Impact of Climate Change on Livelihood of Wheat Farmers in District Chakwal

Syed Asif Ali Naqvi[1,*], Muhammad Laeeq[2], Muhammad Usman[3], Bilal Hussain[4]

[1] Department of Economics, Government College University Faisalabad, Pakistan

[2] Department of Economics, Government College University Faisalabad, Pakistan

[3] Department of Economics, Government College University Faisalabad, Pakistan

[4] Department of Economics, Government College University Faisalabad, Pakistan

*Corresponding Author Email: syedasif_1@yahoo.com

ABSTRACT

This study investigated the impact of changes in climate on the production system of wheat. Data regarding socio-economic characteristic and farming practices were obtained from household surveys conducted in Chakwal district of Punjab. A socioeconomic impact evaluation was conducted using the Decision Support System for Agro Technology Transfer (DSSAT) and the Agricultural Production Systems Simulator (APSIM). Crop modelling was done using five different General Circulation Models (GCM), and yield simulations were done for both crop models and each GCM. For the analysis, the Tradeoff Analysis Model for a Multidimensional Impact Assessment (TOA-MD) version 6 was utilised. For several scenarios, the effects of climate change and adaptation on poverty, net farm returns, and per capita income were estimated. It is clear from the results that famers are vulnerable to climate change. These findings indicated that adaptations to these variabilities are mandatory to offset these losses.

Keywords: Climate change; Punjab, wheat, per capita income, TOA-MD

1. Introduction

Climate variation is a worldwide threat for environmental and development concern. According to IFAD, developing nations are more likely to be effected by the climate changes due to low adaption rate (Sivakumar, 2021). It is projected that climate chnage (CC) is likely to affected food security in the world in the mid of 21st century. A large number of people will be food

insecure in the South Asia (Hijioka et a., 2014). With estimation, cereal crop production will be declined to 30% in year 2060 (Parry, 2004).

According to different studies – (Kreft and Eckstein, 2014; Sathar and Khan, 2021; Ullah et al., 2018), Pakistan is also included in the countries that are vulnerable to CC. According to Global Climate Risk Index Pakistan is ranked at number 12^{th} due to exposures of Extreme weather events (Kreft and Eckstein, 2014). World Bank also incorporate Pakistan at placed 12^{th} in highly climate effected countries (Naqvi et al., 2019). Pakistan is an agrarian country, where agriculture contribution towards GDP is 21.4%. It also employs around 45 percent of the entire work force and feeds 62 percent of the rural population (Abid et al., 2011). Despite its major contribution to the general economy, it is still experiencing serious challenges as a result of climate changes, such as rising temperatures, droughts, and floods, as well as an overall loss in net returns (Naqvi et al., 2019). In developing countries such as Pakistan, the majority of people living in rural areas are directly associated with the agriculture industry, while the urban community is also indirectly involved with this sector. As a result, adjusting the agricultural sector to the negative effects of climatic variability is required to provide food security for the country and to safeguard rural people' livelihoods.

Pakistan having a big landmass is situated on the tropic of latitude 23◦ to 38◦N and longitude of 60◦to 80◦E. climate is basically defined as the continental characterization by tremendous changes in temperature, both daily and seasonally. Due to hot summer and cold winter season Pakistan is also well known. Having Two thirds area of its arable territory range from semi-arid to arid climatic environment, while a small zone of northeast Punjab adjoining Kashmir experiences sub humid to humid conditions. The study area is located to sub humid agro climatic zone from semi arid agriculture zone (MI) (Ali, 2018), where July and August is the famous month for summer monsoon. The season of monsoon i.e. July to September is mostly linked with monsoon depression which is produced over the Bay of Bengal. Due to their Westward motion, they first move towards India and then Pakistan and it lies on their strength. Southwesterly is another cause of precipitation.

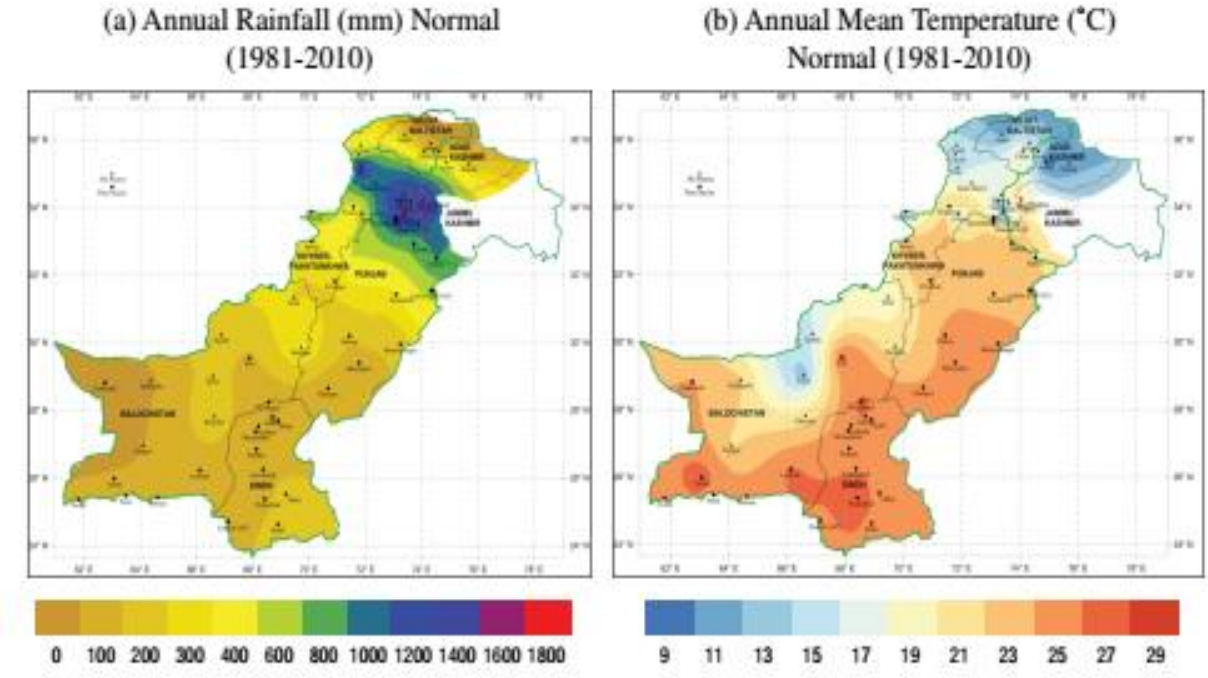

Figure 1. Climate of Pakistan 1981–2010

For small farmers, adaptations to these climatic variations is a significant measure that can decrease the vulnerability of the farmers and helping them to protect themselves from extreme weather events that have adverse impacts on farming system (IPCC, 2014). Due to lack of capital and less technological development, support to agriculture sector in case adaptation to CC is limited up to some extent (OECD, 2011).

