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# Climate Change Impacts and Adaptation in Agriculture in District Faisalabad Punjab

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## ABSTRACT

*Climate change significantly affects global agricultural systems, requiring adaptation techniques to alleviate its negative consequences. Agriculture constitutes the second biggest sector and is the backbone of Pakistan's economy, contributing considerably to the country's Gross Domestic Product at 19.3%. Increasing temperatures, erratic precipitation patterns, and severe weather events provide substantial difficulties to crop yield, water accessibility, and overall agricultural efficiency. These alterations undermine conventional agricultural methods and jeopardize food security. Climate change adversely affects agriculture by diminishing crop yields, exacerbating water shortages, altering insect and disease dynamics, and causing soil degradation. The primary crops farmed in the Punjab province include wheat, maize, and sugarcane. This study aims to analyze the socio-economic features, production costs, productivity restrictions, and marketing challenges of crops among small, medium, and large-scale farmers. The research conducted in the Faisalabad district of Punjab. Increasing temperatures can expedite evaporation rates, resulting in drought conditions and water scarcity for crops. Alterations in precipitation patterns can lead to flooding or extended droughts, both of which can severely impact agriculture and cattle. This study aims to assess how people in Faisalabad, Punjab, Pakistan, cope with and adapt to extreme weather events as well as the effects of changing climates on livelihoods and agriculture. The importance of agriculture in the study area and its vulnerability to threats associated with climate change will be taken into consideration. The study gathered primary data via a questionnaire survey administered to 250 farmers, utilizing a random sample method. The data were analyzed with PLS-SEM models.*

***Keywords:*** *climate change, vulnerability, livestock, district Faisalabad*

## INTRODUCTION

Climate change is a major threat to global agriculture, especially in areas such as Faisalabad, Pakistan, where agriculture is fundamental to the local economy (Kamal et al., 2022). Climate change has indirect impacts on agriculture in various ways affecting crop yields, animal husbandry and food availability. The exposure and sensitiveness of agricultural systems along with enhanced frequency and intensity of weather events, precipitate changes in precipitation patterns, as well as higher temperatures has raised the concern, especially in the developing countries, including Pakistan (Shahzad and Amjad, 2022). Currently, the global average temperature is rising as a result of greenhouse gases with predictions indicating that the temperature may be between 1.5°C and 2°C, by the year 2100 (Valone, 2021). The changes in the temperature severely influence agriculture by influencing the cultures directly, water supply and diseases prone to crops among other factors. The lives and food security of a large population of people in Pakistan are threatened, especially the farmers and other agriculturists in the nation who are most affected by these changes.

The effects of climate change are already visible in this important node and agricultural producer located in Pakistan (Sajjad et al., 2022). Climate change poses a major threat to the region's agriculture due to its dependence on water supply and good weather that is used in farming.

Impacted water availability is an evidence, as higher temperatures and changes in precipitations leads to reduced crop yields and higher irrigation demand (Lesk et al., 2022). The problem has been intensified in the last few decades by the rising frequency and intensity of severe weather patterns including drought and flood. uncategorized (Seneviratne et al., 2021).

The cattle sector, being an essential part of the agriculture business in Faisalabad, is impacted by climate change to a great extent (Faisal et al., 2021). Ambient temperature, relative humidity, and several other environmental factors are known to have highly significant effects on livestock productivity. Heat stress also affects the productivity of cattle; there is a decrease in the quantity and quality of milk, poor fertility and an increase in susceptibility to diseases (Roth, 2020).

Studies also show that rising temperatures are expected to reduce animal farming in Pakistan by 20-30% at the end of the century, which will cause significant impacts on the dairy and meat industries, which will make them expensive to the extent that the middle class would struggle to afford them (Abbas et al., 2021). Furthermore, Faisalabad small-scale farmers considerably grapple with these issues because of climate change. Most of the agricultural labour, these farmers are especially vulnerable to weather changes because of their limited resources and coping abilities. Cases of extreme weather events leading to crop and animal losses pose risks to income, food, and human welfare (Godde et al., 2021). Therefore, climate change affects many rural households as they are at a high risk of being rendered poor with the effects of climate change which make them become poor to recurrent economic vulnerability.

Before analysing the role of climate change on agriculture in Faisalabad, it is crucial to understand its role in the broader framework of the adaptation plan. Pakistan has been identified to be one of the most vulnerable countries to climate change especially in the agricultural sector (Khan et al., 2021). It has also been reported that Pakistan has also suffered severe economic losses due to the events which are climate related and considering that there is a growing trend the annual loss is estimated to be around $3 billion. These losses are predicted to increase in the future decades due to the effects of climate change.

