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Rural Farmers' Perceptions for the Impacts of Climate Change and Adaptation Policies on Wheat Productivity: Insights from a Recent Study in Balochistan, Pakistan

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Abstract: Climate change (CC) is a worldwide environmental issue affecting all economic sectors, especially agriculture. Pakistan is one of the countries most affected by CC due to the country's vulnerability to catastrophic events and limited ability to adapt. Assessing existing activities for adaptation to CC at the farm level is critical to understanding their success and recommending additional government measures. This study analyzes possible farming practice modifications that Pakistani farmers may adopt to reduce the loss of agricultural output due to the rising prevalence of dangerous weather events by CC. Data for the current research were gathered from 432 wheat farmers in rural Pakistan. This article investigates many factors that impact farmers' decisions to CC adaptation in crop production utilizing binary logit (BL) and multivariate probit (MVP) models. Gender, education level, farming experience, farm size, level of damage, access to finance, and training participation are characteristics that substantially affect farmers' likelihood of adapting to CC. Farm size and participation in CC training were the most critical factors influencing farmers' CC adaptation decisions. Policy recommendations were presented to increase the farmers' resilience in the study areas to CC. These comprise expanding CC training courses, developing regulations to encourage agricultural integration, and integrating CC and adaptation to CC principles into the operations of regional organizations. Finally, based on the findings, policymakers will be better equipped to address the challenges posed by CC and create a more resilient agricultural sector. This, in turn, will contribute to improving food security, ensuring sustainable agricultural growth.

Keywords: climate change; crop yield; adaptation; farmers; rural Pakistan

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1. Introduction

The effects of global warming jeopardize the achievement of the Sustainable Development Goals (SDGs), which include providing food security for all, promoting sustainable agriculture, helping farmers around the world, and encouraging climate change (CC) action at all levels [1]. The CC predictions and increasing climate hazards pose enormous difficulties for agricultural growth in less developed countries [2]. Pakistan has been identified as one of the countries most affected by CC due to its limited adaptive capacity and poor infrastructure [3]. It is expected that by 2050, the temperature in Pakistan will increase by two to three times, and there will be a significant change in the distribution of rainfall [4]. According to the Global Climate Risk Index, Pakistan ranks eighth in the list of countries most affected by CC and hazardous weather events from 1995 to 2014 [5]. Over the past two decades, extreme weather and CC have had a major impact on rural life and agricultural production of major crops such as rice, wheat, and sugar cane [6,7]. The historic floods from

2010 to 2014 and the extreme drought from 1999 to 2003 demonstrated the susceptibility of rural households to CC in Pakistan [2,6].

Given that more than 2–3% of Pakistan's population live in remote areas and depend on the agricultural sector for their livelihoods, the resilience of the agricultural sector to CC is one of the most pressing issues for economic growth in the country [8,9]. CC has a negative impact on local food security in Pakistan, which is mainly dependent on food crops, destructively affecting food production and food costs [10–12]. According to one study, 37% of daily caloric intake in Pakistan comes from wheat, which is cultivated on 8.66 million hectares [2,13]. Nevertheless, the current average grain yield in the country (2797 kg/ha) is much lower than the world average yield (3268 kg/ha) [14]. In Pakistan, farmers harvested only 32% of the potential crop yield [13,15]. One of the main reasons for the lack of food supply across the country is the huge gap between crop yields and potential yields. For example, Abed et al. [2] and Lei et al. [16] pointed out that the gap between Pakistan's per capita wheat demand and supply is widening from 2013 to 2050. Uneven agricultural expansion and continued population growth can have severe impacts on local food security and livelihoods [1,17]. Poor and slow management of CC can make things worse.

A successful farming adaptation level is needed to provide food security and safeguard rustic livelihoods from the negative influences of CC [18–20]. However, an important issue at the local level is that growers, as key stakeholders, must alone bear most of the adaptation load. Under ideal market conditions, farmers may still benefit and receive price increases to cover higher production costs. However, this is not always the case, especially in emerging countries such as Pakistan, where non-market influences (flawed environments) dominate price decisions and farmers may experience higher production costs and poorer returns. Therefore, there is an urgent need to develop public adaptation strategies that consider farmers' goals and adaptation potential. From a policy perspective, it is critical to understand the variables that influence growers' adaptation choices and the impact of their actions on agricultural productivity, which can vary across regions and scales [21–23]. Investigating the dynamics of advantages from continuing private adaption initiatives to CC may also be useful. According to Arshad et al. [24] and Abid et al. [2], if there are significant short-term adaptation advantages, for instance, this may encourage policymakers to make more efforts to assist growers in the adaptation procedure by granting them access to farm consulting services and assistance from experts.

In the last 10 years, research on CC and agriculture has progressed from research on mitigation [25,26]. However, in the analyses of the impact and studies on adaptation [27], the majority of the literature on agricultural adaptation to CC is from emerging or developed African nations [28]. However, there is limited research on how South Asian nations, particularly Pakistan, are adapting to CC, and limited studies such as Abid et al. [2] and Esham and Garfoth [29], look at CC from the angle of agricultural adaptations to changes in the environment. The majority of research on adaptation has emphasized farmers' responses to shifting climatic circumstances, their adaptation tactics, drivers, and related restrictions for various geographic and socioeconomic contexts. Few studies have focused on this issue at the farm, and empirical assessments of the efficacy of adaptation efforts are difficult to come by [2,30]. Therefore, more research that economically evaluates existing adaptation processes may be able to show the size of the benefits and make policy recommendations on activities needed to accelerate community adaptation [2,8]. Due to the information vacuum, the current study explores how farmers adapt to CC and its impact on wheat production in rural areas. The current study highlights the following issues: The two main objectives of this study were (i) to investigate the key mitigation measures adopted by farmers in rural Pakistan to address CC and the variables influencing these measures, and (ii) to assess the impact of these measures on farmers impact on wheat production. The findings may help develop more targeted economic measures to improve the ability of these farmers to adapt to climate change.