At a countrywide, an integrated strategy for adapting the agriculture zone to variations in the climate is needed (Farooqi et al., 2005). mostly studies indicates that adaptation strategies towards the climate change includes the farmer's awareness, new verities of seeds that is heat-tolerant, insurance of the crop and awareness about the other social activities (Schlenker and Lobell, 2010). For the betterment of the famers and the way they recognize that CC is critical to design useful strategies for the support of successful adaptations of the agriculture community. Furthermore, it is significant to have particular know how about the degree and extent of adaptation techniques being taken up by rural households and rooms for further advances in existing adaptation setup. This up gradation of knowledge will finally boost up the worth of policies and its strength to come over the problems being created by the extreme climate

variations (Deressa et al., 2009). Various profiles like research, policy, extension, private welfare organizations, local communities and farmers are needed for adaptation purpose.

Figure 2. Pakistan wheat production from 2011-2016 (thousand tons)

Adaptation to climate change is a very serious problem in today's world and number of studies has been done on this topic in all over the world (Bryan et al., 2009). The first stage in the process of adapting agriculture to CC is to perceive it (Deressa et al., 2011). As a result, focusing on how farmers viewed climate change and what factors affect their adaptive attitude is important for adaptation research (Mertz et al., 2009; Weber, 2010). As a result of this, most study on CC adaptations is conducted on a worldwide basis, but only a small amount is conducted in South Asia. Likewise, a few researches are done on CC in Pakistan. Now a time, studies in this sector have totally limited to the impacts of CC on a specified crop (Naqvi et al., 2019). None of the research took into account farmers' views and adaptive behaviour, which is critical for understanding climate change adaptation in agriculture because farmers are the key decision makers and stakeholders in the agricultural sector. Farmers' adaptation strategies are determined by a variety of social, economic, and environmental factors (Deressa, 2007; Brayan et al., 2013). The precise awareness of these elements may aid policy in improving agricultural adaptation by recognising these aspects and investing in farmer-friendly initiatives for the betterment of the agricultural sector (Deressa, 2007).

As per scientific indication and predictions of various studies some serious adverse impacts of CC on will be faced by developing nation in the near future (Agrawal and Perrin, 2008; Naqvi et al. 2019). Environmental changes impact studies be supposed to description not only for climate impacts in the country of focus but also on changes in farming output due to climate change in the rest of the world (Zhang et al., 2014). Due to CC, Global Food Security will face greater challenge in future. According to FAO, global food security demand will be raised up to 70% more up to 2050 from 2000 (FAO, 2009). China's demand for food will be increased up to 25.1 million ha from 11.6 million ha from 2000 to 2020 (Huang et al., 2019).

Farming communities have the problem of under education and large family which might be the hindrance in their way to adaption of climate changes. The tool to reduce this vulnerability might be reduced imparting education to the rural sector and providing advanced technology and adaptation measures (Howden et al., 2007). Wheat as the staple food in the world has much more importance than any other crops of the world. In leading wheat producers in the world European Union is on top and Pakistan is on the 8^{th} .Wheat is also the staple food of Pakistan. Annual wheat consumption of Pakistan is 24.500 metric tons in 2016. Pakistan save little for future consumption in case of natural calamities we are unable meet the consumption needs. Climate change is the gradual process but it has mighty impacts on production and consumption of wheat. Pakistan has to adapt to these climate changes to sustain its wheat production in areas like district Chakwal where there is a lot of climate change role in production of wheat for local communities. Pakistan is second biggest nation in the South Asia and in the world it is placed at number 36. The overall area of Pakistan is 79.6 million ha, from which 22 million ha are utilized for production purpose. Out of which 19 million hac is most irrigated area. As per government of Pakistan' report 86% are small famers having an area of no more than 5 hectare and 5% of farmers have more than 10 hectare land (Government of Pakistan, 2010).

Pakistan's biggest province is Punjab as in both aspects i.e. agriculture production and population respectively. Historically, the name "Punjab" is originated from two words i.e., "Punj" meaning "five" and "Ab" meaning "water". Punjab has a very good infrastructure of canal for irrigation because five rivers encompass in this province. Pakistan's agriculture system has two basic seasons Kharif and Rabi. Rabi season started from November to April and Kharif

season started from May to October. So, Pakistan's agriculture production is dependent on these two seasons. Table given below Statistics of rice and wheat in Pakistan (2008–2013)

Table 1. Statistics of Rice and Wheat in Pakistan (2008-2013)

	Rice				Wheat			
Year	Area		production		Area		Production	
	000 ha	% change	000 Tone	% change	000 ha	% change	000 tone	% change
2008-09	2963	—	6952	—	9046	—	24033	—
2009-10	2883	−2.7	6883	−1.0	9132	1.0	23311	−3.0
2010-11	2365	−18.0	4823	−29.9	8901	−2.5	25214	8.2
2011-12	2571	8.7	6160	27.7	8650	−2.8	23473	−6.9
2012-13	2311	−10.1	5541	−10.0	8693	0.5	24231	3.2

Source: **Government of Pakistan (2016)**

During Rabi season, wheat is a major crop cultivated by most of the famers. The overall yield of wheat in 2013-14 was 25.3 tones and the area used for cultivation was 9.04 million ha. Another major crop for the Kharif season is rice having production of 6.8 million tones and cultivated on 2.79 million ha... Wheat is a staple crop that plays an important role in the value added of the total production of the agriculture sector. After wheat Rice is another major cereal crop that also have a significant share in the agriculture production sector i.e. 3.1% of the total production. Historic data in the above mentioned (Table-1) that there is inconsistency in production and cultivation of staple crops, i.e. Wheat and Rice. The inconsistency is due to lack of availability of water, change in seasonal variation, and change in crops price and input subsidies (Government of Pakistan, 2014).

The purpose of this research is to analyse the impact of extreme meteorological events on the livelihoods of subsistence farming communities that are already on the verge of poverty or worse, and to propose a package to mitigate the vulnerabilities caused by these catastrophes. The purpose of this study was to address a research vacuum by determining the impact of a CC

severe event on several socioeconomic variables of agricultural communities in different agro-ecological zones of Punjab that are more vulnerable to this problem.

