Research Article

Navigating Climate Uncertainty: Determinants of Agricultural Adaptation Strategies in District Peshawar

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Abstract | The study aims to explore the determinants of short-term and long-term agricultural adaptation strategies in response to climate change in District Peshawar. Primary data of 400 farmers is analyzed through a multinomial logit model for both periods separately. Short-term strategies are immediate or seasonal responses to climate change, including crop diversification & changing in farm operation, nutrient & pest control management, and mixed cropping. However, long-term adaptation strategies are the enhancement of structural resilience to climate change. Long-term strategies include changing crop types & location, water management, and the development of new technology. The short-term model shows that experience, access to climate change information, access to the market, and awareness of climate change play crucial roles in an immediate response to climate change, particularly the crop diversification & changing in farm operation. The long-term model results show that experience, climate change information, water availability, adaptation cost affordability, access to markets, access to technology, and financial resources significantly determine the selection of long-term strategies, particularly changing crop type & location and the development of new technology. Overall, short-term adaptation strategies are mainly driven by experience and climate awareness, while long-term strategies depend on human capital, resource availability, and institutional support. This confirms that adaptation decisions are heterogeneous and strategy-specific rather than uniform across farmers and periods. Based on empirical analyses, this study suggests that awareness programs, water availability, subsidy provision, and access to agricultural technologies are required to strengthen farmers' adaptive capacity to climate change and to enhance agricultural productivity.

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Introduction

The agriculture sector plays a crucial role in the economies of the developing world (Azam and Shafique, 2017). In the case of Pakistan, it generates around 24 % share of GDP and 37.4 % of total employment (GoP, 2024). This sector is the most traditional and oldest form of economic subsistence, where new adaptation and greater productivity are essential for economic sustainability (GoP, 2019). Unfortunately, its performance is declining continuously more than expected because of less crop production and poor strategies. The inefficiencies reduce the overall output and make this sector vulnerable to climate change (CC), which continuously affects agricultural production (Janjua *et al*., 2010).

Pakistan has four distinct weather conditions with different cropping seasons; as a result, crops are sensitive to climate change. Thus, higher temperatures affect crop production, with excessive rainfall weakening this sector and negatively affecting agricultural productivity (Shakoor *et al*., 2011; Abbas and Mayo, 2021). Pakistan ranks among the top rice producers and exporters, accounting for around 8% of global rice. During 2010–2017, the rice cultivation area declined by about 10%, and rice yield reduced by 6.8%. This is mainly associated with climate variation (Janjua *et al*., 2021). Similarly, wheat is the main crop and a leading staple food of the agricultural sector. However, a reduction of around 14.7% in wheat crop has been observed in recent years due to climate change (Syed *et al*., 2022). This sector faces more hurdles due to a lack of facilities and improper use of available resources (Haider *et al*., 2016).

It is important to protect the agriculture sector from the negative impact of CC through various strategies, as it is one of the main sources of income and livelihoods (Rahman *et al*., 2022). To cope with the adverse impact of CC, adaptation is one of the most effective tools. Adaptation, according to the Intergovernmental Panel on Climate Change (IPCC), is the process of adjustment to actual or expected CC and its impact (IPCC, 2014). Likewise, GoKP (2022) defines adaptation as the process of reducing actual and expected CC effects. According to the geographical and environmental needs of crops, several adaptation methods can be used to cope with CC and improve overall agricultural productivity (Smit and Skinner, 2002; Mustafa *et al*., 2017).

Adaptation strategies in the theoretical literature are often grouped into long- and short-term adaptation strategies. According to the literature, short-term strategies are defined as immediate responses to address existing or expected short-term weather fluctuations. These actions are primarily intended to mitigate seasonal fluctuation (Smit and Skinner, 2002; Kurukulasriya and Rosenthal, 2003). Short-term strategies include crop diversification & changes in farm operation, nutrient & pest control management, and mixed cropping. On the other hand, long-term adaptation involves progressive strategies that go beyond immediate responses and require adjustments in agricultural planning to enhance the stability of the agriculture sector over decades. It is the enhancement of structural resilience to CC in the agricultural sector. Long-term strategies include changing the types & location of crop cultivation, development of new technology, and better management of water (Kurukulasriya and Rosenthal, 2003; Tafula *et al*., 2025).