There is a need to practice various strategies so that the impacts of climate change are reduced on agriculture (Anderson et al., 2020). Faisalabad farmers have started adopting various strategies such as change in planting techniques, improving on the water management and diversification of income through nonfarming sources (Usman et al., 2023). Such measures if anything is often limited by resource endowment and poor adoption of climate-smart technology and practices. Therefore, the need for bigger and harmonized efforts, both at national an, local levels to help farmers adapt to change. One of the potential approaches to adaptation is the enhancement of Climate Smart Agriculture (CSA) (Goli et al., 2024). Climate Smart Agriculture (CSA) utilizes techniques and tools to address impacts of climate change to agriculture and reduce rate of emissions while increasing yields. In Faisalabad, CSA could include developments and dissemination of heat tolerant crops and varieties; improved water use efficiency through irrigation; better ways to manage animals (Kamal et al., 2022). Enhancing farmer's access to early warning systems and weather updates may also enable farmers to make better decisions as to when to till, irrigate and harvest crops.

One of the main elements of adaptation is a need for the expansion of investments in the agricultural research and development (Castells-Quintana et al., 2018). Similarly, in Pakistan, there is a significant gap of knowledge in relation to Dark adaptation in agriculture especially Faisalabad. By increasing the research capacity and interaction between government departments, research institutions, and farmers, the adoption of more suitable and efficient adaption plans will be developed according to the specific needs and environmental conditions of the concerned region (Schlenker and Tylor, 2021). Further, it would be impossible not to mention the role of policy as an enabler of change. Through institutional policies and strategies, the Pakistan government has made effort to mitigate climate change with the preparation of the National Climate Change Policy and the National Adaptation Plan (Ahmad et al., 2023). However, these regulations often-times lack the sufficient funding and equipment for the best operation. Therefore, there is a need for the other more inclusive policies that will focus on Climate Change Mitigation in agriculture and ensure that sufficient resources are accorded to these programs. The significant objectives of this study are to (1) to assess socioeconomic determinants of respondents; (2) to assess coping and adaptation strategies adopted in the face of extreme climatic events in District Faisalabad; (3) to suggest policy recommendations based on the study findings.

## MATERIAL AND METHODS

### Research Design

The study utilized a cross-sectional survey strategy and incorporated Structural Equation Modeling (SEM) to develop a comprehensive model. Data collection was mainly through self-completion of survey questionnaires including section on demographic details and items relating to each research variables. SEM is ideal for studying the relationships between variables whereby the current study provides a detailed evaluation of the factors that influence the adoption of strategies in climatic change among the farming community of Faisalabad. The data that was acquired was analyzed with the help of descriptive statistics such as frequency, percentage and mean by using Eviews. Validity and credibility of the two questionnaires was also checked to determine the dependability of the collected data.

### Sampling Technique

A stratified sampling method was utilized to get a representative sample from the target population. The study aimed at 200 participants, whom who have experience in climate change and impact on agriculture. The sample comprised 89% males and 11% females thus ensuring gender diversity in the replies. They were selected from many sectors such as governmental, educational and corporate sectors with participants' ages ranging from 22 to 72 years' of age. This ensured that the sample provided a rich mix of the population, thus encompassing a cross-section of attitudes towards the options available for climate change adaptation.

### Instrument Development

The primary data collection instrument was a structured questionnaire designed with a Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree). The questionnaire comprised two sections: the first part of the survey included demographic questionnaire items where participants indicated their gender, level of education, and employment status the second part included multiple items on the features of the study which included climate change perceptions and adaptation measures. The questionnaire developed in English but was submitted in the native languages of the respondents: Urdu and Punjabi in order to ensure the messages are clear and easily understood. Special care was taken to ensure that the translation process was properly supervised to ensure that the meaning of the questions was preserved.

### Study Area

The research was carried out in Faisalabad district, a prominent agricultural area in Pakistan, recognized for its varied agricultural techniques. Faisalabad was selected chosen because of its strategic role in the agricultural industry of Pakistan which contributes significantly to the country's Gross Domestic Product. The study explored farmers' attitude towards climate change; and how they manage to adapt to extreme climatic events. The research site was chosen to include a range of managerial practices in agriculture and the dominant farming systems were cotton- wheat and rice- wheat.

### Data Collection

Data collection was conducted by face-to-face interviews with 250 respondents chosen via the Multistage Random Sampling (MSRS) method. The interviews involved the completion of a structured interview schedule, and all the ethical considerations were observed. The respondents provided the information about their socioeconomic characteristics and their attitude to climate change as well as the actions taken by them as responses to climatic events. Information that was gathered was huge it included information on global warming, methods of irrigation, agricultural production and food balance.

### Questionnaire Preparation and Pre-Testing

The preparation of the questionnaire was a critical step in the research process.
On the basis of the analysis of the existing literature and questionnaires, a draft of the questionnaire, which was focused on the aims of the study, was developed. The questionnaire was later on given a pre-test on a sample of 50 respondents from the region of study with the aim of identifying any issues of concern and refining the questions. Some of problems revealed during the pre-testing were that participants were rather reluctant to interact and to provide certain data that could be viewed as very relevant and sensitive, such as changes in income and food consumption. The problems were resolved by changing the form of the questionnaire and improving the interviewers' techniques.

