Effects of Climate Change Adaptation on Agricultural Productivity in Malakand (Khyber Pakhtunkhwa)

Mubasher Khan[1], Inayatullah Jan[2], Absar Ul Hassan[3], Sher Ali[4] and Osama Riaz[5]

https://doi.org/10.62345/jads.2024.13.3.22

Abstract

The study was conducted to investigate the effects of climate change adaptation on agricultural productivity in selected villages of District Malakand, Khyber Pakhtunkhwa, Pakistan. Adapting to climate change in District Malakand, is vital for helping farmers protect their crops from unpredictable weather, ensuring they can continue to grow enough food. Data were collected from 143 sampled households from Kot, Maina, and Mungai through a semi-structured questionnaire, and to analyze the data, descriptive statistics and binary logit regression were used. The study identified various adaptation strategies used by farmers for climate change and the effects of these adaptations on agriculture productivity. The adaptation strategies include changes in irrigation practices, adjustment of sowing periods, and the use of chemical fertilizers etc. Binary logit regression result indicates that the co-efficient and significance of the sample respondents for age (β=.058, p=.024), education (β=.111, p=.025), family size (β=.234, p=.007), income (β=.000, p=.018), landholding (β=.224, p=.036), farming experience (β=.090, p=.031), and tenancy status (β=1.120, p=.045) had a positive and significant relationship with adapting climate change adaptation strategies for agriculture productivity while the specific strategies for climate change adaptation is (β=-1.385, p=.023) had a negative and significant relationship with adapting climate change effect for agriculture productivity. The study recommended the formulation of a comprehensive national climate action plan, increased investment in rural infrastructure, and targeted policy measures to support the agricultural sector.

Keywords: Climate Change, Adaptation Strategies, Agriculture Productivity, Binary Logit.

Introduction

Climate change is a significant environmental challenge and impacts all economic sectors, including energy, water, health, biodiversity, and agriculture (Abbas, 2022; Ali et al., 2019). Sustainable agricultural production is expected to decline due to environmental changes, primarily affecting those reliant on food production (Khubaib et al., 2021). Developing countries, such as Pakistan, feel the majority of climate change effects due to their vulnerability and limited mitigation capacity (Piao et al., 2010). Agriculture in these regions faces severe impacts from temperature changes, changed rainfall patterns, floods, droughts, and adverse effects on water and

[1]*Postgraduate Students, Institute of Development Studies, The University of Agriculture Peshawar, Pakistan. Correspondence Author Email: mubashirkhan044@gmail.com*
[2]*Director, Institute of Development Studies, The University of Agriculture Peshawar, Pakistan.*
[3]*Lecturer, Institute of Development Studies, The University of Agriculture Peshawar, Pakistan.*
[4]*Postgraduate Students, Institute of Development Studies, The University of Agriculture Peshawar, Pakistan.*
[5]*Department of Entomology, The University of Agriculture Peshawar, Pakistan.*

land resources (Mendelsohn, 2008). Pakistan, contributing 0.8% of global greenhouse gas emissions and ranked 135th worldwide (Naqvi et al., 2021), is the seventh most susceptible country on the Global Climate Risk Index 2017. With a largely dry or semi-arid landscape and rapidly melting glaciers, over 40% of its population depends on agriculture, making it particularly susceptible (Othieno & Shinyekwa, 2011). According to the Climate Change Ministry of Pakistan, stated that Khyber Pakhtunkhwa (KP) is the most vulnerable area to climate change. Climate change has a negative effect on agriculture and decreased crop efficiency and productivity, usually in rainfed areas (Zubair et al., 2015). Due to the temperature rising, changing patterns of rainfall and scarcity of water, crucial crops like maize, wheat and rice productivity have declined by up to 30% (PARC, 2022). Moreover, the World Bank specifies that agricultural productivity could decrease by up to 50% by 2050 in Khyber Pakhtunkhwa without proper mitigation (Abbas, 2022). In KPK, climate change causes rising temperatures and changes in rainfall patterns, leading to melting glaciers and snowpacks in the Himalayas, affecting the flow of rivers and irrigation. This results in droughts, floods, and increased pest infestations, further harming crop yields (Rehman et al., 2020; Audu et al., 2013). Globally, climate change affects agriculture by changing temperature, rainfall, and humidity, directly affecting food production (Jan et al., 2021). Developing countries like Pakistan face extreme heat, floods, and severe droughts, which hamper crop development and productivity (Ahmad et al., 2020; Mendelsohn, 2008). Agriculture, which is vital for human food and survival, is heavily impacted by climate change (Ahmad et al., 2017). Addressing climate change effects, particularly in developing countries, is crucial. Pakistan, already facing various issues, is experiencing severe negative impacts on its agricultural productivity due to climate change (Salman et al., 2018).