This paper is divided into six parts after the introduction, Section 2 describes the literature review and conceptual framework. Section 3 presents the material and methods. Section 4 describes the research results. Section 5 describes the discussion. The final section presents conclusions, policy recommendations, limitations, and future directions of the study.

2. Literature Review and Conceptual Framework

2.1. Literature Review

Adaptation has been described as the act of reducing a community's sensitivity to change [1]. Climate adaptation requires reducing sensitivity to existing and future threats of CC. An individual's ability to adapt largely determines his vulnerability. While a few people are better equipped than others to respond to a crisis, not every community or family member will be equally affected by a given climate event. Therefore, the adaptation to CC depends on various situations [31]. Many studies emphasize the significance of farmer attributes in the adoption of CC adaptation techniques. In an investigation by Deressa et al. [32], gender has a favorable impact on growers' adaptation decisions. According to Huffman [33], education enhances growers' capability to study and obtain info and expertise regarding CC and adaptation technology. Diendéré et al. [34] argue that an increased understanding of climatic events and agricultural technology could help in adaptation. The potential for CC adaptation is also directly connected to household size. For example, Khatri-Chhetri et al. [35] determine that bigger household members are more likely to embrace innovative agricultural methods. Aside from these variables, the presence of a climatic shock influences the adoption of CC adaptation techniques [36,37]. According to the Intergovernmental Panel on CC [1], when a producer has previously experienced a temperature-linked climate shock, they are more inclined to apply adaptation approaches. According to Deressa et al. [32], decreasing precipitation induces producers to implement soil conservation techniques. Furthermore, some study indicates a beneficial association between the usage of digital technology and growers' CC adaptation methods. According to Diendéré [38], innovative technology enables farmers to obtain actual data without incurring trip expenditures and so make suitable modifications.

The use of coping mechanisms is also influenced by farm features. Multiple investigations show that farm size influences the adoption of adaption techniques. According to Perz [39], pesticide adopters had a bigger amount of cleared land than non-adopters. Furthermore, some studies contend that economic variables explain the possibility of adopting various agricultural techniques in response to CC [39–41]. Some other authors demonstrated that agricultural funding, particularly transfers of cash, alleviates this cost restriction and hence encourages the adoption of CC adaptation measures [42–44]. Investigations show that, besides economic and farmer features, institutional variables are expected to play a significant influence in CC adaptation. According to Yegbemey et al. [45], show that farming groups and relative growers can help adapt to CC adaptation strategies because farmer groups frequently serve as venues for the exchanging of information, individual experiences, and social assistance. Furthermore, Diendéré and Ouédraogo [1] approve that interactions with agri-extension services improve the possibility of implementing soil conservation techniques. Agri-extension services educate and advise farmers on optimum agricultural techniques. This literature synthesis emphasizes four kinds of characteristics that are more likely to impact the selection of CC adaptation techniques. There are three categories: institutional considerations, financial factors, and characteristics of the farmer.

Many research investigations have been conducted to evaluate the influence of CC adaptation techniques on family profits and food guarantees. This section provides an overview of available research on the impact of coping methods. A few findings highlight the influence of CC adaptation technology on food insecurity and household income, via econometric and comparative empirical surveys. On the one hand, some research demonstrates that adopting CC adaptation measures improves food security and boosts adopters' income. On the other hand, research indicates that adaption strategies have

no beneficial or substantial influence on income or food insecurity. According to several investigations, adopting CC adaptation approaches increases food security and boosts adopters' revenue.

Zakari et al. [46] employ matching approaches to indicate that producers' adaptation tactics have a favorable effect on family revenue and food insecurity. Researchers claim that growers who utilized CC adaptation strategies have a higher likelihood of raising their family's profits by 7722 FCFA than growers who do not. Authors found that those who employ adaptation tactics are seven to nine percent more probable to have access to food than people who do not. According to Ndiaye et al. [47], implementing CC adaptation techniques raises the average yearly farmers' income by 607,000 to 702,000 FCFA. Furthermore, the authors discover that using adaptation techniques raises the average value of family nutrition utilization by 8–37 points. Farmers that use adaptation choices had greater caloric food ingestion [48]. Berhe et al. [49] suggest that coping measures such as income diversification, and land management methods are among the most significant indicators of family profits. In general, research shows that adopting agricultural methods has a favorable influence on production, household income, and food safety [1,50–52]. On the other hand, research indicates that adaption strategies have no beneficial or substantial influence on income or food insecurity. Mulumeoderhwa et al. [53] demonstrate that adaption measures employed by rural producers are unlikely to provide food for families in the long run in the Minembwe mountains of South Kivu. Correspondingly, Pailler et al. [54] indicate that in Tanzania, community-based natural resource management approaches had little effect on the income of households. Berhanu and Beyene [55] also found that the widespread practice of growing food with fences did not substantially contribute to household food security in southern Ethiopia. This work stands in stark contrast to other literary works in several respects. First, this analysis assesses the impact of CC adaptation on crop production by rural farmers using panel data. Second, we used BL and MVP models in the current study, which are very helpful for agricultural development systems at national and international levels.

