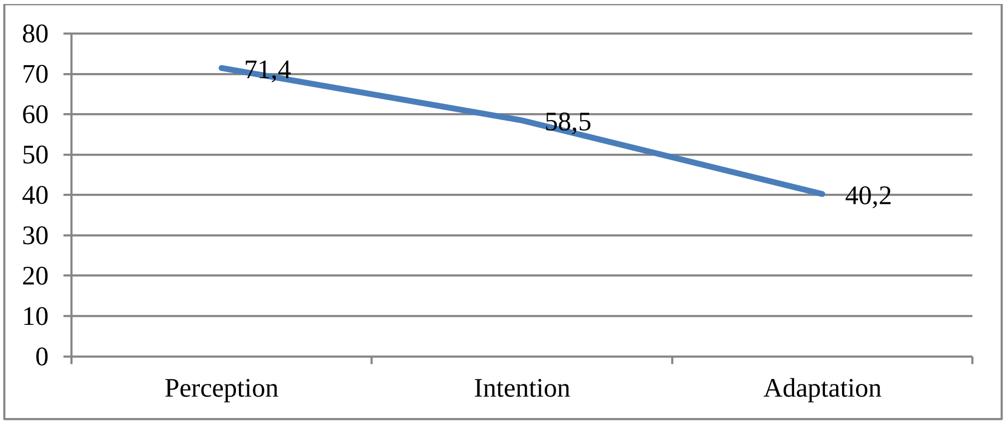


Figure 2. Adaptation Stages of the Study

Study took 5 adaptation strategies such as change crop variety (56.3%), change planting dates (44.6%), plant shaded trees (37.5%), increase/conserve irrigation (39.7%) and diversification (49.2%). Adaptive capacity and adaptation could be hampered by some constraints (Uddin et al., 2014; Tessema et al., 2013 and Komba and Muchapondwa, 2012). For instance, this study found that lack of money, lack of information, lack of irrigation water, no access to services and labor shortage and lack of resources for each adaptation strategies as can be seen in Figure 3 for their frequency distribution.

The study found the three stages of adaptation process. There are different socio, economic, demographic, institutional and geographic factors that affect these stages. For instance, farmers' perception to climatic variations increases with socioeconomic, demographic and institutional characteristics discussed in Table 3. These all factors lead farmers to perceive about CC. After perceiving about climate change, farmers intend to adapt to climatic adversaries. Again external and internal factors are there that have significant effect on intention to adapt. At third and last step farmers adapt if no constraints are there. Finally farmers go for adaptation depending on adaptive capacity of farms and farmers (Mandleni and Anim, 2011; Ndambiri et al., 2012; Bryan et al., 2011; Gunamantha et al., 2016; Olarinde et al., 2014; Uddin et al., 2014; Nabikolo et al., 2012 and Bryan et al., 2009). Factors of these three stages are given in literature but these were studies individually. However, adaptation is the complex phenomenon that further required in depth review and this study delineated this phenomenon empirically.

