Assessing the Impacts of Climate Change on Agriculture and Livelihoods in the Potohar Plateau, Pakistan

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Abstract
This paper is an exploratory study on how climate change has been perceived to affect agricultural livelihoods at the Potohar plateau, one of the places that is most vulnerable to the degradation of the environment. A structured questionnaire given to 400 respondents is used in this research to examine the impact of dynamic climatic conditions, including rising temperatures, irregular rainfall patterns, the prevalence of pests, and extreme weather conditions, on crop production, livestock health, and traditional farming technology. The other question that the study looks into is how well local communities are implementing adaptive methods and how they are ready to engage themselves as participants of climate-smart agricultural training programs. The results indicate that most of the respondents confirm the fact that there are serious climate related shocks to agricultural productivity and income. The majority of farmers state that the traditional activities are getting less and less productive, and they also see the alterations in botany of the crops as well as the growing stress of the animals. Correlation analysis reveals positive relationship between perceived impact and adoptive measures of the adaptive, which means the stronger the impact is perceived to be, the greater the chances are to find measures towards the solutions. On the other hand, constraints that have a moderate association with challenges associated with adoption of adaptation strategies entail the following: shortage of resources, shortage of knowledge, as well as institutional constraints. Positively, a high number of the respondents show readiness to take part in training programs and people habits to be innovative. In addition, local knowledge has been playing a crucial role in the context of local adaptation efforts. The paper has reached the conclusion that both the indigenous wisdom and modern climate-resilient methods should be combined, enhancing institutional support, and extending outreach under some capacity-building activities targeted at agricultural resilience building. The study can be of use to better comprehend the grass root climate vulnerabilities and provide practical guidelines to policymakers, extension workers or development practitioner who may be interested in improving the adaptive and sustainable livelihoods of the people in the climate vulnerable areas such as Potohar.

Keywords: Climate Change, Agriculture livelihood, livestock health, Climate-resilient, Potohar

Introduction

The Potohar Plateau, which is a semi-arid region in the Northwest of Pakistan, is becoming highly susceptible to climate change, which, in turn, is having huge effects on its agriculture and rural livelihoods. Genix and Naz (2022) showed in their study that the agricultural drought was spatially and temporally dynamic using remote sensing and geospatial analysis of the Potohar rainfed region. In their study, they found that since 2000, there have been more droughts and their effects have been more extreme, especially on wheat, which is a staple crop in the area. In the research, it was noticed that drought mapping should be done to support adaptation responses.

Sardar et al. (2022) explored the determinants of farmers' adoption of climate-smart agriculture (CSA) in the Potohar region. They discovered that practices like education, availability of information and the support of the institutions are significant determinants in adopting CSA practices. The study outlined that improving these elements would lead to resilience against climate-induced stresses. Abbas (2022), investigated the impact of the climate change events on streamflow within the Kanshi River, which is a component of the Potohar plateau. The paper found that there was a substantial increase in temperature and a decrease in rainfall over the last 50 years, leading to a drop in water discharge. Such alterations to hydrology pose a threat to agricultural and other water supplies.

Aitzaz et al. (2024) discussed the broader implications of climate change on the sustainability of agriculture in Pakistan, including the Potohar region. They observed that the changing weather patterns and increased occurrences of extreme events are degrading crop yields and threatening food security. The authors proposed using climate-resistant farming methods and better use of water. The effect of climatic change on the groundwater-based livelihood was measured in the Soan River Basin of the Potohar region through a study conducted by [Authors] (2023). The study concluded that unpredictable precipitation has caused a decrease in groundwater levels, resulting in low output from dug wells that are crucial in irrigation and household use. In the study, there was an emphasis on the necessity of modernizing water extraction methods to support livelihoods.