2.2. Conceptual Framework

The concept of adverse weather events brought on by CC, such as floods, droughts, cold snaps, etc. could have a negative impact on agricultural production and the household's ability to support itself. Therefore, to reduce the adverse effects of CC on their existence, farmers will adopt various adaptation strategies. However, the household's resources for generating income could impact these adaptive actions. This study examines how family assets for subsistence affect how households adjust to CC in crop productivity. This study's central premise is that households with higher CC damage levels and better assets for their livelihood will be more inclined to apply adaptive measures compared to other households. Natural, human, physical, social, and financial capital are the five assets that are recognized as being essential to a household's ability to support itself. Human capital is defined at the household level as the quantity and caliber of labor available (Figure 1) [56,57].

The term "social capital" refers to the social assets that enable people to achieve their livelihood goals, including networks and connections that increase access to larger institutions, membership in more organized groups, and relationships based on mutual respect, reciprocity, and trade. Natural resources that are important to people's livelihoods are referred to as "natural capital", and this encompasses both intangible public goods such as the environment and biodiversity as well as divisible resources utilized directly for production. Basic infrastructure includes things such as providing access to inexpensive transportation, safe homes and buildings, and a sufficient quantity of clean water and sanitary facilities. It also involves access to knowledge and producer commodities, such as tools and equipment, as well as clean and inexpensive energy. Financial resources for accomplishing livelihood goals, including available stock and consistent cash flow, are included in financial capital.

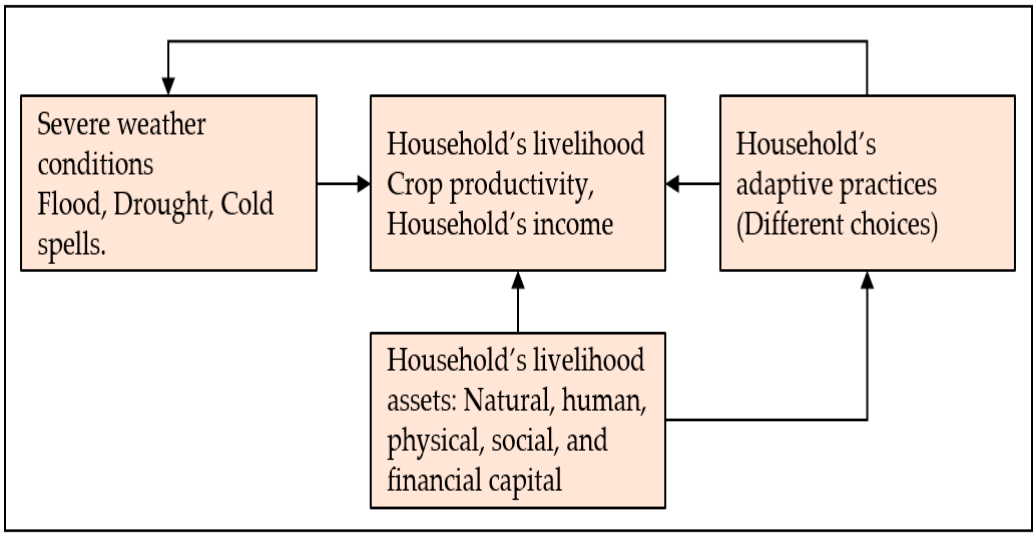

Figure 1. Factors influencing household climate change adaptation strategies (adapted from DfID [57]).

3. Material and Methods

3.1. Description of Research Site and Data Collection

Balochistan is a province in southwest Pakistan with a land size of 347,190 square kilometers. It is Pakistan's largest province in terms of landmass, accounting for 44% of the country's total landmass, nevertheless, it has a low population. Agriculture has enormous economic potential in Balochistan [58,59]. Many places in the province are suited for the cultivation of cash crops. However, due to several causes, agriculture's actual potential is not being fulfilled. Water shortages, CC, and a lack of energy, for example, are affecting agriculture in the province, and over 81% of farmers are concerned about these challenges [60]. The current study was carried out in Pakistan's Balochistan province from September 2022. To obtain the data needed for the current investigation; (i), 432 questionnaires were delivered to wheat growers. Direct meetings with respondents were conducted utilizing a multistage random sample approach to gather basic information. To better understand, the influence of CC adaptation on crop yield in Balochistan, study data were composed from 4 districts namely (Ziarat, Loralai, Qilla Saifullah, and Harnai), based on their proportion of agricultural production (Table 1).

Table 1. Samples distribution.

Country	Province	Districts	Tehsils	UCs	Villages	Farmers	Samples
Pakistan	Balochistan	Harnai	2	4	4	108	432
		Loralai	2	4	4	108	
		Killa Saifullah	2	4	4	108	
		Ziarat	2	4	4	108	

In the (ii) step, 8 tehsils were selected from 4 districts to complete the planned questionnaire, and in the (iii) stage, 16 union councils (UCs) is nominated from 8 selected tehsils. In the (iv) stage, 16 nominated villages were randomly tracked from 16 UCs and finally obtained key information from 432 respondents in designated villages. The questionnaire for this study is separated into several portions. The primary unit of the prepared questionnaire covered the socioeconomic and demographic data of the particular samples. The rest of the feedback form was planned to collect CC data from respondents. Questionnaires were used to obtain existing data from wheat growers. Due to the questionnaire's complexity, we conducted detailed interviews. The questionnaire was pre-tested to eliminate uncertainties. This contained detailed information on farmers' socio-economic factors, CC

adaptation, and other study-relevant variables. Stata 14 was used to edit and code the data to verify the accuracy, authenticity, homogeneity, coherence, and completeness.