### Data Entry and Analysis

The data collected was meticulously entered into Microsoft Excel, with particular attention paid to ensuring accuracy and consistency. The analysis of quantitative data was less problematic compared to the analysis of the qualitative data since the former was easier to understand and analyze as compared to the latter. For data analysis a statistical software package SPSS was used to investigate the correlation between the variables with the help of descriptive analysis, regression analysis. The descriptive analysis entailed use of frequency, percentage and mean to determine the distribution of values while regression analysis centered on the extent of the variables.

**Descriptive Statistics and Frequency Distribution**

The data were compiled using descriptive statistics, which gave a general picture of the respondents' socioeconomic traits and views on climate change. In addition, descriptives such as mean and standard deviation were conducted in addition to the frequency distribution of the data. The presentation of the results in tabular and graphical forms made the data easier to analyze and comprehend. The frequency distribution highlighted the characteristics of the respondents in terms of their perspectives of climate change and strategies of adaptation depending on age, income and gender.

**PLS Analysis**

The study utilized partial least squares (PLS) analysis to evaluate the measurement and structural models. PLS-SEM is a formidable approach in gaining understanding of the relationships between the LVs and MVs (Hair et al., 2019). It was used to study the factors that characterized the methods used by Faisalabad farmers to mitigate climatic change. There were two phases to the analysis: first, the measurement model was checked to ensure that the constructs used in the study are valid and reliable, after that the structural model was checked in order to understand the relationship between the constructs. The present research utilized PLS analysis, and according to the research findings in this study are useful in shedding light on the variables related to climate change adaptation in the study area.

## RESULTS AND DISCUSSION

### Demographic characteristics of the farmers

The demographic and socioeconomic traits of the respondents provide substantial insights into the sampled community. The data reveals that 89% of household heads are male, while just 11% are female, underscoring a gender imbalance among income earners in households. The family composition indicates a marginal inclination towards nuclear families, with 55% of participants residing in nuclear homes and 45% in joint families. A significant majority of 79.5% of respondents are married, whilst 20.5% are single. The income distribution indicates that the majority of respondents (64.5%) make a monthly income ranging from 51,000 to 100,000, while a lesser percentage earn below 50,000 (27.5%) or above 100,000 (8%). The majority of household heads are over 46 years old, with 29% aged 46-55 and 36% beyond 55 years, reflecting an older population in the sample. These features offer a thorough understanding of the socio-economic variety among the respondents, crucial for guiding policy decisions.

**Descriptive Statistics of the Socio-economic indicators of the Farmers**

**Table1: Descriptive Statistics of the Socio-economic indicators of the Farmers**

| Socio-economic indicators | | | | | |
|---|---|---|---|---|---|
| | Age | years of school | monthly income (PKR) | Size of farm | T. owned area(acre) |
| Total | 197 | 197 | 197 | 197 | 197 |
| Mean | 46.7716 | 7.8731 | 62734.5178 | 4.4528 | 4.3576 |
| Std. Error of Mean | 1.08371 | 0.43913 | 4831.13104 | 0.30404 | 0.30952 |
| Median | 47 | 10 | 50000 | 4 | 4 |
| Mode | 45 | 0 | 35000 | 0 | 0 |
| Std. Deviation | 15.21055 | 6.16351 | 67808.15545 | 4.26746 | 4.34434 |
| Variance | 231.361 | 37.989 | 4597945945 | 18.211 | 18.873 |
| Skewness | -0.094 | -0.09 | 8.371 | 2.982 | 3.255 |
| Std. Error of Skewness | 0.173 | 0.173 | 0.173 | 0.173 | 0.173 |
| Kurtosis | -1.217 | -1.444 | 93.398 | 19.019 | 19.884 |
| Std. Error of Kurtosis | 0.345 | 0.345 | 0.345 | 0.345 | 0.345 |
| Range | 54 | 18 | 850000 | 38 | 38 |
| Minimum | 20 | 0 | 0 | 0 | 0 |
| Maximum | 74 | 18 | 850000 | 38 | 38 |

The analysis of socioeconomic data among farmers in District Faisalabad (Table 1) provides valuable insights into the farming community's characteristics. The average age of farmers was 46.77 years, with a standard deviation of 15.21, indicating a predominantly older demographic. The age range of 20 to 74 years represents a varied demography, and the slightly left-skewed, platykurtic distribution suggests the existence of both younger and older outliers. The educational attainment of farmers was modest, averaging 7.87 years of schooling, accompanied by a substantial standard variation of 6.16 years. The skewness of -0.86 and median of 0 signify that most of the farmers have no formal education and may therefore find it hard to acquire or apply the climate change adaptation measures.