Further, the paper is broken down into four sections. Section 2 follows the introduction and discusses the conceptual framework, empirical modelling, and methodology. The results and discussion is presented in Section 3. Finally, Section 4 discusses the results' conclusion and policy implications.

2. Material and methods

2.1.Sampling and data collection

This research was conducted out in the context of the Chakwal district. It is a rain-fed environment in the Potohar Plateau (Pakistan). The Potohar Plateau physiographic area is located in the northern portion of the Sind-Saghar doab. The region is located between the rivers Indus and Jhelum. The research area is located at 32° 55′ 29.39″ N and 72° 51′ 11.99″ E. (Figure 3). Chakwal District has a total size of roughly 6687 km2. Despite the fact that rural regions house 81 percent of the study area's overall population (PBS 2017). In the southwest, the study area's diverse landscape is covered by forest. In the north and northeast, the flat plains are interspersed with arid, stony areas. The Salt Ranges in the district's south are the most notable physical feature. The highest point in the research region is the Chail mountain (1128 m) (GoP, 2014). Wheat, maize, barley, sorghum, millets, lentils, gramme, groundnut, and brassicas are the main crops grown in the area (Brassica rapa).

Field studies was conducted in three administrative units (tehsils) of Chakwal district, namely Chakwal, Kallar Kahar, and Talagang. A systematic questionnaire was used to collect the data. In 2018, the data collecting was concluded. The research area's 120 respondents (40 from each tehsile) were chosen at random.

Figure 3. Map of the study area

2.2 Tradeoff Analysis for Multidimensional Impact Assessment (TOA-MD) Model

Various techniques have been used for climate change assessment such as Global Change Assessment Model (GCAM), Integrated Assessment Model (IAM), and Trade of Analysis model for Multi Dimensional Impact Assessment (TOA-MD). We use TOA-MD model into our analysis because it compares heterogeneous population which is not feasible with other model. Another big difference is that we cannot compare social systems with natural system. TOA-MD is a simulation model developed for assessing the multidimensional effect of agriculture and

aquaculture technologies, analysing ecosystem service provision, and assessing climate impact and adaptation. The study is based on a statistical characterisation of a diverse producer population. Antle and Validivia (2006) developed this model, which was followed by Nalukenge et al. (2006), Bagamba et al. (2012), and Claessens et al. (2012). The Tradeoff Analysis Model for Multi-Dimensional Impact Assessment (TOA-MD) is a simple, general model for analysing technology adoption (e.g., adaption methods), impact assessment (e.g., climate change), and ecosystem services. The TOA-MD 6.0 model extended the prior Minimum Data approach to calculate effects on the agriculture sector through social, environmental and economic factors. The latest model of TOA-MD calculates the heterogeneous population of households, aquaculture sub systems and livestock. Figure 4 presents the components of TOA-MD.

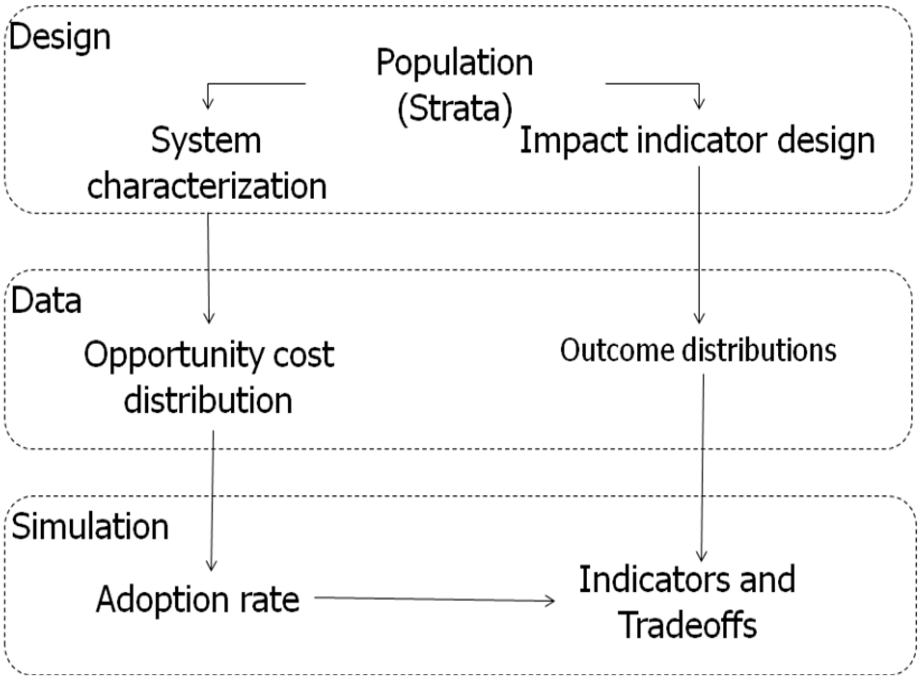

Figure 4. Components of TOA-MD

The main system variables in a farm system model that can be represented in TOA-MD – the challenge in a modeling study is to capture the essential ones as well as possible given the available data. Main system variables for the TOA-MD model are presented in Figure 5.