3.2. Data Analysis Models of the Study

3.2.1. Binary Logit (BL) Model

The Binary logit (BL) model, also known as the logistic regression model, is a statistical model used to analyze binary (dichotomous) dependent variables. It is a type of regression model that estimates the probability of an event occurring (coded as 1) versus not occurring (coded as 0). Overall, the BL model provides a useful framework for analyzing binary outcomes and understanding the relationship between predictor variables and the probability of an event occurring. Since the 1960s, the BL model has been frequently used due to its analytic benefits for handling discrete binary outcomes [61]. According to Cramer [61] and Greene [62], a BL model has the following basic structure [63]:

$$Pi(\mathrm{Y}_i = 1)\frac{e^{X\beta}}{1 + e^{X\beta}} \tag{1}$$

where Pi is the chance that one event will occur $Y_i = 1$: event occur; $Y_i = 0$: event does not occur), X is a vector of the factors impacting and β is a vector of parameters. The BL model may be extensively analyzed using the marginal effect coefficient. The following equation is used to calculate marginal effect coefficients:

$$ME = \frac{\partial \Lambda(X\beta)}{\partial X} = \Lambda(X\beta)[1 - \Lambda(X\beta)]\beta \tag{2}$$

where X is the independent variables matrix in the logit model (influencing factors). The logit model's parameter matrix is β. To assess the many factors influencing growers' decisions to use adaptation techniques for extreme weather events in agricultural productivity, a BL model was utilized in the current research. Choosing whether to use adaptation tactics is a distinct choice for farmers (yes or no). One particularly refers to growers who have adjusted their crop yield to CC. Zero designates growers who did not adjust to CC, in contrast. The investigation's main hypothesis was that a variety of issues affect growers' choices when it comes to using CC adaptation measures in crop productivity (Table 2).

3.2.2. Multivariate Probit (MVP) Model

The Multivariate Probit (MVP) model is a statistical model used to analyze multiple correlated binary (dichotomous) dependent variables simultaneously. It is an extension of the binary probit model, which is used for analyzing a single binary dependent variable. Overall, the MVP model provides a useful framework for analyzing and understanding the relationship between multiple correlated binary outcomes and their predictor variables. The grower's strategies for adapting to extreme weather occurrences in this research region give a variety of options based on the data gathered. These possibilities are intricately connected and rely on one another theoretically. In other words, there is a correlation between different agricultural producers' adapting techniques to severe occurrences [11]. According to Belderbos et al. [64], the connection between error terms is mostly caused by the correlation between the many numerous alternatives. Nevertheless, the MVP model might get rid of these associations [65]. Sequential models are a component of the MVP model. These models represent the effects of descriptive features set on each of several alternatives and permit error terms to be flexibly associated [66]. The MVP method also permits the unobservable variables to have a flexible correlation structure [67]. The MVP method assumes that based on the explanatory factors, the multivariate output is an unobserved latent variable resulting from a multivariate normal distribution [68]. According to the equation for MVP method for observation, i and m are as follows [69]:

$$Y_{im} = 1 \; if \; Y_{im}* > 0 \; and \; 0 \; otherwise \; (i = 1, 2, \ldots, N; m = 1, 2, \ldots, M) \; Y_{im} = Y_{im} \; farmers'^{*}\beta_m + \varepsilon_{im} \tag{3}$$

where N shows the observation number, M represents the number of the option, X_{im} indicates the matrix of the explanatory variables, β_m is the parameters matrix, and ε_{im} is the error term matrix. We utilized the PVP method to examine the variables distressing the likelihood that farmers would employ various adaptation methods to deal with extreme weather occurrences. The research also advanced the theory that a variety of factors affect how farmers adapt to CC. The human, physical, social, economic, and natural capitals, as well as other livelihood assets, were all directly affected by these elements (Table 2).

Table 2. Descriptive statics of the model variables.

Variables Name	Descriptions	Mean (S.D)
Gander	Gender of farmers (1 = male)	0.24 (0.43)
Age	Farmers' age (years)	45 (12)
Education	Farmers' education (years)	7.9 (3.8)
Farm income	Farm income of household (PKR/year)	16.1 (11.7)
Level of damage	Level of damage because of extreme weather events (PKR/year).	1.9 (2.4)
Tube well	1 = farmer owner, 0 otherwise	0.64 (0.48)
Animal	Number of animals at the farm (number)	3.47 (1.92)
Climate Change	1 = if farmer has experienced related to CC; 0 otherwise	0.86 (0.34)
Extension services	1 = if a grower has aware of extension services; 0 otherwise	0.27 (0.15)
Tractor	1 = if the farmer keeps a tractor; 0 otherwise	0.09 (0.13)
Farm size	Farm size (ha)	6.6 (4.5)
Labors	Household farm laborers on participating farms	0.2 (0.1)
Farming experience	Farmers' farming experience (years)	24.01 (12.0)
Cultivated areas	Area of cultivated (ha)	6.6 (4.3)
Wheat productivity	Productivity of wheat (kg/ha)	1980 (450.8)
Membership	Member in organizations (1 = yes)	0.96 (0.20)
Participation	Participate in CC training (1 = yes)	0.22 (0.42)

4. Empirical Results

4.1. Descriptive Statistics of the Model Variables Description Statistics of the Variables

According to the descriptive data presented in Table 2, it is observed that 22 percent of respondents in the study area actively participated in CC training. Furthermore, the average age of the respondents is approximately 45 years, indicating a relatively mature sample. In terms of education level, the average respondent has completed about 8 years of schooling, highlighting the educational background of the participants. Interestingly, the data reveals that 64% of the growers in the study possess tube wells, while the remaining 36% rely on borrowing water for irrigation purposes. This finding suggests a thriving groundwater market in Pakistan. Moreover, the study outcomes indicate that a significant proportion of growers are living in poverty, as estimated through various indicators. Additionally, the average area of cultivated land per household is reported to be 6 hectares, emphasizing the substantial agricultural activities in the region. The average wheat yield per hectare is recorded to be 1980 kg, providing insight into the productivity levels of wheat cultivation in the study area. These findings contribute to a comprehensive understanding of the socioeconomic and agricultural aspects within the context of the research.