Climate Change Adaptation and Mitigation

Pakistan is one of the most impacted states, and has a wide range of problems like water scarcity, heat waves, floods, droughts, and troubles with food security by climate change. Therefore, a list of adaptation strategies and initiatives has been developed by the country to adapt to climate change (Ahmad et al., 2017). According to National Climate Change Policy assimilates adaptation into all sectors, focusing on adaptation, reducing, capacity building, and research. It measures contains to improve water management, improve agricultural productivity, and promote renewable energy (Shahid, 2021). Furthermore, the Climate Change Act. 2017 gave the Climate Change Council the Authority to coordinate and implement policies (Ahmad et al., 2017). However, the National Disaster Management Plan 2020 was reviewed to incorporate climate adaptation to strengthen susceptible communities and reduce greenhouse gas emissions. Pakistan targets to make 30% of its electricity from renewable sources by 2030, with projects like the Khyber Pakhtunkhwa hydropower initiative generating 4,320 MW (Asseng et al., 2015). The Billion Tree Tsunami creativity goal is to plant 1 billion trees by 2023 to increase forest cover and combat deforestation (Khan et al., 2019).

Need for Climate Change Adaptation

The provinces of Pakistan and especially Khyber Pakhtunkhwa are tremendously vulnerable to climate change impacts such as floods, droughts and heat waves due to their geographical locality, topography, and socio-economic conditions (Global Climate Risk Index, 2020). Local communities lack the resources and infrastructure to deal with these disasters (Sonia et al., 2019). Due to climate change, decreasing precipitation, changing patterns of rainfall, increasing droughts, significantly reducing groundwater table and affecting agriculture, which is the backbone of

Pakistan, specifically the KPK economy (Ahmed et al., 2020). Likewise, heat waves are also becoming more frequent and severe, causing health problems, for example, heat stroke and dehydration (Singh et al., 2021). However, Pakistan has initiated a National Climate Change Policy to reduce these problems and focuses on implementing climate change adaptation measures at various levels (Asif et al., 2014). KPK Climate Resilient Infrastructure Development Project goals to strengthen infrastructure against the effects of climate change. It is essential to implement policies that make communities more strong against these climate impacts, with regional administrations working with investors to improve adaptation strategies (Ali et al., 2019). Farmers in KPK have adopted several climate change adaptation strategies according to their geographic context and land tenure. These include water management, altering cropping patterns, using climate-resistant varieties, and adjusting cropping times (Iqbal et al., 2022). District Malakand has a significant impact of climate change, which has led to irregular crops and livestock production, prolonged droughts, and high temperatures. Farmers struggle to acclimate to strategies for climate change that affect their livelihoods. This study aims to analyze how climate change adaptation strategies impact agricultural productivity in the Malakand district. It intends to offer insights into agriculture's vulnerability to climate change and inform stakeholders about effective adaptation methods for sustainable agricultural development. The study attentions on the challenges faced by rural farmers of Malakand district due to climate change, which affects agriculture production. Pakistan, a developing country whose population directly or indirectly depends on agriculture, has faced numerous problems due to climate change, such as droughts, floods, heat waves, and irregular rainfall, adversely affecting millions of agriculturalists. Causal factors consist of limited access to up-to-date agricultural technologies, inadequate infrastructure, and weak policy contexts. The current research is necessary to understand climate change's effects on Pakistan's agricultural productivity and find real solutions to alleviate these impacts. The main objectives of the study are:

- To investigate the climate change effects on agriculture productivity.
- To identify the adaptation measures that farmers use in response to climate change in the study area.