The implementation of adaptation strategies reduces crop vulnerability to CC and improves productivity, but farmers face different challenges in this process. Various factors affect farmers' choices of selecting these adaptation strategies. Variables such as farmers' working experience, land size, land type (irrigated or unirrigated), and land ownership status (owned, rented, or half-shared) determine farmers' decisions to adopt adaptation strategies. Similarly, other resources, including access to CC information, availability of water, affordability of adaptation, access to the latest technology, and awareness of CC impact & adaptation to CC, influence farmers' behavior in selecting any strategy (Mustafa *et al*., 2017; Dang *et al*., 2019).

Most empirical studies analyze adaptation as a single aggregated choice. Adaptation strategies are tools or processes that farmers prioritize to adapt according to the time framework, environmental conditions, and crop requirements. These strategies are diverse in nature; some are short-term, while others are long-term processes in terms of timing framework. Literature, particularly empirical studies, neglected time-horizon limits policy insights. A few theoretical studies separate these methods into periodic groups, such as short-term and long-term strategies. To the best of our knowledge, no empirical study has separately examined the determinants of short-term and long-term agricultural adaptation strategies within a unified framework. This study will explore the determinants of these strategies separately through a multinomial logit model. Based on empirical results, it will suggest how to protect crops from the impact of CC and enhance agricultural productivity in both short- and long-term.

Theoretical framework

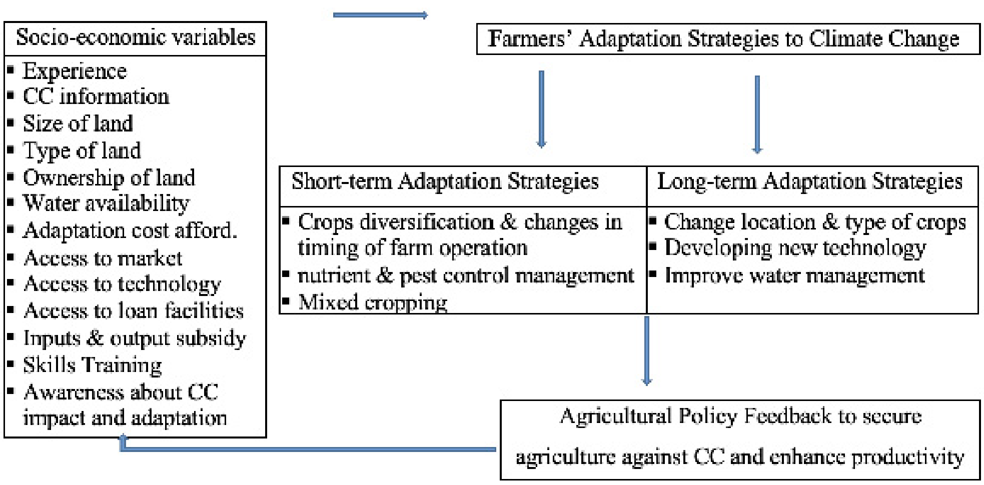
Random Utility Theory by McFadden (1974) is a fundamental framework used to model individual decision-making, particularly when choosing among multiple alternatives. It posits that individuals aim to maximize their utility/profit. An outside observer cannot predict choices with certainty due to unobserved factors. This makes choices probabilistic. In this context, farmers have different options in the short and long run, and each option gives different costs and benefits. They opt for the most suitable option in both periods to protect the agriculture sector from the effects of CC and to increase overall agricultural productivity.

Production maximization decisions depend on socio-economic factors. Various theories explain how socio-economic and technological factors determine farmers' adaptation decisions to CC. According to the Human Capital Theory by Schultz (1961), education, skill, and training are critical investments in human capital that increase productivity and economic growth. The theory in this framework explains that experience, skill development, training, and awareness of CC affect farmers' decisions to select a suitable strategy to protect crops from the negative effects of CC and to enhance overall output. Farmers, particularly those with more experience, have better knowledge; thus, they make better decisions and have higher expected benefits from the adaptation. Similarly, the Resource-Based View theory by Barney (1991) explains how access to resources enhances individual capacity for progress and production. In this context, farmers with larger land generally have more internal resources and a high capacity to invest. Moreover, Resource Dependency Theory, modified by Hillman *et al.* (2009), explains how individuals manage their strategies to reduce reliance on external resources. In this connection, this theory applies to how farmers' dependence on external factors such as water, weather, market, technology, and credit influences their decisions to adopt these adaptation strategies. For instance, farmers need water for irrigation, but production uncertainty increases with a water shortage. Thus, farmers may shift to a drought-resistance adaptation strategy. These theories serve as guiding frameworks for interpreting how farmers' characteristics, resource availability, and institutional dependencies shape farmers' adaptation behavior.