4.2. The CC Influence on Crop Production

The region's growers identified five substantial negative impacts of CC on their crop yields (Table 3). Decreased crop output and rising production costs were two of the consequences indicated by the farmers that were most common since they were stated by many farmers. Compared to untrained farmers, skilled farmers are substantially more aware of the negative impact of CC on crop yield. The number of trained farmers (97%, 63%, and 15%) who identified the reduction in yield of crops, rise in production costs, and increased costs associated with adaptation as negative consequences of CC on agricultural output is much greater than the proportion of untrained respondents (62%, 29%, and 4%). Training programs play a crucial role in enhancing farmers' understanding of CC and its detrimental effects on agricultural output. These programs provide farmers with the knowledge and skills necessary to adapt their farming practices to changing climatic conditions and mitigate the negative impacts of CC on agricultural productivity. By participating in training programs, farmers can learn about the specific ways in which CC affects their local agricultural systems. They can gain insights into the potential risks and challenges posed by CC, such as changes in temperature, rainfall patterns, and the increased frequency of extreme weather events. This understanding enables them to make informed decisions and take appropriate actions to mitigate potential losses.

Table 3. Growers' assessments on the effects of CC on crop yields (n-432).

Indicators	Trained Farmers (112)	Non-Trained (320)	Different Value
Increase crop production	63	29	34 ***
Decrease crop production	97	62	35 ***
Reduce cultivated land	8	9	−1
Intensify adaptation cost	15	4	9 ***
Soil erosion	4	4	0

Note: *** shows the significance at the level of 1%.

Table 4 demonstrates the agricultural output losses caused by extreme weather occurrences among rural farmers in study areas. A majority of farmers (80%) claimed that extreme weather occurrences had harmed their crop productivity. Furthermore, a significant number of growers (59%) indicated that they were unable to cultivate during the second season owing to drought. This demonstrates the significance or negative consequences of drought on crop productivity in study areas. The majority of farmers in the research areas are unable to grow their crops due to drought and inadequate irrigation infrastructure. Farmers may try to plant green beans during this summer, but the harvest is quite poor because there is a lack of water. As a result, throughout this summer and fall season, farmers leave their properties to go fallow and opt to work as hired agricultural laborers. Their income as hired farm laborers makes up a sizeable portion of the family's revenue [63,70]. Due to severe weather, growers also reported losses in their agricultural output. Each household at the research site lost an estimated 2.3 million Pakistani rupees in every year of agricultural production, or 8.0 million Pakistani rupees, as a result of extreme weather occurrences. The loss was mostly caused by a drop in agricultural productivity and a rise in yield costs (costs of fertilizer, and seedling for replantation). While the yearly crop output deficiency can appear little in terms of absolutes for growers, it accounts for close to 20 percent of their household's annual crop revenue. For the growers in the commune, particularly the impoverished growers whose subsistence relies heavily on crop output, this is an enormous expense.

Table 4. The CC-related losses in agricultural productivity for farmers.

Indicators	Total (n = 432)
Respondents' percentage that drought has hindered second-season planting	59
Percentage of respondents affected by special circumstances	80
Annual crop loss as a percentage of total crop income	19
Assessed yearly crop loss each year (million PKR)	2.3
Assessed yearly crop loss each year (million PKR)	8.0

4.3. The CC Adaptation of Rural Farmers in Agriculture Productivity

The negative impact of CC on the agriculture system, especially in terms of annual crop yield, is evident. This is supported by the assessments provided by growers, who report significant deficits in their crop yields. These deficits can be directly attributed to the region's frequent occurrence of extreme weather conditions caused by CC. Agriculture productivity has been negatively impacted by CC, particularly the annual crop. This is clear from growers' assessments of their deficits in crop yield as an outcome of the region's frequent incidence of extreme weather conditions. Farmers have thus focused more on applying various adaptation methods to avoid or reduce the harm caused by CC to alleviate their circumstances (Figure 2).

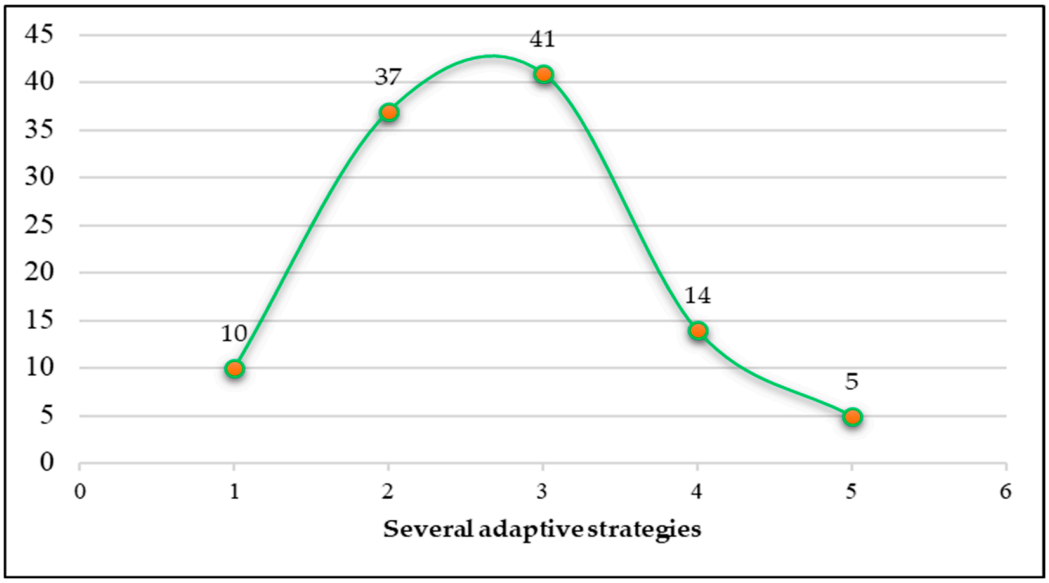

Figure 2. Several techniques that farmers have adapted to CC.