Methods and Materials

Study Area and Sample Design

The study was conducted in Malakand district, tehsil Batkhela. From the selected tehsil, three villages, namely, Kot, Maina, and Mungai, were purposively selected for the study. The total number of households in the research villages was 2860, with 980 in Kot, 900 in Maina and 980 in Mungai. Out of the total households (5%), which is 143 sample size were selected for this study. In the next step, the proportionate sampling technique was used to determine the proportionate sampling for each VC, using the following formula.

$$n_i = \frac{N_i}{N} \times n \quad \text{......} \quad (1)$$

Whereas;

Ni = total number of households in each village

N = total number of household in the study area

n = total sample size required for the study

ni = sample household from each village

n_1 = 980×143/2860 = 49 (Kot)

n_2 = 900×143/2860 = 45 (Maina)

n_3 = 980×143/2860 = 49 (Mungai)

Data Collection and Analysis

After selection and distribution of sample size primary data was collected randomly from the selected sample households through face to face interview schedule methods. For this purpose a well-structured questionnaire was developed. The questionnaire was designed to collect data on the key factors affecting agriculture productivity due to climate change, and the strategies to mitigate the negative impacts of climate change on agriculture productivity. For data analysis descriptive statistics and binary logit regression model was used. The equation of binary logit regression model as follow:

Binary Logit Model

The dependent variable of this study is the perception of the framers about the effect of climate change adaptation on agricultural productivity measured as a dummy variable. The following binary logit regression model was employed.

$$Y = \left(\frac{P}{1-P}\right) = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \beta_6 X_6 + \beta_7 D_1 + \beta_8 D_2 \quad \ldots\ldots\ldots\ldots (2)$$

Whereas;

Y_i = Effect of climate change adaptation on agriculture productivity (Yes = 1, otherwise = 0)

β_0 = Constant

$\beta_1 \ldots \beta_8$ = Regression Coefficient

X_1 = Age of the respondents (years)

X_2 = Education of respondents (years)

X_3 = Family size (numbers)

X_4= Income of the household per months (Rs)

X_5= Land holding (Jirab)

X_6= Farming experience (years)

D_1= Land tenancy status (ower-1, tenant = 2)

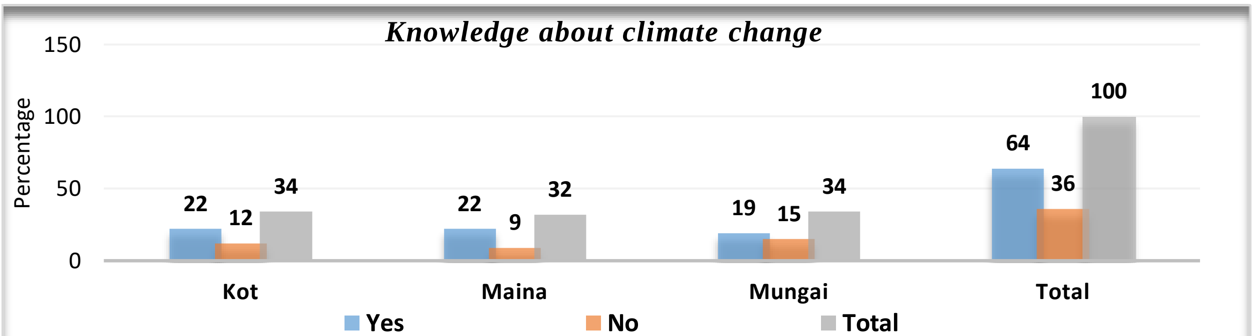
D_2 = strategy for climate change adaptation (yes = 1, no = 0).

Results and Discussions

Knowledge about Climate Change

Climate change entails change in the climatic situations over time. Due to climate change every economic sectors, has effected including energy, water, health, biodiversity, and agricultural production (Sonia et al., 2019). Figure 1 indicates that the distribution of the sample respondents about knowledge of climate change. Figure result reveals that majority (64%) of the respondent opinion were know about the effect of climate change on agriculture productivity while 36% sample respondent views negatively, they are unaware of how farmer adaptation techniques and agricultural productivity are impacted by climate change in study area. These finding are similar to Khanal (2009) study, who stated that famers were aware of the climate change and know about the climate change and it effects.