Drees et al. (2022) employed an application and plan-based approach by using the Soil and Water Assessment Tool (SWAT) to approximate the water balance of the future land use of the Potohar Plateau. Their findings revealed that inland water resources are highly vulnerable to changes in land uses (changes in land cover and changes in land cover types) and climate variability, as the hydrological regime is significantly impacted, affecting water availability that can support crop production. Rahmatullah (2019) studied how climate change is affecting the livelihoods in the Potohar region. The research found out that there are three major livelihood strategies among rural households and that climate change is affecting those disproportionately involved in agriculture, which causes diversification and adaptation practices.

Khoso et al. (2024) carried out an extensive review of the literature about the effects of climate change in the Pakistani countryside. They argued that the rural regions, including the Potohar Plateau, are experiencing a higher level of vulnerability as they have a low adaptive capacity and depend on climate-vulnerable sectors, including the agricultural industry. In one of the research findings on soil erosion within the Potohar plateau by Khan et al. (2023), the influence of climate change was indicated as an added problem to the already existing problem of land degradation. The analysis revealed that erosion is a problem caused by heavy rainfall and deforestation, which decreases land productivity and food security.

A work by Suleri and Shah (2018) dwelled upon the issue of the effect of climate change

on rural households in Rajanpur, characterized by similar climatic conditions as Potohar. The study has found that climate-related stresses like floods and drought affect small landholders badly, causing income to be unstable and leading to food insecurity.

The disastrous impact of floods in Pakistan in the year 2022 was on the agricultural sector and infrastructure. By employing remote sensing to evaluate the damage, Younas et al. (2024) had to acknowledge significant crop losses and late planting seasons, which are, in turn, essential in examining climate risks in such an area as Potohar. In the Swat District, Ali et al. (2023) studied farmers' perceptions of climate change vulnerabilities and their adaptation measures. Despite their geographical differences, the applications of the research findings would provide insight into the adaptive behaviours that may apply to the Potohar context. All these studies speak in multi-faceted terms about the effect of climate change on agriculture and the livelihoods of the Potohar plateau. It would be necessary to envisage a comprehensive solution to these issues that would involve technology and policy as well as community support to increase resilience and sustainability.

Problem Statement

The Potohar Plateau, a semi-arid region in northern Pakistan, plays a critical role in the country's rainfed agriculture and rural livelihoods. Yet, the area is becoming more susceptible to the negative outcomes of climate change, such as the changing rain patterns, constantly occurring droughts, or increased temperature and soil erosion. These changes in the environment are significantly interfering with agricultural output and putting into jeopardy the stability of the social and economic system of the rural communities, which mainly rely on farming as a primary source of income. Nevertheless, even with increasing concern, little empirical literature exists related to the ways through which climate change is transforming agricultural activities and rural livelihoods in the Potohar plateau. It is a problem as it does not provide a localized understanding that would be used to generate specific and long-lasting adaptation strategies. Thus, a multidimensional analysis of climate change effects on agriculture and livelihood within the Potohar is urgently required to inform policy, planning, and interventions to induce community-based adaptations.

Significance of the Study

The study titled "Assessing the Impacts of Climate Change on Agriculture and Livelihoods in the Potohar Plateau, Pakistan" holds significant importance due to the region's socio-economic and ecological vulnerability to climate variability. A substantial part of the rain-fed (barani) Potohar Plateau is also dependent on seasonal rainfalls to carry out agricultural activities, which are the backbone of the rural economy. As the temperature goes up, precipitation becomes less predictable, and even more common, extreme weather develops, exposing the income of farming communities. The research is essential because it seeks to create empirical evidence of the impacts of climate change on agricultural productivity, water, soil, and, ultimately, the income and the food security of the locals.

Moreover, the results of this study will also be helpful to policymakers, development practitioners, and local stakeholders in understanding the exact issues of the Potohar region. The identification of the most susceptible communities and the principal climatic stressors affecting their livelihoods will allow incorporating these

factors into the planning of specific climate adaptation and building of resilience interventions. The study also contributes to the broader context of climate change in South Asia since it analyses issues regionally, where the national level evaluations may not always give the appropriate information. It also contributes to the Sustainable Development Goals (SDGs), specifically the following: SDG 1 (No Poverty), SDG 2 (Zero Hunger), and SDG 13 (Climate Action), by making actionable knowledge available to reinforce local adaptive capacities. Therefore, the present research can be called a crucial Step to the creation of a climate-resistant agricultural system and the provision of sustainable rural livelihoods in the Potohar Plateau.