A substantial proportion of growers in the region, 75 percent, reported using at least one adaptation technique to dangerous weather actions in their crop productivity (Table 5). In addition, some growers (10%) have one CC adaptation plan. Farmers often used two to three adaptive methods. Just three percent of farmers adopted all of the CC adaptation techniques in crop productivity. Table 5 details the particular adaptation measures employed by farmers to deal with CC in crop productivity. These involve the practice of intercropping, changing cultivar types, altering the crop farming schedule, keeping updated on weather predictions, and altering varieties. The most well-liked techniques among them are crop variety changes and weather forecast monitoring. When faced with severe occurrences in agricultural output, 68 and 69% of persons said they changed their crop kinds and paid attention to weather reports, respectively. Many farmers in the area claimed to have employed crop kinds resistant to drought, particularly when growing crops in the second growing season. They as well utilized short-season crop types

to prevent floods, which inevitably happen when the second season's harvest is in full swing [63].

Table 5. Percentage of respondents reporting using specific agricultural methods to adapt to CC. (n, 432).

Indicators Name	Total Sample	Trained Farmers (112)	Non-Trained Farmers (320)	Different Value
Utilize at least one adaption technique	75	87	70	17 ***
Particular adaptive techniques				
Adjust farming timing	28	45	25	20 ***
Change crop varieties	68	79	59	20 ***
Follow-up forecasts of weather	69	87	61	26 ***
Change to other cultivar types	20	12	22	−10
Intercropping	8	20	5	15 ***

Note: *** displays the significance at the level of 1%.

The adoption of adaptable farming methods by farmers to deal with extreme weather events in agricultural output was significantly influenced by CC training programs (Table 5). Compared to farmers who skipped the training classes, a lot more farmers who took part in CC training used adaptive measures. The 87, 79, 45, and 20% of trained growers, correspondingly, watched weather forecasts, changed crop varieties, altered the farming schedule, and used intercropping. In comparison to the number of farmers who did not undertake training (61, 59, 25, and 5%), the statistics are much higher. This reveals the value of CC training programs in enhancing growers' ability to adjust to extreme weather events that affect crop yield.

4.4. The CC-Related Factors Influencing Farmers' Decisions on Crop Production

The factors influencing farmers' decisions to adjust crop yields to extreme weather occurrences were examined using a BL model. Farmers' decisions have a discrete value of (One and Zero). One indicates farmers who have adapted to CC adaptation strategies, whereas zero indicates farmers who have not adopted these strategies. Initially, the model had 15 explanatory variables (Table 2). However, only 12 variables were ultimately used in the empirical model after checking for multicollinearity utilizing the correlation matrix among descriptive factors. Furthermore, a robust standard error approach was used to solve the model's heteroskedasticity problem. Studies show that the robust standard error can successfully address heteroskedasticity since it provides reasonably precise *p*-values to guarantee the model's relevance [71]. The observed BL model's estimated parameters are displayed in Table 5. The Wald χ^2 (12), which is highly significant at 1% (Prob > χ^2 = 0.0000), indicates that there is a substantial association at the 1% level between the probability of farmers adapting and the 12 key factors. These 12 factors described 15.20% of the likelihood that growers will adapt to CC, according to the Pseudo R^2 value of 0.1520.

The likelihood of farmers adapting was favorably impacted by three important criteria. These comprised the farm size, level of damage, and participation in CC-related sessions (Table 6). The likelihood that farmers will adapt to CC was most significantly influenced by participation in CC training courses. Ceteris paribus, farmers who attended the CC training course had a 15.7% higher likelihood of adapting than those who did not. Additionally, the findings specified that growers with large farming plots were more probable to adapt to CC than those with smaller farm plots. In a similar vein, households with high damage levels had a 4.7% greater likelihood of adapting to CC than homes with low damage levels. The other variables had no discernible influence on farmers' decisions on CC adaptation.

Table 6. Outcomes of the BL model's evaluation of farmers' choices for agricultural production adaptation to CC.

Variables Name	Coefficients	*p*-Value	Marginal Effects	*p*-Value
Gender	−0.403	0.159	−0.073	0.175
Education	0.020	0.744	0.004	0.744
Farm size	0.141 ***	0.001	0.024 ***	0.001
Farming experience	0.012	0.357	0.003	0.359
Damage level	0.282 **	0.026	0.048 **	0.015
Climate Change	0.03 ***	0.034	0.02 ***	0.078
Animal	0.278	0.263	0.048	0.271
Tube well	0.04	0.035	0.03	0.079
Participation in CC training	1.137 ***	0.000	0.158 ***	0.000
Extension services	0.01 ***	0.55	0.002	0.017
Membership	0.764	0.163	0.154	0.225
Tractor	−0.02	−1.025	−0.003	0.019
Access to credit	0.286	0.272	0.050	0.281
Constant	−1.845 **	0.048	-	-
Log-pseudo likelihood	−199.33	-	-	-
Wald χ^2 (12)	42.59	-	-	-
Prob > χ^2	0.0000	-	-	-
Pseudo R^2	0.1520	-	-	-
N	432	-	-	-

Note: *** and ** show significance at the level of 1% and 5%, respectively.