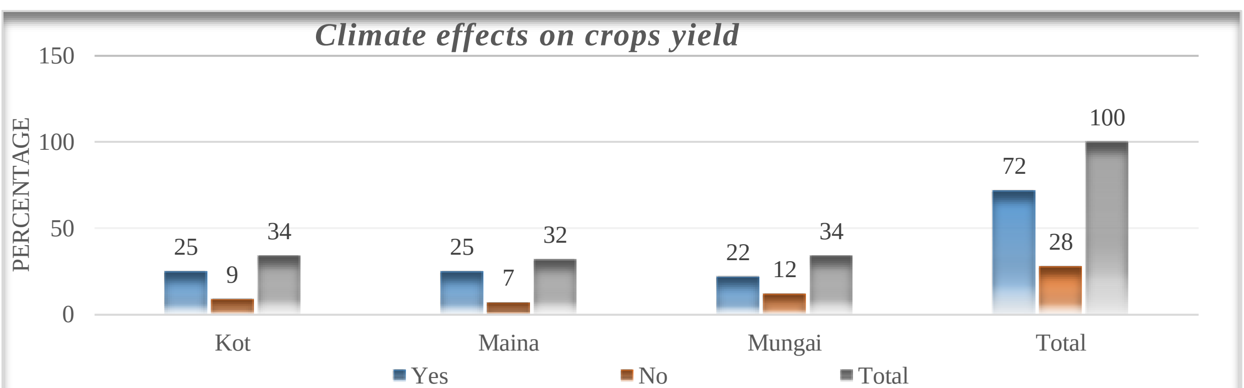
Figure 1: Distribution of the respondents regarding knowledge about climate change



Changing Climate Effect on Crops Yield

Climate change effect agricultural efficiency, quality and crop yield. Figure 2 highlight the effects of climate change on crop yield and quality. The finding show that majority (72%) of the sampled respondents opinion replied that changing climate badly effect crop yield and quality, while on the other side 28% respondents confirmed that changing climate have not effect on crop yield. In the majority positive opinion sampled respondents 25% were from Kot, 25% from Maina and the rest (12%) were belong to Mungai village. The result overall shows that most of the sampled respondents replied were positively that changing climate badly effect on crop yield and quality in study area.

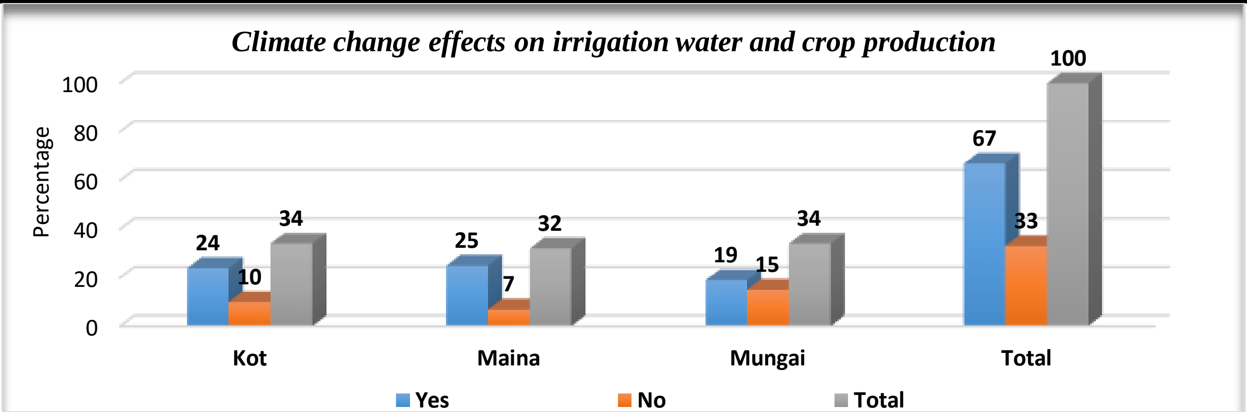
Figure 2: Distribution of the respondents based on changing climate effect on crop yield



Impact of Changing Climate on Availability of Irrigation Water and Crop Production

The impacts of climate change are most strongly felt in developing countries, where vulnerability is high and the ability to respond is limited. In developing countries like Pakistan, where agriculture is a main industry, this makes the sector especially vulnerable to environmental changes. Figure 3 highlight the availability and quality of water for irrigation and crop production due to changes in climate in the study area. The finding shows that majority (67%) of the sampled respondents replied that climate change had badly impact of crop production and irrigation system, while the remaining (33%) of the respondents confirmed that climate change had not effect on crop and water irrigation system. In the majority positive opinion sampled respondents 24% were from Kot, 25% from Maina and the rest (19%) were belong from Mungai village. The results overall indicates that most of the sampled respondents replied were positively that changing climate impact the availability, water quality for irrigation and crop production in the study area. This study findings is similar to Kumar et al. (2021) study, they stated that climate change has a detrimental impact on cereal production due to climate change.