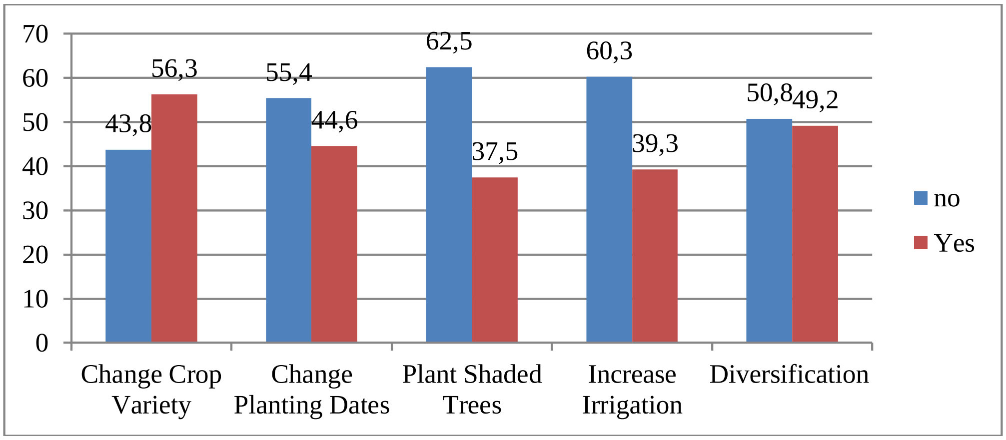
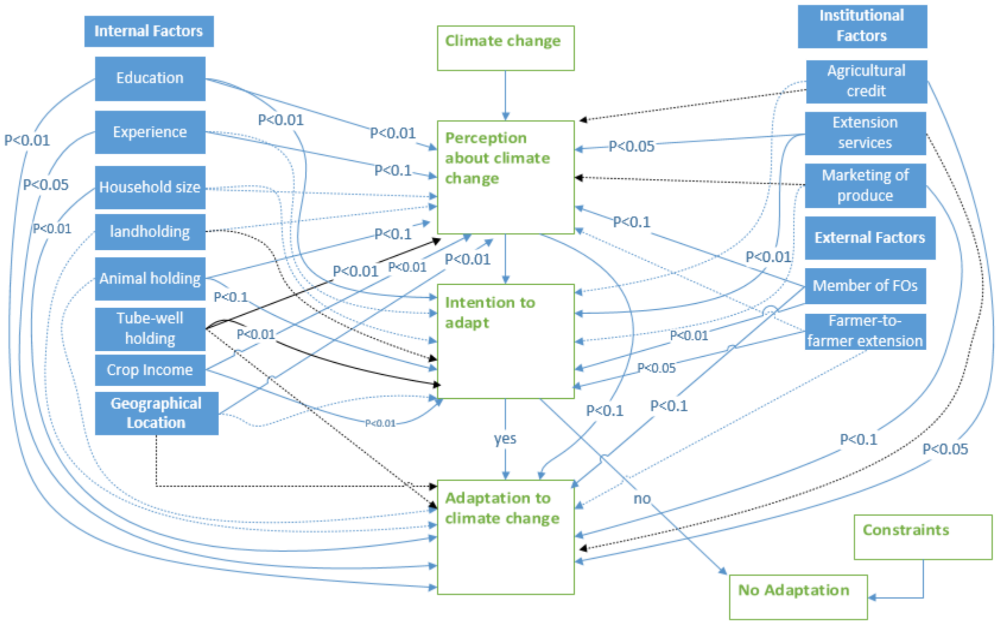


Figure 3. Adaptation Strategies

Literature has revealed that adaptation methods positively affect the crop income which then contribute farmers' adaptive capacity and their total income (Di Falco S and Veronesi, 2014 and Gorst et al., 2015). The current study found that crop income has positive and significant effect on perception and intention. Hence, this way adaptation process moves in a circular way. Empirically the current study proved this process as shown under heading contingency model in Figure 4. The study took one adaptation strategy (change crop variety) as model to develop contingency model however Below et al., (2010) have shown 104 adaptation strategies which can be replace according to parsimony or for any specific strategy on which adaptation process need to explore.



Key: ———— positively significant, ———— negatively significant
- - - - - - - positively insignificant, - - - - - - - negatively insignificant

Figure 4. Contingency Model for Adaptation Process (Change crop Variety)

5. Conclusion

The study found three stages of adaptation process and found that farmers first perceive climatic variations (71.4%), then intended to adapt (58.5%) and finally adapt to climatic variation (40.2%). Literature has found the positive impact of adaptation on crop income. The income from the crops positively affects the perception about CC and intention to adapt as empirically found in this study. Therefore, we found that adaptation process moves in a circular process although study did not find impact of adaptation on crop income. It was also observed that farmers once adapt to climatic variations they continuously adapt until further severe climatic adversaries hamper their adaptive capacity. This is also limitation of the study that we did not quantify the impact of adaptation on crop income for which future research requires.

The study found that farmers react to climatic adversaries through farm level adaptation strategies such as change crop variety (56.3%), change planting dates (44.6%), tree plantation (37.5%), increase/conserve irrigation water (39.3%) and diversification (49.2%). The study found the determinants of these strategies in addition to perception about climate change and intention to adapt. It was estimated that education and perception positively and significantly impact three stages. Therefore, we recommend that in the long run governments should increase education while in the short run they should increase the farmers' awareness to speed up the adaptation process (e.g. to build up perception about climate change) Adaptation process may demolish due to constraints in hand in addition to ever changing climate. So, we recommend that government should give the price incentives to farming communities to increase their adaptive capacity.

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