Methods and Procedures:
This research paper employs a quantitative research design to evaluate the effects of climate change on agriculture and livelihoods in the Potohar Plateau in Pakistan. Quantitative methods would be suitable to measure the variables of climatic pattern, agricultural productivity, and indicators of socio-economic status systematically, as well as generalized conclusions only based on numbers.

Study Area
The research was conducted in selected districts of the Potohar Plateau, including Rawalpindi, Chakwal, Attock, and Jhelum. A predominantly rain-fed agricultural system characterises these districts, making them highly vulnerable to climatic variations.

Research Design
The data will be collected using a cross-sectional survey design wherein multiple data points are collected simultaneously. The research will be focused on finding out the statistical connections between the signs of climate change (e.g., temperature increase, rainfall instability) and their impact on farming (e.g., crop yield, cropping patterns) and livelihoods (e.g., income, food security, level of employment).

Population and Sampling
The intended population will include people who are smallholder farmers and rural households practicing agriculture in the Potohar Plateau. It will use multistage stratified random sampling technique.
1. First, the selection of tehsils and villages will be carried out proportionally in each district.
2. Then villages will be randomly selected and households will be randomly chosen in them.

To ensure representativeness and statistical power, a sample size of 300–400 households will be determined using Cochran's formula.

Data Collection Tools
To carry out data collection systematically and reliably, it will develop a structured questionnaire as the key tool of the study. The survey will be made up of mainly closed-ended questions, which are meant to register quantified answers that resonate with the research purposes. Such questions will be grouped under various sub-heads, such as demographic, understanding climate change, the impacts of changes witnessed in crop and animal production, adaptation measures, limitations experienced by them, and the interest levels towards implementing climate-smart practices. Closed questions assist in

the collection of the same kind of data by a high number of respondents to facilitate coding, analysis and comparison. The small sample will also help the questionnaire to be pre-tested to clear up any ambiguity, as well as make it relevant and valid, before the final data collection is conducted.

Data Analysis
After the collection, the data was then inserted meticulously into the Statistical Package of the Social Sciences (SPSS) system of analysis. Descriptive and inferential techniques of statistics will be used in conjunction. They will be presented in descriptive statistics in the form of frequencies, percentages, means, and standard deviation in the demographic profile of respondents and overall trends in their responses to climate change perceptions and adaptive behaviours. To carry out inferential analysis, in case of continuous variables, such as Pearson correlation, Chi-square tests, and t-tests or ANOVA, depending on the nature of the variables, will be performed to determine the relation and differences between the key variables. These inferential tools will assist in ascertaining the fervor and signification of affiliations, e.g. the connection between the understanding of effects of climate change and the utilization of adaptive measures, or between socio-economic determinants and the perception of limitations. Moderated by SPSS, the process involved in data analysis is sound and consistent, making the results of the research valid and reliable.

Results and Discussions

Univariate Analysis

The table below shows the opinion of respondents regarding different statements on the issue of the effect of climate change on agriculture and local adaptation measures. The respondents rated the questions that were administered by a 5-point Likert scale, with the range being strongly disagree to agree strongly.

Statements	Agree	Strongly agree	Neutral	Disagree	Strongly disagree
Climatic conditions affected the agricultural income of the farmers	63	148	60	58	71
Due to climate change, pest and disease attacks have decreased on crops	48	81	69	66	136
Due to climate change, traditional farming practices are no longer effective.	54	147	65	63	71
Climate change affects the flowering time of crops and fruits.	55	152	57	59	77
Rising temperatures and heat waves affected livestock health	27	186	65	50	72
People rely on traditional knowledge to deal with changes in the climate	54	210	33	42	61

People are willing to participate in training programs on climate-smart agriculture.	96	201	37	33	33

The responses indicate that a significant proportion of participants recognize the adverse effects of climate change on agriculture. For instance, a combined 211 respondents (Agree = 63; Strongly Agree = 148) believe that climatic conditions have negatively affected farmers' income. Similarly, 199 respondents strongly agreed that climate change has altered the flowering time of crops and fruits.