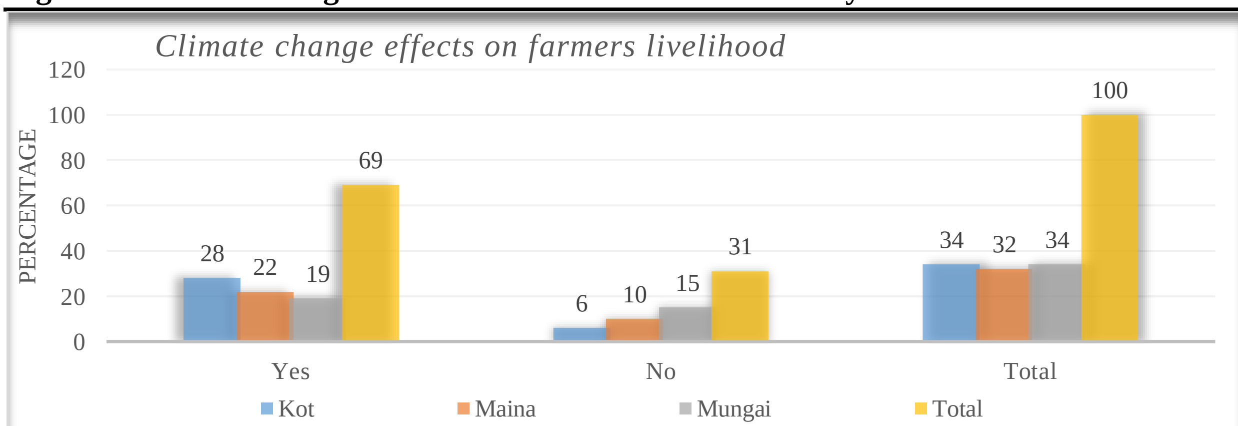
Figure 3: Changes in the availability of irrigation water and crop production due to climate change



Climate Change and Livelihood of Farmers

Climate change has significantly impacted the livelihoods of farmers, posing formidable challenges to their traditional way of life. Figure 4 finding reveals that majority 69 of the sampled respondent's opinion were positive that climate change has affected the livelihood of farmers while 31 percent of the respondents replied that climate change had not effect of farmer livelihood and food production. The results overall show that most of the sampled respondents replied were positive about climate change has affected the livelihood of farmers and food producers in the study area.

Figure 4: Climate change effect farmers livelihood in the study area



Climate Change Adaptations Strategies

Climate change brings change and becomes harsh for agricultural products. So, the farmers adopt various climate change adaptation strategies to combat the effects of climate change and for sustainable and healthy production (Naqvi et al., 2021). Table 1 indicates the distribution of the sample respondents regarding climate change adaptation strategies for agriculture. The result reveals that the majority (90%) of them are opting for improved seeds to better withstand changing climate conditions. Moreover, (83%) of farmers are using chemical fertilizers, and 92% are employing pesticides to protect their crops from the impacts of climate change. Diversification of crops is another prevalent strategy, with 89% of farmers planting different varieties to enhance resilience. Notably, 100% of farmers adjust their sowing periods, demonstrating a unanimous effort to align planting schedules with changing climate patterns. Furthermore, (81%) of farmers change their irrigation times to adapt climate fluctuations. Likewise, (84%) of farmers employ alternative strategies such as crop rotations to enhance their overall climate change adaptation measures in the study area.

Table 1: Farmers used strategies for climate change adaptation

Adaptation Strategies	Yes (%)	No (%)
Improved seed	90	10
Use of chemical fertilizers	83	17
Use of pesticides	92	08
Planting of different crops verities	89	11
Adjustment of sowing periods	100	00
Changes in irrigation times	81	19
Others (crop rotations)	84	16