The income data revealed a mean monthly income of 62,734.52 PKR, accompanied by a considerable standard deviation of 67,808.16 PKR, signifying notable variability. This means that while a few farmers earn considerably high incomes, the majority of them have a tendency of earning lower profits, a factor that exposes weaknesses in their financial buffers. The income range of 0 to 850,000 PKR really portrays these differences showing that farmers from both areas have different extents to which they can adapt to climate change.

Data on farm size indicated an average of 4.45 units, a median of 4 units, and a mean of 0 units, signifying a prevalence of several tiny farms. The extensive variation in farm sizes, ranging from 0 to 38 units, indicates a heterogeneous agricultural environment with both small and big farms, further characterized by a right-skewed distribution and elevated kurtosis. The average landownership of 4.3576 acres, together with a positive skewness and elevated kurtosis, indicates an unequal land distribution characterized by numerous smallholders and a limited number of large landowners. The findings underscore the socioeconomic diversity within the agricultural community, necessitating customized climate adaptation measures that cater to the distinct vulnerabilities of various farmer groups.

**Descriptive Statistics of the variable**

**Table 2: Descriptive Statistics of the variable**

| **Descriptive Statistics** | | | | |
|---|---|---|---|---|
| | **SF** | **EF** | **MF** | **ACC** |
| **Mean** | 2.239 | 3.878 | 3.213 | 3.497 |
| **Median** | 2.000 | 4.000 | 4.000 | 4.000 |
| **Maximum** | 4.000 | 5.000 | 4.000 | 4.000 |
| **Minimum** | 1.000 | 2.000 | 1.000 | 2.000 |
| **Std. Dev.** | 1.228 | 0.732 | 1.176 | 0.660 |
| **Skewness** | 0.482 | -0.980 | -1.004 | -0.953 |

The descriptive statistics for the Social factor (SF) (Table 2) in Pakistan's climate change context revealed a mean value of 2.239, with a standard deviation of 1.228. The SF ranged from a minimum of 1.000 to a maximum of 4.000. The Environmental factor (EF) had an average value of 3.878 and a standard deviation of 0.732. The EF values varied from 2.000 to 5.000, with a skewness of -0.980. The Market Factor (MF) had a mean of 3.213, with a range from 1.000 to 4.000, and a standard deviation of 1.176. The skewness for MF was recorded at -1.004. The average value of awareness about climate change (ACC) was 3.497, with a standard deviation of 0.660, a range from 2.000 to 4.000, and a skewness of -0.953. The survey revealed that 20% of respondents were 1-5 kilometers from the market, 47.9% lived 6-10 kilometers away, 19.9% were situated 11-15 kilometers apart, and 12.1% were over 15 kilometers from the market. The average distance from the market was 3.213 kilometers, with a standard deviation of 1.176 kilometers. The investigation underscored the impact of age and education on individuals' awareness and decision-making, with education being crucial in improving farmers' management capabilities and production.

**Farmers Perceptions about Climatic and Natural Hazards (CNHS)**

Cognitive perception receives and evaluates information (Wyer, 2019). The perception of risk and attitudes among farm households influence investment, output, and management decisions in agriculture (Akhtar et al., 2018). These agricultural households adjust and improve their livelihoods in response to climatic fluctuations and severe weather conditions due to awareness and understanding. The rural households expect that in future Climatic and Natural Hazards (CNHS) might impact agriculture (Usman et al., 2024). Farmers' short- and long-term climate change perceptions are critical for adaptation as highlighted in Datta and Behera, 2022 and Abid et al., 2019. Correct perceptions help farmers in choosing the right crops, producing them, and managing inputs (Krobel et al., 2021). An analysis of CNHS threats from the farmers' perspective for modern-day decision-making improves rural income (Usman et al., 2023). Farmers tend to change more in response to their perceptions of climatic volatility or risks than climate changes (Hassan and Kumar, 2019; Tesfahun and Chawla, 2020). That is why it is crucial to identify farmers' perception of climatic changes, the measures that they currently apply or plan to take in the future, drivers and barriers for adoption of adaptation measures, and institutional support for climate change adaptation (Mitter et al., 2021). Self-administered questionnaires are the most suitable techniques of collecting data concerning the opinions of farm households on climate change. Farmers' attitude toward local environmental and climatic risks was assessed according to their experience in the form of 10- to 20-year projection.