Existing studies identify a wide range of socio-economic and technological factors influencing farmers' adaptation decisions to CC. Empirical evidence highlights the role of human capital and awareness (Abid *et al.*, 2015; Mustafa *et al.*, 2017), resource availability such as land and water (Deressa *et al.*, 2009; Gebrehiwot and Veen, 2013), and enabling factors including markets, finance, and technology (Sanga *et al.*, 2013; Shongwe *et al.*, 2014). Building on the theoretical distinction between short- and long-term adaptation strategies (Smit and Skinner, 2002; Kurukulasriya and Rosenthal, 2003), the proposed conceptual framework synthesizes these strands by linking these factors to differentiated adaptation choices over different periods.

Conceptual framework

Based on the literature review, we explore socio-economic and technological factors that determine farmers' decisions in selecting adaptation strategies to CC. Various theories and studies explain how decisions of adapting adaptation strategies are framed. Experienced Farmers with awareness and access to climate information shape their perceptions of risk and ability to respond to CC. Similarly, adaptation is resource-constrained. Farmers with better land



quality, secure ownership, and reliable water access can adopt structural, or long-term strategies. Similarly, markets, credit, and technology reduce constraints and enable capital-intensive or long-term adaptation strategies. Based on theoretical insights and prior empirical findings, with (short- and long-term strategies) and their determinants, the following conceptual framework is developed. These various factors determine farmers' adaptation decisions to CC, and based on empirical findings, policy feedback could be suggested.

Data and sample size

Primary data was collected through a structured questionnaire in district Peshawar, particularly in four union councils. The district and, particularly, the following Union council are selected due to their agricultural significance and vulnerability to environmental and climatic challenges. Four union councils are chosen to capture heterogeneity within the district. According to the Pakistan Bureau of Statistics, (PBS, 2024) the total population of Palosi, Regi, Urmar and Chamkani are 25399, 25532, 91049, and 33069, respectively. The total sample size of 400 farmers was determined using Yamane's (1967) formula at a 95% confidence level and 5% margin of error. The sample was then proportionally allocated among the four selected union councils using proportionate stratified random sampling. Each union council, Palosi, Regi, Urmar, and Chamkani, presents 58, 58, 208, and 76 farmers, respectively. Finally, respondents within each stratum were selected through simple random sampling.

$$\text{Sample size (n)} = \frac{N}{(1+N*e^2)}$$

Where small 'n' is the sample size, capital 'N' is the total number of populations in all union councils in the area, and 'e' is the precision value or margin of error.

Empirical specification of the model

The Multinomial Logit (MNL) model is used to analyze the determinants of farmers' adaptation strategies (Mustafa *et al*., 2017). It is applied to specify the relationship between adaptation strategies and a set of explanatory variables. This model requires that the dependent variable (adaptation strategies) be categorical and unordered. This study separates adaptation strategies into two periods: short-term and long-term strategies. The following periodical adaptation strategies are further categorized into three unordered categories (Greene, 2003; Train, 2009). Besides this, the model assumes Independence of Irrelevant Alternatives, which is tested through the Hausman test (Hausman and McFadden, 1984). It asserts that the probability of choosing any alternative strategy is independent of other strategies when explanatory variables change by one unit. This study meets the MNL model's assumption and requirement. Therefore, this model is a suitable option for data analysis (Hausman and Wise, 1978; Shongwe *et al*., 2014). To analyze farmers' choices among multiple categorical and unordered adaptation strategies, the MNL model framework is employed.

Utility (latent benefit) function

The decision to adopt any strategy is assumed to be driven by utility/profit maximization. A rational farmer must choose an option from a set of adaptation strategies where the benefits are greater (McFadden, 1974; Train, 2009).

$$U_{ij} = \beta_j X_i + \varepsilon_{ij}$$

U_{ij}= the utility that farmer 'i' receives from choosing strategy 'j'; X_i represents (socio-economic and technological factors that determine farmers' choices); β_j captures (strategy-specific effects).