The MVP approach was employed to assess the variables influencing farmers' decisions regarding which adaptation strategies to implement in their crop production to deal with extreme weather occurrences (Table 5). Five distinct options (farmers' unique adaptation techniques) are included in the MVP model's dependent variable, which is assumed to have a value of one when farmers use such methods and a value of zero when they do not. There were only 12 explanatory factors chosen after checking for multicollinearity utilizing the correlation matrix amongst the descriptive variables. Furthermore, utilizing the robust standard error method, the model was examined for heteroskedasticity. The MVP methods estimations are displayed in Table 7. According to the study results of Wald χ^2 (45) (prob > χ^2 = 0.0000), the overall association among growers' propensity to use particular adaptation methods and descriptive factors is similarly substantial at the 1% level. Furthermore, χ^2 (10), which demonstrates a link between the five adaptive practices, is very substantial (Prob > χ^2 = 0.0000). The extremely substantial association coefficients also demonstrate the interconnectedness of the various adaptive farming techniques. This supports the MVP model's viability in this study. The findings in Table 7 demonstrate that the likelihood of farmers adopting four to five adaptation techniques in their crop production was strongly influenced by their participation in CC training and their farms' size. Family members who participated in the training programs are more inclined to intercrop, change crop kinds, modify the farming schedule, and monitor weather predictions as ways of adapting to CC. To adapt to CC, families with extensive farm sizes are also more likely to alter crop kinds, modify the farming schedule, convert to new seed types, and pay attention to weather predictions.

Table 7. The projected outcome of the MVP model of factors of farmers' adaptation practices in agricultural productivity to CC.

Variables Name	Adaptation Practices				
	Adjust Farming Timing	**Follow-Up Weather Forecasts**	**Change Crop Variety**	**Switch to New Cultivate Types**	**Intercropping**
Gender	0.161	0.064	−0.436 ***	−0.113	0.071
Education	0.030	0.029	0.044	0.082	0.010
Farm size	0.043 ***	0.066 ***	0.052 ***	0.058 ***	0.010
Farming experience	0.012	0.006	0.016 **	0.016 **	−0.005
Damage level	0.037	0.043	0.070	0.083	−0.006
Participation in CC training	0.671 ***	−0.270	0.560 ***	0.670 **	0.820 ***
Climate change	0.039 ***	0.064 ***	0.051	0.057 ***	0.009
Household labor	0.120	−0.080	0.074	0.084	0.064
Extension services	0.035	0.042	0.069	0.081	−0.005
Membership	0.630	0.560	0.623	0.470	0.141
Tractor	0.010	0.003	0.012	0.015	−0.004
Access to credit	0.323 **	0.195	0.066	0.260 *	0.032
Constant	−2.706 ***	−2.215 ***	−1.517 **	−1.916 ***	−1.768 ***
Correlation	Coefficients			*p*-value	
p_{21}	0.530 ***			0.000	
p_{31}	0.360 ***			0.000	
p_{41}	0.215 *			0.054	
p_{51}	0.155 *			0.054	
p_{32}	0.565 ***			0.000	
p_{42}	0.565 ***			0.000	
p_{52}	0.340 ***			0.002	
p_{43}	0.570 ***			0.000	
p_{53}	−0.090			0.328	
p_{54}	0.294 ***			0.001	
Log-pseudo likelihood	−820.33			-	
Wald χ^2 (45)	138.84			-	
Prob > χ^2	0.0000			-	
n	432			-	

Note: likelihood-ratio test of H_0: $p_{21}, p_{31}, p_{41}, p_{51}, p_{32}, p_{42}, p_{52}, p_{43}, p_{53}, p_{54}$ 0; χ^2 (10) = 260.12 Prob > χ^2 = 0.0000. ***, **, and * are significant at 1%, 5%, and 10% correspondingly.

The likelihood that farmers would switch crop types and follow weather forecasts to adapt to CC is greatly affected by their agricultural knowledge and level of damage. Farmers with greater expertise are more likely than farmers with less experience to switch crop kinds and follow weather forecasts to adapt to CC. Similar to how families with high levels of CC damage are more likely to alter their crop types and pay attention to weather forecasts than other households. In contrast, intercropping, changing the farming calendar, and choosing new cultivar kinds are not greatly influenced by the farmer's experience or damage level. The likelihood that farmers would convert to new cultivar varieties and pay attention to weather forecasts is greatly and favorably influenced by their educational level. Higher-educated growers are more inclined to modify their crop kinds and pay attention

to weather forecasts to adapt to CC. At significance levels of 5% and 10%, accordingly, access to financing was substantially correlated with farmers' choices to modify the lunar calendar and pay attention to weather forecasts. By modifying crop cultivation time and keeping updated on weather predictions, households having access to available financial sources are inclined to adjust to CC in crop yield. The probability that growers will switch crop kinds in response to CC was the only factor that substantially influenced gender. Regarding particular adaptation techniques, families are more likely to switch crop kinds to respond to CC if a member has taken CC training. Families with bigger farm holdings and higher levels of CC damage are more inclined to switch up their crop kinds. Changes in crop types to adjust to CC are more inclined to be made by more seasoned farmers, while male farmers are considerably less inclined to utilize this adaptive strategy. To adapt their crop production to CC, households with bigger farms and household heads with greater scholastic achievement are more probable to move to novel cultivar varieties. Participation in CC training, level of education agricultural experience, farm size, damage level, and financial availability all have a substantial impact on the adaptive practice of monitoring weather predictions. Last, intercropping is primarily used by households where at least one member has taken CC training.