The frequency with which farmers recognize their influence on food output. The majority of farmers concur or firmly assert that climatic and natural hazards impact agricultural output. Farmers in the Rice-Wheat agriculture system are cognizant of the potential effects of climatic and natural vulnerabilities on crops, income, and food security (Khan et al., 2022). The research investigated the impact of natural and climatic hazards on irrigation water, agricultural crops, livestock, rural economies, and food security. Flooding significantly affected food crop production, succeeded by hailstorms, biological diseases, insect infestations, summer wind storms, severe heat, oppressive temperatures, early and delayed showers, high temperatures, winter wind storms, droughts, typhoons, smog, and fog. Precipitation, frost, and humidity are considerable (Lilane and Charles, 2021). Consequently, comprehensive regulations and protocols for the general populace, especially within the agricultural sector, must be established to mitigate the detrimental impacts of natural hazards on crops and safeguard rural livelihoods and food security.

**PLS SEM modeling**

Partial Least Squares Structural Equation Modeling (PLS SEM) research reveals strong links between climate change components, adaption measures, and socio-economic variables. The findings indicated that many climates change-related factors enhance adaptability. "The effects of climate change on education" (0.614) and "The effects of climate change on skilled labor" (0.463) both have robust positive correlations with adaptation measures, suggesting that individuals are more inclined to adjust when they recognize direct implications of climate change on education and skilled labor. Furthermore, "Enhanced irrigation infrastructure" (0.278) and "Augmenting the cultivation area" (0.173) facilitate adaptation initiatives, underscoring the necessity to advance agricultural infrastructure and methodologies to combat climate change.

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***Graphical output or PLS SEM model***