Multinomial logit choice probability

Under this framework, the probability of selecting a particular adaptation strategy is modeled using a multinomial logit specification suitable for unordered choices (Greene, 2003).

$$P\,(A_i = j\,/X_i) = \frac{e^{\beta j.Xi}}{\sum_{k=1}^{j} e^{\beta k.Xi}} \qquad j = 1, 2, \ldots, J$$

A_i = choice of adaptation strategy by farmer "i"; X_i = vector of explanatory variables for farmer i (e.g., age, farm size, income); β_j = vector of coefficients for strategy "j" (how strongly each variable affects the likelihood of choosing strategy j); J = number of strategies; $\Sigma^{j}_{k=1} e^{\beta k.Xi}$ Probabilities sum to 1.

Marginal effects

The MNL coefficients do not directly represent changes in choice probabilities; marginal effects are computed for interpretation (Greene, 2003). Marginal effects are calculated to assess how a unit change in Xi affects the probability of selecting each strategy.

$$\frac{\partial P_i}{\partial X_i} = P_{ij}\left(\beta_j \sum_{k=1}^{j} P_{ik}\beta_k\right]\Big)$$

P_{ij} = probability that individual i chooses strategy j; X_i = explanatory variable; β_j= coefficient of X_i for strategy j; $\Sigma_{k=1}^{j} P_{ik}\, \beta_k$ = weighted average of coefficients across all strategies.

The model

Dependent variables such as short- and long-term adaptation strategies are categorized into more than two categories and are unordered, which are the requirements of the MNL model. This study meets the MNL model assumptions and requirements. Therefore, this model is a vital option for data analysis and is used to assess the impact of the explanatory variables on the dependent variable (Hausman and Wise, 1978; Abaynew *et al.*, 2025). Separated equations for both periods: short- and long-term, along with determinants of strategies, are given below.

1) Econometric Equations

$STAS_j = \beta_0 + \beta_1 \exp + \beta_1$ access *CC* Info $+ \beta_3$ Landsize $+..+.\ \varepsilon_i$

$LTAS_j = \beta_0 + \beta \exp + \beta_1$ access *CC* Info $+ \beta_3$ Landsize $+..+.\ \varepsilon_i$

STAS= Short-term adaptation strategies; LTAS= Long-term adaptation strategies

Variables

Dependent variables

Dependent Variables, adaptation strategies, are theoretically classified as short- and long-term strategies (Smit and Skinner, 2002; Kurukulasriya and Rosenthal, 2003). This study follows the same classified categories. Short-term methods are immediate responses, while long-term approaches are the process of improving structural resilience to CC. Short-term strategies include crop diversification & changes in timing of farm operation, nutrient & pest control management, and mixed cropping. However, long-term strategies include changes in location & type of crop, the development of new technology, and water management.

Independent variables

Based on relevant literature, various socio-economic variables are selected as independent variables, such as years of work experience, land size for cultivation, and access to CC information (Abid *et al.*, 2015). Moreover, adaptation cost affordability, enough water availability, type of land (irrigated or rainy land), ownership of land (self-cultivated, rented, or sharecropping), access to market, loans facilities, access to subsidy, access to agricultural technology, and skills development facility are taken from (Dang *et al.*, 2019; Marie *et al.*, 2020) studies.

Analysis and Discussion

Multinomial logit model

The MNL model is used to estimate the marginal effect of socio-economic variables on a farmer's decision to select any adaptation strategy. The IIA assumption of the model is checked through the Hausman test. It asserts that the probability of choosing any alternative strategy is independent of other methods when explanatory variables each change by a unit (Hausman and Wise, 1978; Hausman and McFadden, 1984). Variance Inflation Factor checked the independence of explanatory variables. Both tests' results are given below.

Independence of irrelevant alternatives through the hausman test

The IIA assumption is examined through the Hausman–McFadden test, which results are given in Table 1. For both short- and long-term models, the null hypothesis of no systematic difference in coefficients could not be rejected ($p > 0.05$), indicating that the IIA assumption holds. Therefore, the MNL model is appropriate for the analysis.

Table 1: *Hausman test*

Hausman Test: Short-term Strategies		**Hausman Test:** Long-term Strategies	
Test: Ho: difference in coefficients not systematic		Test: Ho: difference in coefficients not systematic	
Statistic	**Values**	**Statistic**	**Values**
chi² (27) = (b-B)'[(V _b-V_B) ^ (-1)] (b-B)	15.410	chi² (27) = (b-B)'[(V _b-V_B) ^ (-1)] (b-B)	0.160
Prob. >chi²	0.963	Prob. >chi²	1.000
(V _b-V_B is not positive definite)		(V _b-V_B is not positive definite)	

Variance inflation factors (VIF)

The independence of variables is tested through the VIF technique and its results are given in Table 2. If explanatory variable values are less than 10 in the VIF test, then the variables are not correlated (Yong, 2014).