The following table 2 shows binary logit regression relationship and effect of independent variables on adapting climate change adaptation strategies odds ratios. The independent variables in the table includes age, education, family size, income, landholding, f experience, tenancy status and strategies for climate change adaptation. The study reveals that an age has a positive and statistically significant effect on the likelihood of adapting of climate change adaptation strategies. The p-value for the age of the sample households was (P= .024) which is statistically significant at 5% level of significance. It means that if one year increase in age, we expect that (1.060) times increase the effect in adapting of climate change adaptation strategies on agriculture productivity. This study result is similar to Rajkhowa and Sarma (2021) study, they idicated that older farmers tend to have a better understanding compared to younger farmers. This shows that age is important because it is connected to the farming experience and the use of traditional knowledge by farmers. According to the table result education had positive effect on climate change adaptation strategies and statistically significant at 5% level. If one year increase in education, we expect that slightly the odds of adopting climate change adaptation strategies by (1.118) times. This study result is consistent with the study Sarkar et al. (2021), they stated that farmers with higher levels of schooling are anticipated to exhibit greater adaptability to climatic changes. The below table findings highlight that family size of the sample households had positive and significant effect of adapting climate change adaptation strategies. The co-efficient value for the family size is (β = .234 and p = .007), that is statistically significant at 5% level of significant and had positive effect on adopting climate change adaptation strategies. The result indicate that if one member increase in household, we expect that the odds ratio (1.264) times increase the likelihood of adopting climate change adaptation strategies for agriculture productivity. This study result is same like to the study Afzal et al. (2018), they indicated that family size and climate change adaption strategies for increase agriculture production had a fruitful relationship. Table 2 highlight that income coefficient of the sampled household were zero and the p-value is (p=.018) that is statistically significant at 5% level of significant showing that higher income increases the likelihood of adopting climate change adaptation strategies for agriculture is (1.000) times in the study area. The current study alike to the study of Yadav and Singh (2021), they stated that wealthy farmers are more likely than poor farmers to adopt climate change adaptation strategies for their farming activities . According to the below table landholding had positive and significant effect with adopting climate change adaptation strategies. The co-efficeint vaule for landolding is (β=.224 and P= .036), indicates that larger landholdings increase the likelihood of adopting climate change adaptation strategies for agriculture is (1.252) times in the research area. The study result same like with the study of Afzal et al. (2018), they revealed that larger landholding may have the resources and capacity to invest in modern agricultural technology. This can enhance agriculture productivity and makes it easier to adopt climate-resilient techniques. Table result reveals that experience is positive relationship with adapting climate change adaptation strategies. The coefficient value for experience is (β =.090, p = .031) that is statistically significant at 5% level of significance. It means that if one year increase in experience, we expect that the likelihood for adapting climate change adaptation strategies were increase odds by (1.094) times for agriculture. This study result is alike to the study Tubiello and Fischer, (2007), they stated that more seasoned farmers are more likely to notice ongoing climate conditions and more experienced farmers had more knowledge about climate change adapting strategies and had adapt advanced method for climate change adaptation strategies for agriculture to mitigate the negative effects of climate change as compared to less experienced farmers. Tenancy status had positive and significant effect at 5% level of significance on the likelihood of adapting climate change adaptation strategies in the research area. The regression co-effacement for tenancy status is (β = 1.120, p = .045) it means that if the land ownership increase 1 percent, we expect that the likelihood for adapting climate change adaptation strategies for agriculture is increase by (3.065) times. Table findings shows that strategies for climate change adaptation had negative and statistically significant effect of climate change on agriculture productivity. The co-efficient for climate change adaptation strategies is (β = -1.385 and p = .023), it means that if one unit increase in climate change adaptation strategies, we expect that (.250) times decrease climate change effect on agriculture productivity in the study area. The R^2 value shows that the model explains 60% variation in the dependent variables. However, the likelihood ratio (LR) Chi2 test was performed to measure the statistical significance of all the independent variables. The test shows a Chi^2 value of 76.148 with a p-value of .000, indicates that the overall model is statistically highly significant.