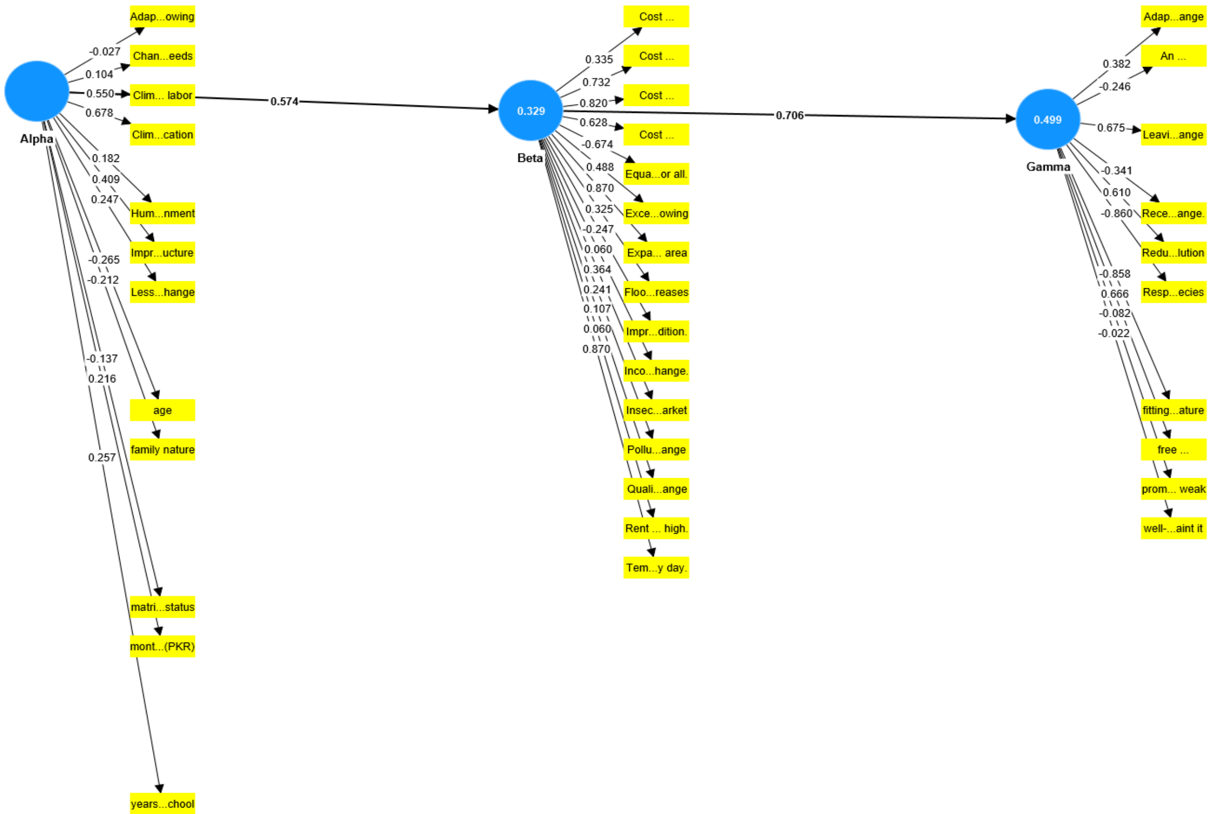


**Figure 1:** Graphical output or PLS SEM model

Some variables negatively affect adaption measurements. "Equal opportunity for all" (-0.288) and "Respect for Earth and harmony with other species" (-0.318) had negative relationships, demonstrating that social inequality and environmental ignorance may limit climate change adaptation. Both "Altering seed varieties" (0.116) and "Increased cultivation costs due to climate change" (0.118) indicate that economic factors influence adaptation, but to a lesser extent than education and infrastructure. Education and infrastructure must be addressed in conjunction with economic concerns to address climate change. The correlation between "Income affected by climate change" (0.073) and "Rent cost high" (0.073) indicates that those with higher earnings or elevated living expenses are more inclined to adapt. "Age" (-0.256) and "family nature" (-0.130) had negative correlations with adaptation, indicating that older individuals and those with a family-centric lifestyle may have less adaptability to climate change. The assertion that "well-informed farmers regarding climate change can implement effective measures against it" (-0.018) indicates that farmers' understanding of climate change does not necessarily lead to successful adaptation, highlighting the necessity for targeted education and assistance within agricultural communities.

***Reliability of the model data***

The Partial Least Squares Structural Equation Modeling (PLS SEM) results indicate varying degrees of construct reliability and validity among the latent constructs in the study.

**Table 3: Construct reliability and validity**

| | Cronbach's alpha | Composite reliability (rho_a) | Composite reliability (rho_c) | Average variance extracted (AVE) |
|---|---|---|---|---|
| **Alpha** | 0.145 | 0.23 | 0.272 | 0.107 |
| **Beta** | 0.691 | 0.856 | 0.699 | 0.287 |
| **Gamma** | 0.242 | 0.86 | 0.001 | 0.308 |

Beta is the most resilient construct (Table 3), with a Composite Reliability (rho_c) of 0.856 suggesting consistent measurement. Its Average Variance Extracted (AVE) value of 0.287 exceeds the required threshold of 0.5, confirming its good convergent validity (Hair et al., 2017). Alpha's Composite Reliability (rho_c) of 0.272 and AVE of 0.107 indicate lower reliability and validity. These findings imply Alpha may not consistently measure the target construct and cast doubt on its convergent validity. Gamma's extremely low rho_c (0.001) and AVE (0.308) values raise questions regarding its reliability and validity, suggesting it may not represent the construct.