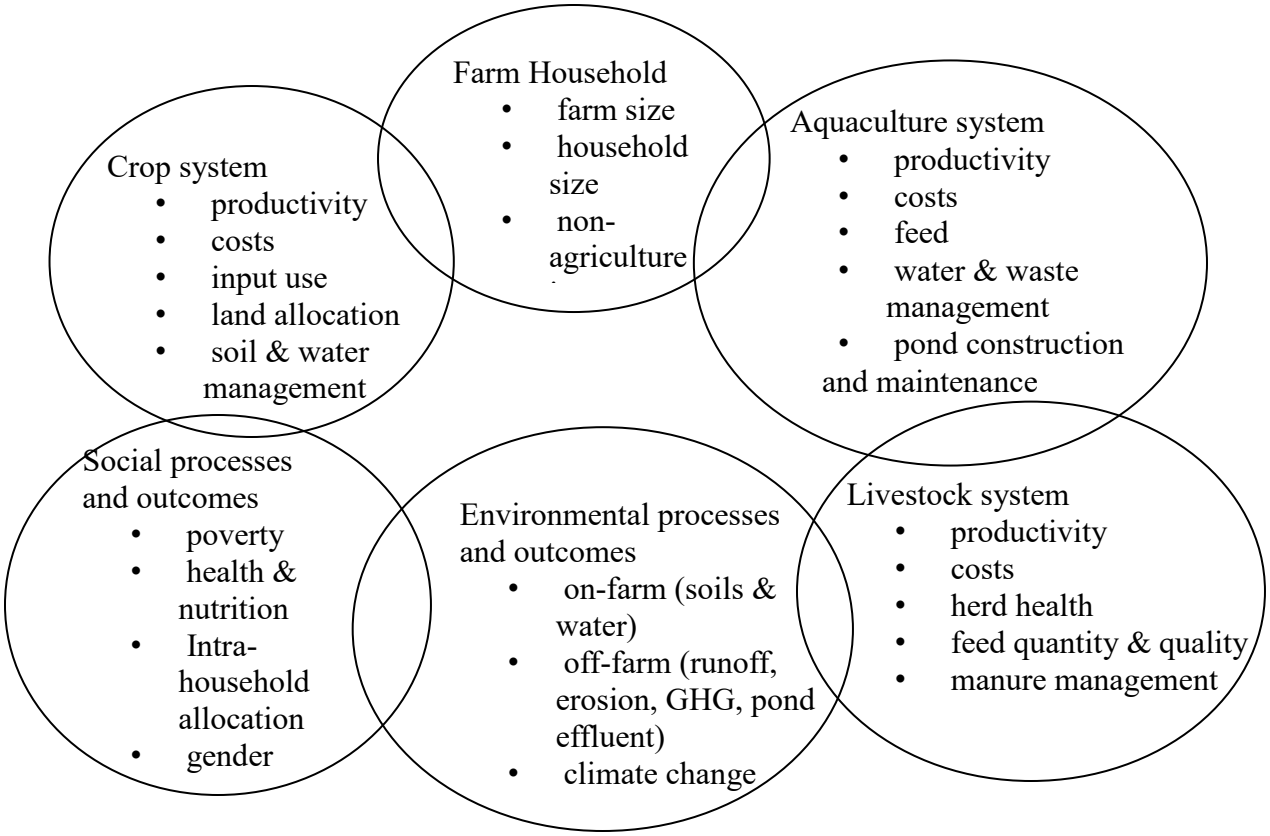

Figure 5. Main system variables for the trade of model

Aggregate activities that are not changing from system 1 to system 2 put net returns into the model directly rather than constructing net returns with price, output and cost put data in per-farm units.

The TOA-MD denote the entire system of agriculture (i.e. including livestock and aquaculture sub-system, crops, and the farm household characteristics). The TOA-MD represents the whole farming community. It is not a model that represents only an individual or single population. As the basic and significant variable included in the model are correlation of economic variable, variance and net farm population. These parameters are used to find out the current productivity of the agriculture population. By using recognized and well known techniques, we can check that how TOA-MD model variables changes with the change in technological adaptations and climatic variations. These variations in the model variables are the basis for the adaptation analysis, vulnerability, and climate impact.

Under the analysis of climate change, a farmer facing expected product and input prices *p* at a site *s* using a production system *h* earns returns *V* in each period equal to**:**

$$y = \beta o + \beta 1\, PCI + \beta 2\, NFR + \beta 3\, POV + \varepsilon o \qquad (1)$$

In (Eq. 1), PCI represents the per capita income, while MNFR and POV indicates the mean net farm returns and poverty, respectively.

$$vt = vt\,(p, s, h) \qquad (2)$$

To simplify the presentation in Equation 1, anticipated prices are assumed to be constant across time, and the returns function is indexed by time to reflect a hypothetical productivity shift. System h offers a discounted net return across T time periods:

$$V\,(p, s, h) = \sum_{t=1}^{T} \delta_t v_t\,(p, s, h) \qquad (3)$$

In this experiment, a population of farms is given the option of sticking with the present or "base" production system (System 1) or switching to a new system (System 2).

3. Results and discussion

3.1.Household and farm descriptive statistics

Table 2 presents the descriptive statistics of households and farm particulars in the study area. The descriptive analysis shows that the average age of the farmers was 46.37 years. In case of education and house hold members the mean value was 10.72 and 9.10 respectively. On the other hand, the overall farming experience was 22.86 years of the farmers of study area. The overall minimum and maximum farming experience of the farmers of study area were as 40 years and 12 years respectively. The results also shows that average area owned by the farmers of the respected study area was 6.94 per acre. Their maximum and minimum landholdings respectively were 14 acres and 2 acres. Samples average for area rented in was up to 0.09 acre. The overall average of the total landholding includes the area rented in and area rented out was 6.94 acres. Similarly, the overall average income level of the farmers was 12120.45 Rs per month. Their minimum and maximum income level was up to Rs 0 and Rs 15000 respectively. The average value of remittances was Rs20000. On the other hand, the minimum and maximum value of

remittances was Rs 30000 and Rs 10000, respectively. While in case of job, the minimum and maximum value of through jobs was Rs 20000 and Rs 10000, respectively. Furthermore, the average value of the own labor shows that own labor spent 95% time in the fields. The mean values of the males and females were 5.71 hours and 0.42 hours, respectively. The minimum and maximum time spent by males in the fields was 0.00 and 8.00 hours respectively. On the other hand, time spent by females in the fields was 0.00 hours and 5.00 hours daily. Additionally, the minimum and maximum level of production was 17 maunds and 22 maunds per acre. The overall average production of wheat was 19.17 maunds per acre. The average price of wheat per maund was Rs 1187.73. The average value of by product weight was 19.64 per maund. The overall price level of by product was Rs 250 per maund. Finally, the mean value of production of minor crop was 13.03 maund per acre. Its minimum and maximum value was found 0.00 maunds and 40.00 maounds per acre. However, the mean value of price per maund was Rs 3695.45. Its maximum value was Rs 6900, respectively.