Both test results clearly indicate no violation of the MNL model's assumptions. Hence, this study can further proceed with multinomial logistic regression. For further analysis, this study takes crop diversification in the short term, and changing location & type of crop in the long term as base categories. The results show farmers' response to select either the base category or other strategies in each period, if any independent variable changes by one unit, while other variables remain constant. However, to investigate determinants of adaptation strategies, this study finds the marginal effects of socio-economic and technological factors on adaptation strategies for both periods. Results are given in Table 3.

Table 2: *Multicollinearity test*

Variables	Value
Experience	1.092
CC information	1.053
Size of land	1.069
Type of land	1.062
Ownership of land	1.101
Water availability	1.072
Adap. cost affordability	1.054
Access to market	1.102
Access to technology	1.371
Access to loan facilities	1.375
Inputs & output subsidies	1.026
Skills training	1.128
The government's role in raising awareness about the CC impact and its adaptation	1.083

Table 3: *Marginal effects at mean values*

Independent variables	Short-term Adaptation Strategies			Long-term Adaptation Strategies		
	Crop diversi. & change in timing of farm operation	Nutrient & pests control management	Mixed cropping	Changing crop type & location	Developing new technology	Water management
Experience	0.002 (0.259)	0.004 (0.579)	0.003*** (0.007)	0.004*** (0.005)	-0.007*** (0.002)	0.003 (0.230)
CC info.	0.170*** (0.004)	-0.165** (0.025)	0.198*** (0.001)	0.002 (0.972)	-0.139*** (0.009)	0.137** (0.022)
Land's size	0.046*** (0.001)	0.031 (0.306)	0.030 (0.113)	-0.013 (0.301)	0.011 (0.282)	0.001 (0.901)
Land's type	0.186*** (0.001)	0.116 (0.202)	-0.014 (0.805)	-0.040 (0.294)	-0.080 (0.109)	0.142** (0.026)
Land owner.	0.142*** (0.005)	0.002 (0.968)	0.020 (0.680)	-0.040 (0.414)	0.095** (0.042)	-0.054 (0.273)
Water availability	0.009 (0.879)	0.051 (0.490)	0.162*** (0.005)	-0.107* (0.087)	-0.016 (0.777)	0.123** (0.045)
Adap. cost afford.	-0.045 (0.279)	0.055 (0.163)	-0.088** (0.024)	-0.116*** (0.005)	0.091*** (0.010)	0.025 (0.547)
Access to market	0.042 (0.448)	0.110** (0.044)	-0.146*** (0.000)	-0.074 (0.194)	0.168*** (0.005)	-0.094 (0.106)
Access to technology	0.108** (0.017)	0.001 (0.972)	-0.047 (0.242)	-0.066 (0.166)	0.101*** (0.009)	-0.035 (0.473)
Access to loan	0.123** (0.049)	-0.028 (0.645)	0.031 (0.589)	-0.091 (0.155)	0.142** (0.016)	-0.050 (0.429)
Inputs & output Subs.	0.132** (0.038)	0.113 (0.116)	-0.068 (0.286)	0.124** (0.049)	-0.054 (0.345)	-0.069 (0.286)
Skills & training	0.147** (0.024)	-0.142** (0.034)	0.077 (0.162)	0.143** (0.029)	-0.069 (0.266)	-0.073 (0.271)
CC impact awareness	0.152** (0.014)	0.153** (0.052)	0.112* (0.074)	-0.095 (0.143)	0.084 (0.126)	0.179*** (0.004)

In the cell above are the coefficient values, and p-values in brackets, while the signs (, **, and *** represent significance levels at 10%, 5%, and 1%, respectively.*

Results and Discussions

The MNL Model is used to analyze the marginal effect of independent variables on short-term and long-term adaptation strategies used by farmers in response to CC. The result of the variable is interpreted based on the coefficient and its P-values as follows:

Short-Term Adaptation Strategies

The following are the results of short-term adaptation strategies to CC.