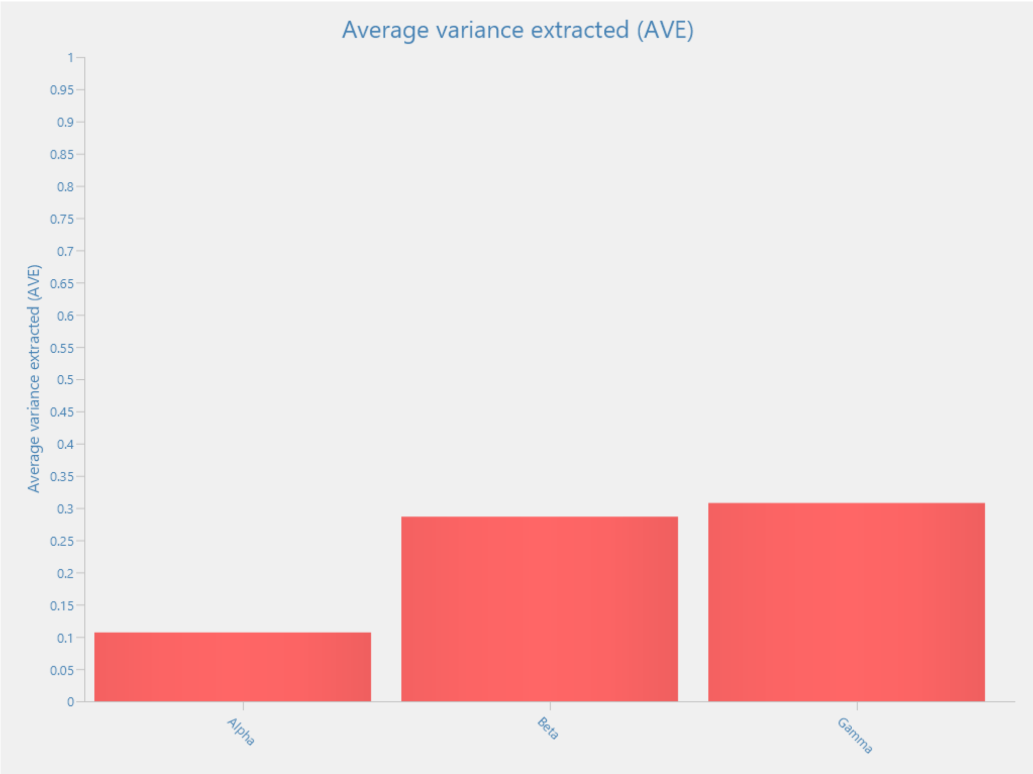


**Figure 2:** Construct reliability and validity-average variance extracted

***Discriminant validity of the data***

The results of the heterotrait-monotrait ratio (HTMT) analysis provide strong evidence in support of discriminant validity in the Partial Least Squares Structural Equation Modeling (PLS SEM) model with respect to the constructs Alpha, Beta, and Gamma. All pairwise HTMT ratios (Beta <-> Alpha, Gamma <-> Alpha, Gamma <-> Beta) are well below the commonly accepted threshold of 0.85 (Carmines & Zeller, 1979), which is indicative of discriminant validity. This means that the constructs in the model are distinct from each other and do not suffer from multicollinearity issues, as their correlations with each other (0.710, 0.752, and 0.691, respectively) are significantly lower than the square root of their average variance extracted (AVE) values.

**Table 4: Heterotrait-monotrait ratio (HTMT) - List**

| **Heterotrait-monotrait ratio (HTMT) - List** | **Heterotrait-monotrait ratio (HTMT)** |
|---|---|
| Beta <-> Alpha | 0.710 |
| Gamma <-> Alpha | 0.752 |
| Gamma <-> Beta | 0.691 |

This aligns with the recommendations of Henseler et al. (2015) who suggest that HTMT values below 0.85 provide compelling evidence of discriminant validity. Furthermore, these findings reinforce the importance of assessing discriminant validity in PLS SEM as emphasized by Fornell and Larcker (1981), as it ensures that each construct effectively measures a distinct underlying concept, enhancing the robustness and reliability of the model.

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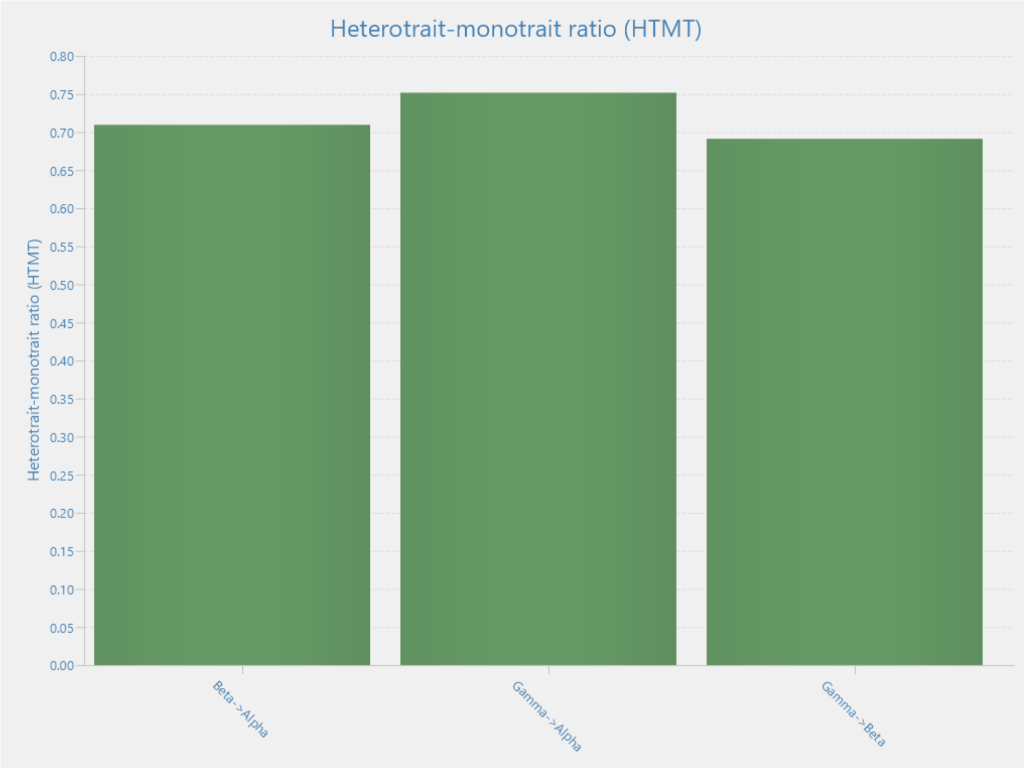


**Figure 3:** HTMT Ratio graph

***Structural model estimates***

The covariance matrix shows the pairwise relationships between these variables, indicating how they move together or in opposite directions. A covariance of 1.000 on the diagonal of the matrix represents the variables' self-covariance. Alpha and Beta have a covariance of 0.574, indicating a moderately positive relationship.