Table 2. Descriptive statistics of households and farms particulars in study area

Particular	**Average**	**St. Deviation**	**Maximum**	**Minimum**
1. Socio economic indicators of the respondents of the study area				
Age (Years)	46.37	8.10	64.00	32.00
Education (Years)	10.72	2.72	16.00	0.00
H.H member (No.)	9.10	2.78	16.00	0.00
Farming Experience (Years)	22.86	6.53	40.00	12.00
2. Land used for cultivation by the farming community in Rabi season				
Area owned (Acres)	6.94	3.17	14.00	2.00
Area rented out (Acres)	0.00	0.00	0.00	0.00
Area rented in (Acres)	0.09	0.67	5.00	0.00
Rent per acre (Acres)	145.45	1073.76	8000	0.00
Total land holding (Acres)	6.94	3.17	14.00	2.00
3. Respondents income other than agriculture sector				
Amount (Rs.)	12120.45	38532.29	15000	0

Remittances (Rs.)	20000	12015.15	30000	10000
Job (Rs.)	10000	2135.23	20000	10000
4. Time spend by the famers and family in the fields of the study area				
Own labor (No.)	0.95	0.25	2.00	0.00
Time spent by Males (No. of Hours).	5.71	1.83	8.00	0.00
Time spent by females (No. of Hours)	0.42	1.13	5.00	0.00
5. Net Farm Returns in the Rabi season of the study area				
Production (Maunds)	19.71	1.67	22.00	17.00
Price / Maund (Rs.)	1187.73	51.22	1250.00	1100.00
By Product Weight (Maunds)	19.64	1.66	22.00	17.00
By Product price / Maunds (Rs.)	250.45	41.47	300	200
6. Net Farm Return of the peanut crop in the study area				
Production (maunds/farm/acre)	13.03	13.04	40.00	0.00
Price / Maund (Rs.)	3695.45	2687.77	6900.00	0.00

3.2 Summary statistics of base production system for peanut and wheat crop of district Chakwal

Table 3 shows the individual and the mean values of the peanut and wheat crop cultivated by the farm households. With regard to peanut crop, the average household size of the farmers of the study area was 9.10. In case of average income the three different strata's was Rs 135500 for Chakwal, Rs 120500 for kallar kahar and Rs 105500 for talla gang. Their overall mean value of off farm income for all these strata's was Rs 120500. The average value of number of livestock for Chakwal was 4.91, for kallar kahar was 4.55 and for last strata were 4.19. The overall mean value livestock was 4.55 in kharif season. In case variable production cost, there individual value

are Rs 31280, Rs 30135 and Rs 29085 respectively and the average value for all these three was Rs 30135. The overall average value of livestock variable production cost was Rs 30230 throughout the year. On the hand, the mean value of crop price per kg for Chakwal was Rs 130/kg, for kallar kahar it was Rs 125/kg and for Talla gang it was Rs 120/kg. The overall mean value of crop price of other major crop in kharif season was Rs 125/kg. In case of milk price, the overall average of milk price was Rs 70/kg. As the value of mean of crop yield and milk production for district Chakwal was 13.03kg/hec and 1850 liter/year. There individual mean values for crop yield are 10kg/hec, 15.5 kg/hec and 13 kg/hec and for milk production their individual mean values were 1980 ltr/year, 1850 ltr/year and 1720 ltr/year respectively, The finding is in line with the results of Jamal (2013) for the same cropping system of province Punjab, Pakistan.

Table 3. Summary statistics of base production system for peanut and wheat

Strata	House Hold Size (No.)	Average Farm Size (Hec)	Off Farm Income (Rs./Year/Household)	Average Livestock (No.)	crop Variable Production Cost (Rs./Hec)	Livestock Variable Production Cost (Rs./Farm/ Year)	crop Price (Rs./ Kg)	Milk Price (Rs./ Kg)	crop Yield (Kg/ Hec)	Milk Production (Litre/ Year)
Summary statistics of base production system for the peanut										
Chakwal	9.08	3.69	135500	4.91	31280	31180	130	68	10	1980
Kalar kahar	9.10	3.53	120500	4.55	30135	30230	125	70	15.5	1850
Talla Gang	9.12	3.37	105500	4.19	29085	29280	120	72	13	1720
Average	9.10	3.53	120500	4.55	30135	30230	125	70	13.03	1850
Summary statistics of base production system for the wheat										
Chakwal	9.14	7.1	154375	3.80	45900	32339	34	63	1923	2110
Kalar kahar	9.06	6.95	134375	3.76	45150	32039	31.25	65	1943	2094
Talla Gang	9.12	6.78	114375	3.72	44400	31739	28.5	67	1963	2078

Average	**9.10**	6.94	134375	3.76	45150	32039	31.25	65	1943	2094

Likewise, the mean value of household size for Chakwal, kalar kahar and talla gang were 9.14, 9.06 and 9.12, respectively. The overall mean value of household size was 9.10. In case of average form size the average value of Chakwal was 7.1 hec. , for kalar kahar 6.95 hectare and for talla gang was 6.78 hectare. The overall mean value of average farm size was 6.94 hectare. The observed mean value of off farm income of the farmers of various tehsil's were Rs. 154375, Rs. 134375 and Rs. 114375, respectively and their overall value was Rs 134375 respectively throughout the year. The variable production cost for Chakwal is Rs 45900, for kalar kahar was Rs 45150 and for Rs 31739 individually and the average of all three was Rs 45150. In case of livestock variable production cost the average value was Rs 32039 respectively. The overall mean value of wheat and milk price was Rs 31.25 and Rs 65 respectively. According to climate change sensitivity analysis the wheat yield for Chakwal was 1923 kg/hec, for kallar kahar was 1943 kg/hec and for Talla gang it was 1963 kg/hec. The overall yield for district was 1943 kg/hec. Lastly, in case milk production the individual values were 2110 liters/year, 2094 liters/years and 2078 liters/year respectively. But there overall mean value for milk production was 2094 liters per year. These results were similar with those of Baig et al (2014). The existing agricultural production system in the study region is predicted to be sensitive to climate change. As a result, future productivity would decline. The majority of farmers would suffer economic losses as a result of the erratic weather.

3.3. Simulation Analysis

Table 4 shows the gains, losses and net mean farm returns for the selected GCMs individually. In case GCM 1, the gainers were 11.56 % and the value of losers was 23.81 % and the net mean farm returns were -12.24 %. Negative sign shows the net loss in the future farmers. As in the GCM 2, the value of net gainers and losers were the 10.56 % and -23.82 %. The overall average of net farm returns for second GCM is -13.25 % respectively. Which indicates that farmers were vulnerable to climate change in future for their livelihood that is directly connected with farming? As in case of third GCM, gainers were 13.56 % and losers are -21.81 % respectively. The overall mean value of the net farm returns for third GCM is -8.22 5 respectively which was

also negative show negative impacts in future for the farmers of study area. As the Asian countries are vulnerable to climate change. According to GCM 4, the mean value of the gainers and losers were 12.55 % and -22.81 % respectively. Their overall mean value of the net return was -10.25 %. In case of GCM 5, overall average of the net mean farm returns was -11.24 % respectively. The mean value of gainers and losers of this was 12.57 % and -23.82 %. As from the climate sensitivity analysis we see that the overall mean value of the net farm returns were negative which obtained by subtracting gains and losses from each other. These findings have similar and consistent results as Naqvi et al. (2017*)* for the same cropping system of province Punjab, Pakistan.