Crop Diversification & Changes in Timing of Farm Operation

Crop diversification & changes in the timing of farm operations (CD & CTFO) is typically a short-term and low-cost strategy. Variables such as access to CC information, land size, land type (irrigated or unirrigated), and land ownership (own, lease, or profit share) significantly increase the chances of selecting this method. These factors guide farmers to adjust planting dates in response to perceived changes in rainfall and temperature patterns, or replace environment-resistant crops with vulnerable crops. Farmers mostly replace rice with wheat due to higher temperatures and lack of proper irrigation, or adjust crop timing operations to climatic conditions. The marginal effect concluded that climatic information, irrigation facilities, and land characteristics significantly increase the likelihood of adopting this method. This indicates that this strategy is practically accessible even for resource-constrained farmers (Hassan and Nhemachena, 2008; Abid *et al*., 2015).

Improved nutrient & pest control management

Improved nutrient and pest control management (IN & PCM) is a costly and immediate response. The results indicate that this strategy is primarily influenced by access to CC information, training facilities, market access, and awareness about the impact of CC. It is a knowledge- and input-intensive strategy that requires access to modern inputs and technical understanding rather than merely experience-based decision-making. The adoption of this strategy is systematically shaped by informational and institutional factors rather than random choice. Compared to other methods, this strategy is costly. Training facilities enable farmers to act proactively and prefer cost-effective strategies to reduce crop vulnerability. However, access to the market and awareness about CC impact positively and significantly affect this method. Input-output market access enhances productivity through fertilizer and pesticides to improve crop fertility and control harmful pests. The model results show that access to CC information and training facilities negatively affect, but access to the market, and awareness of the impact of CC positively and significantly affect, the adoption of IN & PCM. This highlights that these factors have real impacts on farmers' adaptive capacity (Sanga *et al*., 2013; Shongwe *et al*., 2014; Abid *et al*., 2015).

Mixed cropping

Mixed cropping (MC), a risk-spreading and resource-light strategy, is positively associated with experiences, CC information, and water availability. With more farming experience, CC information, and water availability, farmers are well aware of how to utilize land and cultivate multiple crops simultaneously in the same piece of land. This enhances soil fertility and reduces damage in crop plantations. For example, experienced farmers cultivate sugar & wheat, taro & wheat simultaneously in the same field. This increases soil fertility and protects sugar and taro from temperature. On the contrary, this strategy is inversely linked to the cost affordability of adaptation and access to input-output markets. With market liberalization, new techniques are introduced into modern agricultural activities; thus, larger farmers have more options to choose from, but CC information and water facilities make the method a viable adaptation option for smallholders (Deressa *et al*., 2009; Tazeze *et al*., 2012; Abid *et al*., 2015)

Long-Term adaptation strategies

The following are the long-term adaptation strategies to CC:

Changing of crop types & location

Changing of Crop Types & Location (CCT & L) is a structural strategy. The long-term model shows that farmers' experience, access to subsidies, and training facilities significantly increase the probability of selecting this method. Experienced farmers are well-trained to meet environmental conditions. They mostly switch from rice to wheat due to water shortage or temperature issues to reduce crop vulnerability. Similarly, with input-output subsidies provision, farmers might feel financially secure to take risks by replacing crops with one another or relocating crops to the required conditions of CC (Ajao *et al*., 2011; James and Julius, 2013; Sanga *et al*., 2013). Conversely, water availability and the affordability of adaptation costs negatively affect this strategy. Sufficient water availability and adaptation cost-bearing capacity allow farmers to opt for productive methods instead of traditional farming methods (Gebrehiwot and Veen, 2013; Abid *et al*., 2015).

Development of new technology

The development of new technology (DNT) is a long-term and investment-intensive strategy. The result shows that farming experience and access to CC information significantly reduce the likelihood of this method. Farmers are mostly financially disadvantaged, but with experience and access to CC information, they use alternative methods to secure their fields from the negative impact of CC (Ajao *et al*., 2011; Sanga *et al*., 2013). However, market access, access to technology, and access to loans positively and significantly influence this method. Access to markets transforms traditional crops into cash crops and introduces new methods and the use of different seeds in farming. This enables farmers to use high-yielding & climate-resistant seeds, to use machinery rather than traditional labour work (Feder *et al*., 1985; Gebrehiwot and Veen, 2013; Dang *et al*., 2019).