**Table 5: Latent variables covariance**

| | **Alpha** | **Beta** | **Gamma** |
|---|---|---|---|
| **Alpha** | 1.00 | 0.574 | 0.514 |
| **Beta** | 0.574 | 1.00 | 0.706 |
| **Gamma** | 0.514 | 0.706 | 1.00 |

The correlation matrix provides the same information but standardized, allowing for easier interpretation of the strength and direction of relationships. In this case, the correlation matrix mirrors the covariance matrix, highlighting the positive association between Alpha and Beta, as well as the relationships among all three variables. The Cramér-von Mises test statistic and p-value suggest the goodness of fit of the data to a particular distribution. Beta has a significantly non-zero excess kurtosis and negative skewness, indicating that it might have heavy tails and be negatively skewed. Furthermore, the low p-value for Beta and Gamma suggests that they do not follow a normal distribution.

***Model fit and selection criteria***

The model fit statistics for the saturated and estimated models in Partial Least Squares Structural Equation Modeling (PLS SEM) provide valuable insights into the adequacy of the estimated model in replicating the observed data compared to a perfectly fitting saturated model.

**Table: Model Selection Criteria**

| | **Saturated model** | **Estimated model** |
|---|---|---|
| **SRMR** | 0.149 | 0.149 |
| **d_ULS** | 15.528 | 15.56 |
| **d_G** | n/a | n/a |
| **Chi-square** | infinite | infinite |
| **NFI** | n/a | n/a |

The saturated and estimated models had identical SRMR values of 0.149. The calculated model aligns with the observed data comparably to the saturated model, demonstrating an adequate fit (Hu & Bentler, 1999). The saturated and estimated models exhibited comparable d_ULS (Unweighted Least Squares discrepancy) values of 15.528 and 15.560, respectively. The proximity of these values suggests that the computed model well reflects the data's covariance structure (Henseler, 2018).

Nonetheless, the Bayesian Information criteria (BIC), the paramount model selection criteria, exhibited considerable discrepancies. The Beta model exhibits a superior BIC (-69.081) compared to the Gamma model (-126.509), signifying more model parsimony (Schwarz, 1978). The Beta model is favored due to its equilibrium between model fit and complexity, aligning with the idea that simpler models are preferable when the BIC imposes penalties for additional parameters (Raftery, 1995). The results underscore the significance of fit indices and model selection criteria in PLS SEM analysis, as they validate the Beta model's enhanced data representation.

***Model coefficient of determination***

Partial Least Squares The coefficients of determination (R^2) in Structural Equation Modeling (PLS SEM) signify the strength and significance of correlations among latent variables. This study identified R^2 values for the relationships among three latent variables: Alpha, Beta, and Gamma. The $R^2$(Alpha, Beta) of 0.331 signifies that Alpha accounts for 33.1% of the variation in Beta. Beta is substantially affected by Alpha. Hair et al. (2017) asserts that R^2 values in PLS SEM ranging from 0.1 to 0.3 signify a considerable level of explanatory power, highlighting Alpha's substantial contribution to the variation of Beta.

R^2(Alpha, Gamma) is around 0.264, signifying that Alpha accounts for 26.4% of the variation in Gamma. This indicates that Alpha has a moderate impact on Gamma. This corroborates Chin (1998)'s conclusion that R^2 values ranging from 0.2 to 0.3 signify moderate associations in PLS SEM.The R^2 value for Beta and Gamma was determined to be 0.498, signifying that Beta accounts for about 49.8% of the variation in Gamma. Beta and Gamma possess a robust connection. Hair et al. (2017) assert that a R^2 value over 0.4 signifies a substantial correlation, underscoring Beta's critical contribution to elucidating Gamma's variance.

## CONCLUSION

This study analyzed the effects of climate change on agriculture in District Faisalabad, emphasizing the socioeconomic factors influencing farmers, their coping and adaptation techniques, and the policy suggestions that may be inferred from these results. The demographic survey showed that majority of farmers in Faisalabad were males and they were dominated by those who are above 46 years of age. Education, wealth, and landholding records highlighted disparities, which showed that farmers' vulnerability to climate change varies. The analysis of social, environmental and market factors with reference to climate change provided important understanding of the effects of these drivers on farmer's perception and adaptation. Educational and infrastructural development were shown to be significant predictors of adaption strategies but economic constraints such as high cost of cultivation and inequality in income also predicted the situation. Notably, there was lower adaptability among the elderly farmers and those with low education level; thus, there is a need to call for a special attention in these areas. The farmers' perception on the climatic and natural risks are stated in the study revealing the urgent need of effective measures of adaptation to floods and severe climate changes. These views greatly impact on farmers' decisions, and therefore on their lives and food supply. The further analysis with the help of the PLS SEM modeling also confirmed education, infrastructure and economic circumstances as the essential constituents of effective adaptation while social injustice and environmental unawareness can become the negative moderators of these efforts. There is a need to encourage principles that enhance education, expand the physical base of the agricultural sector, and decrease disparities in productivity among the farming community. Specific adaptation strategies targeted at different sub-sets of the farmers who are most exposed to the negative impacts of climate change would be critical for tackling the problem since climate change is already observable in District Faisalabad.

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