Table 4. Gains, losses, and net impacts as percent of mean net farm returns for selected GCMs

GCM	Gains (%)	Losses (%)	Net Impacts (%)
CM2 bnu	11.56	23.81	-12.24
CM2 CCSM4	10.56	23.82	-13.25
CM2 CMCC	13.56	21.81	-8.25
GDFL CM3	12.55	22.81	-10.25
GCM Inmcm4	12.57	23.82	-11.24

4.4. Sensitivity of Current Agriculture System to Climate Change

Climate change is basically a real phenomenon that has noteworthy impact on agriculture production of Pakistan with a rise occurrence of natural disasters like floods, droughts and low intensity of rainfall and uncertain rainfalls. The sensitivity analysis with current technology and other economic is done to show the vulnerabilities for the farmers who depends on agriculture for their livelihood. For all GCM's the mean net returns of gainers and losses are shown given below.

The overall values of wheat yield change in wheat productivity, milk production gains, losses and net returns of all the GCM are given in the Table 5 The results shows that the observed mean yield of wheat is 17057.2 in both cases with climate change and without climate change. The mean value of change in yield of wheat is reduced from -2.6 to -5.7 percent. The observed mean

value of milk production of livestock of the study area for all the GCMs is 3502.3 liters with an average reduction of 12.0 percent according to sensitivity analysis. The net gainers of the respected study area are 12.5655 percent and the net losers are 23.8154 percent respectively. In case of observed net returns the value of net returns is Rs 128330.2385 is without climate change and which is reduced to Rs 108376.573 in with climate change. Observed per capita income is Rs 30134.88 without climate change and Rs 28731.29 with climate change. In case of observed poverty rate, the value is 28.78 percent without climate change which is observed to be increased to 30.55 percent with climate change. From the context of climate change model, the amount gains is 11.5655 % and losses is 23.8154 %, which indicates that the value of losses are more than the gains in future who worse off economically under perturbed climate change.

Table 5. Climate sensitivity of current agricultural production systems for the Wheat Cropping System of District Chakwal GCM CM2 bnu

Aggregated Results	**Without Climate Change**	**With Climate change**
Observed mean yield wheat (Kg/Farm)	17057.2	17057.2
Mean yield change wheat (%)	-5.7	-2.6
Observed mean production milk (Litre/Farm/Annum)	3502.3	3502.3
Mean production change milk (%)	-12.0	-12.0
Gains (% mean net returns)	11.56	11.56
Losses (% mean net returns)	23.81	23.81
Observed net returns (PKR/Farm/Year)	128330.23	108376.57
Observed per-capita income (PKR/Person/Year)	30134.88	28731.29
Observed poverty rate (%)	28.78	30.55

NOTE: Poverty Line= @ USD 1.25/Person/Day and USD 1= PKR 94.68, Season or Time Duration= 365 Days.

Table 6 shows that the mean yield of wheat is 17244.3 kg / hec for without climate change and with climate change. The overall mean percentage change of wheat is -5.8 % for without climate change and -2.8 % for with climate change. The observed mean milk production is 3422.3 ltr / farm / annum for without climate change and with climate change. The percentage change in milk production is 10.56 % for without climate change and -11 % for with climate change. In case of net farm returns the values of gainers and losers are 10.56 % and -23.81 % . This is same for both scenarios with climate change and without climate change. The observed net returns from farms for without climate change are Rs 128330.23 and for with climate change the net farm returns are Rs 108376.57 per farm per year. The observed per capita income per person in case of without climate change is Rs 30134.88 per year and in case of with climate change the per capita income per person throughout the year is Rs 28731.29. The observed poverty rate in case of without climate change is 28.78 % and for with climate change the poverty rate is 30.55 % for the year. The net returns after climate change shown in the above diagram are 13.2499 %. In which the value of gainers are 10.56 % and the value of losers is 23.81 %, which shows that farmers are more vulnerable to climate change in future with respect to current scenario.

Table 6. Climate sensitivity of current agricultural production systems for the Wheat Cropping System for GCM CM2 CCSM4

Aggregated Results	**Without Climate Change**	**With Climate change**
Observed mean yield wheat (Kg/Farm)	17244.3	17244.3
Mean yield change wheat (%)	-5.8	-2.8
Observed mean production milk (Litre/Farm/Annum)	3422.3	3422.3
Mean production change milk (%)	10.56	-11.0

Gains (% mean net returns)	10.56	10.56
Losses (% mean net returns)	23.81	23.81
Observed net returns (PKR/Farm/Year)	128330.23	108376.57
Observed per-capita income (PKR/Person/Year)	30134.88	28731.29
Observed poverty rate (%)	28.78	30.55

NOTE: Poverty Line= @ USD 1.25/Person/Day and USD 1= PKR 94.68, Season or Time Duration= 365 Days

The results of third GCM are reported in Table 7 which show that the observed mean yield of wheat is 17158.22 kg / farm. This is same in both cases with climate change and without climate change. The percentage mean yield change of wheat for without climate change is -5.6 % and for with climate change it is -2.8 %. The observed mean production of milk from farms is 3402.3 liters / year for with climate change and without climate change. The percentage observed mean production milk is -10 % for without climate change and same in case of climate change. The observed mean value gains from net farm return is -10 % for both without climate change and climate change. On the other hand, the value of losers for net farm returns is -21.82 %. This is more from gainers. The negative sign shows that the value of losers is more than the gainers. This shows that with change in future there will be more losers than gainers. The value of net mean farm returns in the form of rupees for without climate change is Rs 128330.23 per farm per year and for climate change it is Rs108376.57 per farm per year. The observed per capita income for without climate change is Rs 30134.88 per farm per year and in case climate change it is Rs 28731.29 per farm per year. In case of observed poverty rate, it is 28.78 % and 31.55 % for without climate change and with climate change respectively. Further,from the viewpoint of climate model, the value of gains is 13.56 % and losses are 21.81 %. This indicates that the overall net returns from future agriculture are losses. That the farming community faces at some future time period. The net gains are less in number and the ultimate results shows the negative

returns. The net returns line moves downward rather than upward from the base line.