Improve water management (IWM)

Improve Water Management (IWM) is a capital-intensive, long-term strategy. The model shows that access to CC information, land type, water availability, and awareness of CC are positively and significantly related to IWM. Guidance related to water-logging, awareness about irrigation systems, installation of proper canal systems, and provision of tube-well facilities with the solar system, provision of sufficient water, all these measures a farmer uses to save crops from the adverse impact of CC and to enhance agricultural productivity. The marginal effects reveal that farmers with sufficient water sources and access to finance are substantially more likely to invest in this method. This highlights the importance of infrastructure and credit support (Deressa *et al*., 2009; Abid *et al*., 2015).

Overall, both models' results indicate that short-term adaptation strategies, including crop diversification & changing in farm operation, nutrient & pest control management, and mixed cropping, are mainly driven by experience and climate awareness. However, long-term adaptation strategies, including changing crop types & location, water management, and the development of new technology, depend on human capital, resource availability, and institutional support. This also confirms that the decisions of adaptation strategies to CC are heterogeneous and strategy-specific rather than uniform across farmers and periods (Smit and Skinner, 2002).

Conclusions

The study objective is to analyze the determinants of short- and long-term adaptation strategies in response to CC in district Peshawar. Primary data of 400 farmers was collected through a questionnaire. The MNL model is applied because dependent variables (adaptation strategies) are categorical and unordered. The model's assumptions, independence of irrelevant alternatives, and multicollinearity, are tested through the Hausman and VIF tests. The dependent variables (adaptation strategies) are classified into two periods: short-term and long-term. Short-term strategies, immediate or seasonal responses, include crop diversification & changing in farm operation, nutrient & pest control management, and mixed cropping. However, long-term adaptation strategies refer to structural resilience enhancement in the agricultural sector. These are changing crop types & locations, improved water management, and the development of new technology. The short-term model shows variables such as experience, access to CC information, access to market, and awareness of CC play crucial roles in the selection of an immediate response to CC, particularly crop diversification & changing in farming operations. On the other hand, the long-term model results show that experience, CC information, water availability, adaptation cost affordability, access to input-output markets, access to the latest technology, and financial facilities are key factors in the selection of long-term adaptation strategies, particularly changing crop type & location, and development of new technology. The overall results concluded that short-term adaptation strategies are mainly driven by experience and climate awareness, while long-term strategies depend on human capital, resource availability, and institutional support. This confirms that adaptation decisions are heterogeneous and strategy-specific rather than uniform across farmers and periods. Based on empirical analyses, this study suggests that awareness of CC, water availability, provision of input-output subsidies, and the latest agricultural technology are required to strengthen farmers' adaptive capacity to CC and to enhance overall agricultural outcomes. The government's guidance on water-logging, irrigation system awareness, canal system installation, and tube-well facilities with solar systems ensures adequate water supply to plants, thereby preventing the adverse effects of CC on crops. Being an agrarian country, Pakistan is importing even major crops from international markets, showing a complete failure of agricultural policy and this sector.

Recommendations

Socio-economic factors play a crucial role in the selection of adaptation strategies in response to CC. Variables such as experience, access to CC information, water availability, input-output subsidies, skills & training, and awareness of CC play important roles in farmers' decisions. These variables are more closely associated with most adaptation strategies. Based on empirical results, experienced farmers who are well-informed about CC variation opt for cost-effective options in both periods. Therefore, training programs targeting small farmers and investment in irrigation equipment require special attention in agricultural policy formulation to address rapid change and climatic uncertainty and to enhance agricultural productivity. This will not only make the country self-sufficient but also make it an exporter of agricultural products.

Limitation

This study empirically analyzed the determinants of farmers' adaptation strategies to CC. It is limited to cross-sectional data, farmers' self-reported adaptation, and potential endogeneity between the short- and long-term periods. Therefore, panel data, experimental design, and a dynamic adaptation model are required for the future study.

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Novelty Statement

This study provides the first comprehensive analysis of periodical-based adaptation strategies to climate change, while previous literature, particularly empirical studies, considered agricultural adaptation strategies as a unified framework. In fact, short-term strategies are immediate or seasonal responses, and long-term strategies are structural adjustments to climate change in the agricultural sector.

Author's Contribution

Nazish Ehsan: Conceived the idea, designed the study, managed data collection, created figure and tables, and drafted the manuscript.
Uzair Ahmad: Assisted with data collection, performed the statistical analysis, interpreted results, and finalized the manuscript for submission.
Both authors read and approved the final version of the manuscript.

Generative AI and AI-assisted technology statement

The authors declare that no generative AI and AI assisted technology was used in the creation of this manuscript.

Conflict of interest

The authors have declared no conflict of interest.

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