5. Discussion

According to the research's results, producers used intercropping, changing crop kinds, altering the agricultural schedule, switching to other cultivar types, and monitoring weather forecasts as important adaptation methods. These results are similar to Nhemachena and Hassan [72] and Trinh et al. [63] regarding how growers in several areas of China and Africa adjusted to CC. Among the adaptive techniques employed by growers in a research area, switching crop kinds was the maximum widely utilized tactic. This well-known adaptation technique was also revealed in investigations by Comoé and Siegrist [73] in Côte d'Ivoire, Mu et al. [74] in Myanmar, Asfaw et al. [75] in Malawi, and Jin et al. [76] in China. The investigation additionally showed that employing weather prediction info to alter agricultural production under CC conditions is the maximum preferred adaptation approach utilized by growers. This contradicts the conclusions of previous research, such as Mu et al. [74], which indicated that weather information is just a factor influencing farmers' adapted strategies to CC rather than a farmer's adaptive strategy. Previous surveys found that weather information had no substantial impact on farmers' decisions about CC adaptation.

The findings of the BL and MVP models used in the present research indicate that farmland and participation in CC training are the most significant influences on farmers' decisions about CC adaptation. Comparing farmers who did not attend any training to those who did, it was exposed that the latter group adopted adaptive methods more frequently. The research revealed that the majority of wheat growers in the research area have little awareness related to CC. The study indicated that the majority of growers have little awareness regarding CC, while growers who attended CC training sessions had greater knowledge of the phenomenon, its effects, and the significance of adaptation in minimizing losses. They become more likely as a result to adjust to CC and lessen the losses in their crop production. Just 22 percent of growers reported having attended CC training sessions. However, skilled farmers have far greater knowledge of CC than untrained farmers (Table 3). The proportion of skilled farmers who used CC adaptation measures is also much greater than that of untrained farmers. This demonstrates the need of expanding the number of farmer-specific CC training courses.

Nevertheless, research by Mu et al. [74] in Burma and Piya et al. [68] and Gentle et al. [77] in Nepal revealed that training either had adverse consequences or had no influence on farmers' decisions to adapt to CC. Further research outcomes display that families with large farms size were more probable to adapt to CC than those with smaller farms. Nhemacena and Hassan's [72] findings as well as those of Gentle [77], agree with these findings. This may be attributed to the reality that bigger farms often experience greater financial hardship from CC than smaller ones. Agricultural household work and

participation in community organizations appeared to have no impact on farmers' ability to adjust to CC. These results concur with those of Mu et al. [74] in Myanmar and Piya et al. [68]; Gentle et al. [78] and Khanal et al. [79] in Nepal. There was no discernible difference in analyzed households' access to agricultural labor in the research region. This could help clarify why this element did not have a substantial influence on growers' probability of acclimatizing to CC. Furthermore, the majority of administrations, excluding the growers' union, were people's groups that prioritized fostering social activities above increasing agricultural output. Therefore, becoming a member of these associations did not assist farmers become more CC adaptable.

6. Conclusions, Policy Recommendations, Limitations, and Future Directions

6.1. Conclusions and Policy Recommendations

This research analyzed the adaptive strategies of rural farmers in Pakistan and identified the elements impacting growers' response to CC. Outcomes indicated that farmers had lost 20 percent of their yearly revenue from farming output owing to extreme environmental actions related to CC. Growers in the area used several adaptation measures to reduce these losses, including changing crop forms, moving to new crop forms, altering agricultural calendars, monitoring weather forecasts, and intercropping. Farmers in the study region's most popular adaptation techniques, nevertheless, were weather prediction monitoring and crop variety changes.

According to the findings of BL and MVP models, the size of the farmer's farm and their participation in CC learning were key factors in determining how likely they were to adapt to CC. Other elements that had a substantial impact on the farmers' propensity to adopt adaptive practices were their degree of education, the extent of CC damage, availability of financing, and gender. Conversely, the farmers' likelihood of adjusting to CC was not greatly affected by the availability of family agricultural labor or participation in local groups. Consequently, expanding the training programs on CC may be a good method to increase farmers' abilities to adapt to CC in the area. Farmers with less education and experience might benefit from these important training programs. The majority of farmers, particularly those with less education, should be capable of comprehending and following the training sessions on CC adaptation. The provincial government should also put in place regulations that would encourage the region's farms to be consolidated. To do this, it is first important to demonstrate how this strategy works in practice in other areas to inspire locals to sign up for the program. Second, local governments need to spread knowledge about the advantages of combining agriculture to withstand adverse weather conditions. Third, administrative processes must be simplified to attract both farmers and businesses to engage in the program. Finally, additional regional development projects/planning must incorporate the required rules to encourage land agglomeration. Government policies should promote the incorporation of CC principles and adaptation strategies into the operations of community organizations.

6.2. Limitations and Future Directions

This research study has various limitations. First, since the research focused on wheat productivity, caution should be exercised when extending the findings to other crops. This is because agricultural extension services vary in nature from crop to crop. To avoid generalizing the results to other crops, future studies should be conducted to investigate the effects of CC adaptation on other crops. Researchers can also explore differences in the requirements of different crops for agricultural extension. Second, the number of participants in this study is still small due to the limitation of survey funds. The sample farmers are from one province. In this context, caution must be exercised when extending the findings of this paper to other provinces of Pakistan. To overcome the limitation of small sample size, future surveys can increase the sample size by selecting farmers from multiple provinces. Alternatively, researchers could use data from a national survey to increase the sample size. Third, it is hard to analyze the effect of CC adaptation on crop productivity

using cross-sectional data. To overcome the limitations of utilizing cross-sectional data, future investigations may utilize panel data to capture changes over time. This will allow researchers to observe the dynamic impact of CC adaptation on agricultural production and sustainable agriculture.

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