Table 7. Climate sensitivity of current agricultural production systems for the Wheat Cropping System of the study area for GCM CM2 CMCC CMS

Aggregated Results	**Without Climate Change**	**With Climate change**
Observed mean yield wheat (Kg/Farm)	17158.22	17158.22
Mean yield change wheat (%)	-5.6	-2.8
Observed mean production milk (Litre/Farm/Annum)	3402.3	3402.3
Mean production change milk (%)	-10.0	-10.0
Gains (% mean net returns)	13.56	13.56
Losses (% mean net returns)	21.82	21.82
Observed net returns (PKR/Farm/Year)	128330.23	108376.57
Observed per-capita income (PKR/Person/Year)	30134.88	28731.29
Observed poverty rate (%)	28.78	31.55

NOTE: Poverty Line= @ USD 1.25/Person/Day and USD 1= PKR 94.68, Season or Time Duration= 365 Days

The outcomes of fourth climate model presented in Table 8 show that the observed mean yield of wheat for without climate change is 16957.2 kg per farm and with climate change it also same. The percentage change in observed mean yield of wheat is -5.9 % for without climate change and -2.9 % for with climate change. This shows that climate change negatively affect the productivity of wheat. The average milk production of the animals throughout the year in case of without climate change is 3602.3 liters per farm and with climate change it is 3602.3 liters per farm. In case of percentage change in average yield of milk the value for without climate change

and with climate change is same that is -14 % . The percentage gains from net mean farm returns are 12.56 %, which is same in both cases without climate change and with climate change. On the other hand the value of net mean farm returns for without climate change and with climate change is -22.81 %. The net impact is of loss as the value of the losses is higher than the gains. The observed net farm returns value in the form of rupees is Rs 128330.23 per farm per year for without climate change and Rs 107976.57 per farm per year. The value observed per capita income for without climate change is Rs 30134.88 per person per year and it is Rs 27931.29 per person per year in case climate change. The observed poverty rate is 28.78 % for without climate change through the year and for with climate change its value is 32.55 % respectively. The mean value of gains and losses from sensitivity analysis is 12.65 % and 22.82 % respectively. The result shows that farmers are more vulnerable to climate change in future. The predicted results threaten the future agriculture of Pakistan.

Table 8. Climate sensitivity of current agricultural production systems for the Wheat Cropping System for GCM GFDL CM3

Aggregated Results	**Without Climate Change**	**With Climate change**
Observed mean yield wheat (Kg/Farm)	16957.2	16957.2
Mean yield change wheat (%)	-5.9	-2.9
Observed mean production milk (Litre/Farm/Annum)	3602.3	3602.3
Mean production change milk (%)	-14.0	-14.0
Gains (% mean net returns)	12.56	12.56
Losses (% mean net returns)	22.81	22.81
Observed net returns (PKR/Farm/Year)	128330.23	107976.57
Observed per-capita income (PKR/Person/Year)	30134.88	27931.29
Observed poverty rate (%)	28.78	32.55

NOTE: Poverty Line= @ USD 1.25/Person/Day and USD 1= PKR 94.68, Season or Time Duration= 365 Days

According to climate sensitivity analysis of GCM five presented in Table 9, the observed mean value of wheat yield for without climate change is 16857.2 kg per farm for the year and for with climate change its value is 16857.2 kg per farm annually. In case of percentage yield of wheat the value for without climate change is -4.7 % and for with climate change its value is -2.2 % annually. The observed mean value of milk production for without climate change is 3702.3 liters per farm per year for without climate change and in case of with climate change the value of milk production is 3702.3 liters per year. The overall change in milk production in case of without climate change and with climate change is -13 % throughout the year. In case of gains from net mean farm returns for without climate change and with climate change is 12.56 %. While for losers the value of net mean farm returns for without climate change and with climate change -23.81 % respectively.

Table 9. Climate sensitivity of current agricultural production systems for the Wheat Cropping System for GCM inmcm4

Aggregated Results	**Without Climate Change**	**With Climate change**
Observed mean yield wheat (Kg/Farm)	16857.2	16857.2
Mean yield change wheat (%)	-4.7	-2.2
Observed mean production milk (Litre/Farm/Annum)	3702.3	3702.3
Mean production change milk (%)	-13.0	-13.0
Gains (% mean net returns)	12.56	12.56
Losses (% mean net returns)	23.81	23.81
Observed net returns (PKR/Farm/Year)	128330.23	108376.57
Observed per-capita income (PKR/Person/Year)	30134.88	28731.29
Observed poverty rate (%)	28.78	30.55

NOTE: Poverty Line= @ USD 1.25/Person/Day and USD 1= PKR 94.68, Season or Time Duration= 365 Days

The observed net farm returns value for without climate change is Rs 128330.23 and for with climate its value is Rs 108376.56 per year. The observed per capita income per person for without climate change is Rs 30134.88 per year and for with climate change its value is Rs 28731.29 annually. In case of observed poverty rate, the value for without climate change is 28.78 % and for with climate change its value is 30.55 % throughout the year. The overall net returns value is 11.25 '% in the future. The negative sign of net returns value shows that farmers' bear lose in future from farming system. This is due to perturbed change in weather conditions of future. The individual value also shows that the losses are more than the gains.

4.Conclusion and policy implications

Less developed countries are more vulnerable to climate change with respect to developed countries. As they use labor intensive techniques because of less capital, old technology and low adoption rate. On the other hand the developed nations can cope on climate conditions with advance technology and higher adoption rate. Pakistan is one the major risk related country with respect to climate change. Major portion of the economy is directly connected with agriculture for their livelihood. By using TOA-MD, findings of the study shows that climate change have negative impacts on the farmers. According to climate change sensitivity analysis the wheat yield for Chakwal is 1923 kg per hectare, for kallar kahar 1943 kg per hectare and for Talla gang it is 1963 kg per hectare. The overall yield for district is 1943 kg per hectare. According to climate sensitivity analysis, it is observed that the overall mean value of the net farm returns are negative which obtained by subtracting gains and losses from each other. It is clear from the results of the study that famers are vulnerable to climate change in future those who completely dependent on agriculture sector for livelihood. That ultimately reduces the per capita income and raises the poverty rate of the farming community. While adaptations to this climate change will decrease the poverty level and increases the per capita income of the farmers of the study area. Farmers will have the courage to adopt new high yielding verities of seed and adopt new technologies to raise the productivity. The study recommended that government and policy makers to focus on technological progress to assess the climate variability. Farmers should have to shift the cultivating dates to avoid the drought hazard that effect wheat yield. Further, government should develop rice growing techniques by using appropriate local wheat varieties with higher yield

under water shortage and improvement of soil fertility by using green manure for farm environment and reducing CO2 emissions. There is also need to enhance the water availability to increase the productivity of wheat and maintenance of irrigation systems for enough allocation of water demand in the dry season.