In contrast, when asked whether climate change has decreased pest and disease attacks, a large number disagreed or strongly disagreed (66 + 136 = 202), indicating that pest issues may have worsened.

Traditional farming practices were seen as less effective due to the changing climate by a majority (Agree = 54; Strongly Agree = 147), and 213 respondents felt that rising temperatures and heatwaves have compromised livestock health.

Interestingly, 264 participants (Agree = 54; Strongly Agree = 210) acknowledged the role of traditional knowledge in coping with climate change. Furthermore, an overwhelming majority (297 respondents) expressed willingness to participate in training programs on climate-smart agriculture, indicating a positive attitude toward capacity-building initiatives.

Bivariate Analysis

The table below shows the association between the influence of the terms of climate change on the respondents and the adaptive measures adopted. To determine the significance of this relationship, a Pearson correlation test was run to assess the strength and importance of the relationship.

Correlations			impact	Adoption
impact	Pearson Correlation		1	.390**
	Sig. (2-tailed)			.000
	N		400	400
adoption	Pearson Correlation		.390**	1
	Sig. (2-tailed)		.000	
	N		400	400

The correlation analysis reveals a statistically significant positive relationship between the impact of climate change (or intervention, depending on context) and the adoption of adaptive measures by the respondents. The Pearson correlation coefficient is 0.390, indicating a moderate positive correlation between the two variables. This suggests that as the perceived impact increases, the likelihood of adopting adaptive strategies also increases. The p-value is 0.000, which is less than the conventional significance level of 0.01, confirming that the correlation is statistically significant. The sample size for this analysis is 400 respondents, which supports the reliability of the results. The table below presents the Pearson correlation between perceived constraints and

the impact of climate-related challenges. This analysis was conducted to examine the direction and strength of the relationship between the two variables.

	Constraints	Impact
Constraints	1	**.312****
Sig. (2-tailed)		.000
N	400	400
Impact	**.312****	1
Sig. (2-tailed)	.000	
N	400	400

The results indicate a moderate positive correlation between constraints and impact, with a Pearson correlation coefficient of 0.312. This relationship is statistically significant at the 0.01 level (p = 0.000), suggesting that as constraints increase, the perceived impact of climate-related issues also tends to rise. The analysis was based on responses from 400 participants, adding reliability to the findings.

Recommendation
On the basis of the study findings, a number of important recommendations are put forward to improve the climate resilience and sustainable agricultural livelihoods in the Potohar Plateau. To begin with, it is evident that local communities are still heavily depending on traditional knowledge as a means of coping with altering climatic condition. The 264 who have answered in agreement or strongly agreed to this is a clear indication that we need to combine the traditional forms of practice with the new forms of climate smart agriculture. The inherent agricultural practices including organic pest management and water conservation strategies should be identified as well as their documentation and validation by the institutions of agricultural extension. It may help the farmers to adapt to climate variability by integrating an ancient piece of wisdom with new scientific advancements.

Secondly, considering almost 300 respondents were willing to be involved in training programs on climate-smart agriculture, indicates the significance of capacity-building activities that have their specific definitions. These training programs are supposed to be on drought resistant crop, good irrigation system such as drip irrigation, integrated pest management and practicable livestock. Such programs can be better reinforced with demonstration plots and community workshops as well as mobile-based learning modules in local languages. Gender friendly methods must also be embraced so that women farmers are not left out in the process of adaptation.

The occurrence of pests and diseases is also a key issue, given that most of the respondents did not agree with the assumption that the situation has reduced because of climate change. As a matter of fact, climate variability seems to have led to increased pests and diseases vulnerability. To help mitigate these, Community-based pest surveillance systems which are supplemented by training on the technique of biological

controls and the less use of chemical pesticides can help to build a more sustainable agriculture. Collaborations with the agricultural research organizations must as well be enhanced in order to present to the agricultural sector the more pest resistance crop varieties and adaptive solutions that have been tested together with the local environment.