Table 2: Estimation of empirical model for effect of climate change adaption on agriculture

Independent Variables	β	S.E.	Wald	Sig.	Exp.(β)
Age	.58	.026	5.103	.024	1.060
Education	.111	.050	5.037	.025	1.118
Family size	.234	.087	7.268	.007	1.264
Income	.000	.000	5.567	.018	1.000
Landholding	.224	.107	4.395	.036	1.252
Experience	.090	.042	4.641	.031	1.094
Tenancy status	1.120	.558	4.025	.045	3.065
Strategies for climate change adaptation	-1.385	.610	5.145	.023	.250
Constant	-5.924	1.344	19.433	.000	.003
Number of observations =143,	R^2 = 60%,	LR Ch^2 =76.148,	Ch^2 p-value = .000		

Source: Own Calculation

Justification of the Findings

The study shows that various factors such as age, education, family size, income, landholding, farming experience, and tenancy status positively influence farmers' ability to adopt climate change adaptation strategies, making them more likely to protect and improve agricultural productivity. However, older and more experienced farmers are better equipped to use traditional knowledge and adapt to climate challenges. Moreover, education also plays a vital role in adopting climate strategies, as more educated farmers are more likely to adopt effective climate change adaptation strategies. Larger families, higher incomes, and higher landholdings provide farmers with more resources to invest in climate resilient practices. Furthermore, the study also shows that simply increasing adaptation strategies may not always lead to better outcomes, as complexity and costs can reduce effectiveness. Generally, overall the model used in the study is highly reliable, explaining nearly 60% of the variation in how farmers adapt to climate change.

Conclusion

The study concludes that climate change has had a major impact on farmers' ability to grow crops, manage irrigation systems, and sustain their livelihoods in the area. To discourse these challenges, strong adaptation strategies and effective actions are essential. Although farmers are trying to adapt to extreme climate conditions, they face significant difficulties due to limited knowledge and the high cost of necessary agricultural inputs. The low returns from their crops make it even harder for them to afford these inputs. Moreover, the study reveals that many farmers are unaware of the extension services that could assist them. The government has not yet sufficiently find out the needs of these farmers, leaving them unable to fully understand and tackle the challenges posed by climate change. Despite these difficulties, certain factors like age, education, family size, and income influence how farmers plan and adapt their farming practices. Furthermore, other important factors like size of their land, their farming experience, whether they own or rent their land, and the specific strategies they use to adapt to climate change. These factors are essential in determining how well farmers can adapt to the changing climate and maintain agricultural productivity. The study suggested that government make a broad national climate action plan that comprises specific strategies for mitigating climate change and adapting to its impacts on the agricultural sector and allot funds to improve rural infrastructure, containing resilient irrigation systems, flood control measures, and storage post-harvest facilities. These investments will improve the sector's capability to withstand extreme weather events. The study also recommended that government should prioritize the agriculture sector in policy decisions by offering free agricultural inputs, low-interest loans, and regularly surveying to villages to understand farmers' challenges and find effective solutions. It also emphasizes the need for farmer training and education programs focused on climate-smart agriculture, water-efficient practices, and pest and disease management in a changing climate, while also valuing traditional knowledge and indigenous practices.

References

- Abbas, S. (2022). Climate change and major crop production: evidence from Pakistan. *Environmental Science and Pollution Research*, *29*(4), 5406-5414.
- Afzal, M., Ilyas, M., Jan, S. S. A., and Jan, S. A. (2018). 2. Impact of climate change on crop adaptation: current challenges and future perspectives. *Pure and Applied Biology (PAB)*, *7*(3), 965-972.
- Ahmad, M. J., Iqbal, M. A., and Choi, K. S. (2020). Climate-driven constraints in sustaining

future wheat yield and water productivity. *Agricultural Water Management*, *231*, 105991.