References

Abid, M., Ashfaq, M., Hassan, S., & Fatima, N. (2011). A resource use efficiency analysis of small BT cotton farmers in Punjab, Pakistan. *Pak. J. Agric. Sci*, *48*(1), 65-71.

Agrawal, A. (2008). The role of local institutions in adaptation to climate change. Available online: **http://hdl.handle.net/10986/11145** (accessed on 10 November 2018).

Ali, G. (2018). Climate change and associated spatial heterogeneity of Pakistan: Empirical evidence using multidisciplinary approach. *Science of the Total Environment*, *634*, 95-108.

Antle, J. M., & Valdivia, R. O. (2006). Modelling the supply of ecosystem services from agriculture: A minimum-data approach. *Australian Journal of Agricultural and Resource Economics*, *50*(1), 1-15.

Bagamba, F., Bashaasha, B., Claessens, I., & Antle, J. (2012). Assessing climate change impacts and adaptation strategies for smallholder agricultural systems in Uganda. *African Crop Science Journal*, *20*, 303-316.

Baig, I.A., M. Ashfaq, S.A.A. Naqvi, A. Ahmed, G. Hoogenboom, J.M. Antle and R.O. Valdivia. 2014. Ex ante impact assessment of wheat crop in Punjab-Pakistan. J. Appl. Environ. Biol. Sci. 4:358-363

Bryan, E., Deressa, T. T., Gbetibouo, G. A., & Ringler, C. (2009). Adaptation to climate change in Ethiopia and South Africa: options and constraints. *Environmental science & policy*, *12*(4), 413-426.

Bryan, E., Ringler, C., Okoba, B., Roncoli, C., Silvestri, S., & Herrero, M. (2013). Adapting agriculture to climate change in Kenya: Household strategies and determinants. *Journal of environmental management*, *114*, 26-35.

CHANGE–IPCC, I. P. O. C. 2014. Climate Change. Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Working Group II Contribution to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Ed.

Claessens, L., Antle, J. M., Stoorvogel, J. J.,Valdivia, R. O., Thornton, P. K., and Herrero, M. (2012).

Deressa, T. T. (2007). Measuring the economic impact of climate change on Ethiopian agriculture: Ricardian approach. *World Bank Policy Research Working Paper*, (4342).

Deressa, T. T., Hassan, R. M., & Ringler, C. (2011). Perception of and adaptation to climate change by farmers in the Nile basin of Ethiopia. *The Journal of Agricultural Science*, *149*(1), 23-31.

Deressa, T. T., Hassan, R. M., Ringler, C., Alemu, T., & Yesuf, M. (2009). Determinants of farmers' choice of adaptation methods to climate change in the Nile Basin of Ethiopia. *Global environmental change*, *19*(2), 248-255.

Farooqi, A. B., Khan, A. H., & Mir, H. (2005). Climate change perspective in Pakistan. *Pakistan Journal of Meteorology*, *2*(3).

Government of Pakistan. (2010). Economic survey of Pakistan, Economic Advisor's Wing, Finance Division, Islamabad.

Government of Pakistan. (2014). Economic survey of Pakistan, Economic Advisor's Wing, Finance Division, Islamabad.

Hijioka, Y., Lin, E., Pereira, J. J., Corlett, R. T., Cui, X., Insarov, G. E., ... & Surjan, A. (2014). Asia. Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part B: Regional Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. *Cambridge University Press, Cambridge, United Kingdom and New York*, 1327-1370.

Howden, S. M., Soussana, J. F., Tubiello, F. N., Chhetri, N., Dunlop, M., & Meinke, H. (2007). Adapting agriculture to climate change. *Proceedings of the national academy of sciences*, *104*(50), 19691-19696.

Huang, J., Ma, J., Guan, X., Li, Y., & He, Y. (2019). Progress in semi-arid climate change studies in China. *Advances in Atmospheric Sciences*, *36*(9), 922-937.

Jamal, H. 2013. Predicting sub-national poverty incidence for Pakistan. Social Policy and Development Centre (SPDC). Available at: http: // www.spdc.org.pk/pubs/rr/rr85.pdf. Last accessed at March 23, 2014.

Mertz, O., Halsnæs, K., Olesen, J. E., & Rasmussen, K. (2009). Adaptation to climate change in developing countries. *Environmental management*, *43*(5), 743-752.

Nalukenge, I., Antle, J. M., Stoorvogel, J. J., & Claessens, L. (2006). Payments for Environmental Services (PES) as a new approach to tackle land degradation in Pallisa District. In *Workshop Report USAID (Soil Management CRSP) and FAO, Pallisa, Uganda*.

Naqvi, S. A. A., Nadeem, A. M., Iqbal, M. A., Ali, S., & Naseem, A. (2019). Assessing the vulnerabilities of current and future production systems in Punjab, Pakistan. *Sustainability*, *11*(19), 5365.

OECD. Publishing. (2011). *Better policies to support eco-innovation*. Organisation for Economic Co-operation and Development.

Parry, M. L., Rosenzweig, C., Iglesias, A., Livermore, M., & Fischer, G. (2004). Effects of climate change on global food production under SRES emissions and socio-economic scenarios. *Global Environmental Change*, *14*(1), 53-67.

Sathar, Z. A., & Khan, K. (2019). Climate, population, and vulnerability in Pakistan: Exploring evidence of linkages for adaptation. *Islamabad: Population Council. The Population Council confronts critical health and development issues—from stopping the spread of HIV to improving reproductive health and ensuring that young people lead full and productive lives. Through biomedical, social science, and public health research in*, *50*, 5.

Schlenker, W., & Lobell, D. B. (2010). Robust negative impacts of climate change on African agriculture. *Environmental Research Letters*, *5*(1), 014010.

Sivakumar, M. (2021). Climate Change, Agriculture Adaptation, and Sustainability. In *Climate Resilience and Environmental Sustainability Approaches* (pp. 87-109). Springer, Singapore.

Ullah, W., Nihei, T., Nafees, M., Zaman, R., & Ali, M. (2018). Understanding climate change vulnerability, adaptation and risk perceptions at household level in Khyber Pakhtunkhwa, Pakistan. *International Journal of Climate Change Strategies and Management*.

Weber, E. U. (2010). What shapes perceptions of climate change?. *Wiley Interdisciplinary Reviews: Climate Change*, *1*(3), 332-342.

Zhang Y Q, Cai Y X, Beach R H, McCarl B A. 2014. Modeling climate change impacts on the US agricultural exports. *Journal of Integrative Agriculture*, 13, 666-676.