Another factor being noticed by the study is the growing effect of the scarcity of water and temperature rise. The impacts of heatwaves negatively impacting on the livestock and the time of flowering of crops as widely recognized by the respondents. There is thus a suggestion to ensure that people embrace water harvesting methods e.g., by constructing farm ponds, check dams and rooftop rainwater collection. Moreover, introducing more efficient systems of irrigation to irrigate water by sponsoring the management of the watershed with the community can help a lot to increase the efficiency of water use and to distribute the resources more fairly, at least during the drought seasons.

The early warning systems and climate advisory services also need to be developed in order to further support more farmers. Farming suggestions, current weather scenarios, and warnings on pests ought to be broadcasted in the local dialects through SMS, local radio, and social media. This kind of timely information can assist farmers make informed decisions so that losses of crops can be limited and preventive actions by farmers on behalf of livestock and crop yields can be implemented. The other important recommendation that would capitalize on the fact that smallholder farmers are vulnerable to income shocks due to floods and draughts is livelihood diversification. Farmers are to be motivated and assisted to venture into high-value productions of horticulture, agroforestry as well as small-scale animal rearing. They can also get better returns through cooperative marketing, food processing, and packaging of their produce. Training of farmers on how to venture other activities to earn income, as well as micro finance programs would further supplement the capacity of farmers to engage in other income generating activities.

In addition, effective adaptation is facilitated by policy and institutional backing. The provincial, district, and agricultural departments at the local level should maintain climate resilience in their planning and budget. This includes special subsidies to climate-resilient inputs, crop insurance, and infrastructure creation. Scaling up successful practices and mobilization of resources to adapt to the climate can also be done by enhancing the capacity of local agricultural officers and fostering public-private partnerships. Finally, the idea of monitoring and evaluation should be given the most significant emphasis. Incorporation of participatory monitoring systems should be made to monitor the effect of the adaptation strategy, changes in productivity and income, and to obtain regular responses from farmers. This data-oriented practice will be helpful in planning training, design of policy interventions, and making adaptation process responsive to changing needs of farming communities.

Finally, results indicate that both the local communities in the Potohar Plateau have a strong desire and dire need to embrace climate-smart practices. Through integration of conventional expertise along with scientific innovations, as well as increasing the support given to institutions and encouraging inclusive and flexible approaches, sustainable farming systems that will endure the negative consequences of climate change can be established. Such initiatives will, in the end, lead to the

achievement of rural livelihoods and long-term food security in the area.

Conclusion

The results of this research reveal a profound effect of climate change on agriculture and the rural economy in the Potohar Plateau. Farmers are facing climatic changes in a variety of ways, such as changes in rainfall patterns, the rise in temperature, pest and disease attacks, and a reduction in the traditional farming tools that the farmers have been using. All these are not only causing problems in crop yields and livestock health but are also destabilizing the income and causing food insecurity among smallholder farmers.

Though these facts are discouraging, the research also shows that respondents have a high level of awareness about climate change, as well as a high readiness to change through capacity building and implementing climate-smart agricultural practices. Such positive attitudes towards training programs and orientation on traditional knowledge serve as a sound basis for community-based adaptation strategies. The relationships between the perceived impacts, implementation of the adaptive practices and constraints also reinforce the need to ensure that farmers receive adequate institutional, specific training and appropriate information on time. Increasing access to climate-resistant technology, water management systems, incorporating traditional knowledge, and providing early warnings are essential measures that would be taken to become resilient.

Summing up, climate change is a particular threat to the agricultural stability of the Potohar region; however, with collaborative tasks of governmental institutions, research centres, and locals, one could achieve proper adaptation. It can be believed that at least the negative impacts of climate change can be alleviated and the rural livelihood in the region can become sustainable by enabling farmers to respond, as the case is, by using the available knowledge and tools as well as making use of available resources, to act proactively.

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