- Ahmad, S., Israr, M., Yaseen, A., and Ahmad, N. (2017). Climate change trend analysis on selected food crops at central Khyber Pakhtunkhwa of Pakistan. *International Journal of Development and Sustainability*, *6*(12), 2082–2093.
- Ali, S., Andaleeb, N., and Ali, A. (2019). Technical Efficiency of Wheat Growers in District Swabi of Khyber Pakhtunkhwa, Pakistan. *Sarhad Journal of Agriculture*, *35*(4), 1336-1343
- Asseng, S., Ewert, F., Martre, P., Rötter, R. P., Lobell, D. B., Cammarano, D., & Zhu, Y. (2015). Rising temperatures reduce global wheat production. *Nature climate change*, *5*(2), 143-147.
- Audu, E. B., Audu, H. O., Binbol, N. L., & Gana, J. N. (2013). Climate change and its implication on agriculture in Nigeria. *abuja journal of geography and development*, *3*(2).
- Global Climate Risk Index 2020: https://www.germanwatch.org/en/17307
- Iqbal, E., Kazi, F., and Raza, S. (2022). Status of wheat production and associated nematode pests in Pakistan. *Pakistan Journal of Nematology*, *40*(1), 49-61.
- Jan, I., Ashfaq, M., and Chandio, A. A. (2021). Impacts of climate change on yield of cereal crops in northern climatic region of Pakistan. *Environmental Science and Pollution Research*, *28*(42), 60235-60245.
- Khan, A., Ali, S., Shah, S. A., Khan, A., and Ullah, R. (2019). Impact of climate change on maize productivity in Khyber Pakhtunkhwa, Pakistan. *Sarhad Journal of Agriculture*, *35*(2), 594–601.
- Khanal, R. C. (2009). Climate Change and Organic Agriculture. *Journal of Agriculture and Environment*, *10*, 116–127.
- Khubaib, N., Asad, S. A., Khalil, T., Baig, A., Atif, S., Umar, M., Kropp, J. P., Pradhan, P., and Baig, S. (2021). Predicting areas suitable for wheat and maize cultivation under future climate change scenarios in Pakistan. *Climate Research*, *83*, 15–25.
- Kumar, A., Nagar, S., & Anand, S. (2021). Climate change and existential threats. In *Global Climate Change*. (pp. 1-31) Elsevier.
- Mendelsohn, R. (2008). The impact of climate change on agriculture in developing countries. *Journal of Natural Resources Policy Research*, *1*(1), 5–19.
- Naqvi, S. A. A., Laeeq, M., Usman, M., and Hussain, B. (2021). Impact of Climate Change on Livelihood of Wheat Farmers in District Chakwal. In *35th AGM & Conference. Pakistan Society of Development Economists (PSDE)*.
- Othieno, L., & Shinyekwa, I. (2011). *Trade, revenue and welfare effects of the East African Community Customs Union Principle of Asymmetry on Uganda: an application of Wits-Smart simulation model.*
- Piao, S., Ciais, P., Huang, Y., Shen, Z., Peng, S., Li, J. & Fang, J. (2010). The impacts of climate change on water resources and agriculture in China. *Nature*, *467*(7311), 43-51.
- Rajkhowa, S., & Sarma, J. (2021). Climate change and flood risk, global climate change. In *Global Climate Change*. (pp. 321-339) Elsevier.
- Rehman, A., Ma, H., and Ozturk, I. (2020). Decoupling the climatic and carbon dioxide emission influence to maize crop production in Pakistan. *Air Quality, Atmosphere and Health*, *13*(6), 695–707.
- Salman, A., Husnain, M., Jan, I., Ashfaq, M., Rashid, M., & Shakoor, U. (2018). Farmers' adaptation to climate change in Pakistan: Perceptions, options and constraints. *Sarhad Journal of Agriculture*, *34*(4), 963–972.

- Sarkar, M., Pandey, D., Rakwal, R., Agrawal, G. K., & Sarkar, A. (2021). Impact of tropospheric ozone pollution on wheat production in Southeast Asia: An update. In *Global Climate Change*. (pp. 235-266) Elsevier.
- Shahid, F., & Adnan, M. (2021). Climate Change: Impacts on Pakistan and Proposed Solutions. *Pakistan Social Sciences Review*, *5*(2), 223–235.
- Singh, P., Yadav, D., and Pandian, E. S. (2021). Link between air pollution and global climate change. In *Global Climate Change* (pp 79-108) Elsevier.
- Sonia, Sadozai, K. N., Khan, N. P., Jan, A. U., & Hameed, G. (2019). Assessing the impact of climate change on wheat productivity in Khyber Pakhtunkhwa, Pakistan. *Sarhad Journal of Agriculture*, *35*(1), 284–292.
- Tubiello, F. N., & Fischer, G. (2007). Reducing climate change impacts on agriculture: Global and regional effects of mitigation, 2000-2080. *Technological Forecasting and Social Change*, *74*(7), 1030–1056.
- Yadav, P., & Singh, B. (2021). Radioecology: Dissecting complexities of radionuclide transfer under climate change. In *Global Climate Change* (pp. 297-320) Elsevier.
- Zubair, L., Nissanka, S. P., Weerakoon, W. M. W., Herath, D. I., Karunaratne, A. S., Prabodha, A. S. M. & McDermid, S. (2015). *Climate change impacts on rice farming systems in Northwestern Sri Lanka* (No. GSFC-E-DAA-TN22326). Imperial College Press.