

## Article

# Determinants of Farmers' Strategies for Adaptation to Climate Change in Agricultural Production in Afghanistan

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**Abstract:** Climate variability and extremes adversely affect the agricultural production system, food security, livestock sector, and water resources. With the cumulative effects of climate variability, there is a need to anticipate and develop appropriate adaptation strategies to cope with changing climatic conditions. It is necessary to study the adaptation strategies that are to be followed for climate change to examine the ability of vulnerable communities and people, frequently affected by drought and other climate-related risks, to adapt to climate change impacts. Hence, the present study examined the determinants of various climate change adaptation strategies followed by farmers as a measure to face climate variability, which will be ultimately beneficial and enlightening to policymakers to gain knowledge about the measures to be taken to mitigate the impact of climate change. The study was undertaken using data collected from 105 farm households with an organized pre-tested interview schedule in the central agro-climatic zone of Afghanistan. The multivariate probit econometric model was used to analyze the factors responsible for major adaptation strategies to mitigate the impact of climate change. The key findings of the model indicated that the probability of educated farmers migrating to the non-agricultural sector for employment has increased by 1.3 percent, and those who have more land area have adopted a reduction in irrigation by 5.2 percent as an adaptive mechanism. The study also found that having access to technical guidance from extension officials increased the likelihood of farmers changing their cropping pattern by 18.6 percent and of diversifying

their farms by 19.2 percent. On the other hand, expert guidance reduced the likelihood of drilling new bore wells by 20.5 percentage points and decreased the probability of selling livestock by 10.8 percentage points. The results of the study provide policy insights to improve the ability of farmers to modify their practices through improvement in extension services, irrigation infrastructure facilities, watershed development, and climate-resilient agricultural systems.

**Keywords:** agriculture; adaptation strategies; climate variability; determinants; farmers; probit model; Afghanistan

## 1. Introduction

Climate change is one of the most significant environmental hazards to the entire world's population [1] and it has a significant impact on agriculture and allied sectors. Changes in the most significant climate parameters of rainfall and temperature might have an adverse impact on crop yields. Furthermore, catastrophic occurrences like storms, floods, and drought are becoming more frequent and variable due to climate change [2]. Moreover, climate change is very likely to affect food security at the global, regional, and local levels by disrupting food availability, accessibility, and affordability [3]. The Intergovernmental Panel on Climate Change [4] reported the prevalence of vulnerable regions and populations that require urgent adaptation. The most vulnerable regions that are affected by climate change hazards are particularly located in East, Central, and West Africa, South Asia, Melanesia and Micronesia, and Central America. The United Nations emphasized that developing countries are more vulnerable to climate change impacts due to lack of technical, financial, and social resources to implement efficient adaptation measures [5]. Climatic and non-climatic factors, including socio-economic shifts, lead to both supply and demand water stress in the regions of Asia. Climate events have negatively affected the yield of all agricultural sectors, which has an impact on food security and the livelihood of the farming communities [4].

The adaptation process enables farming communities to deal better with an uncertain future and take appropriate actions for reducing the adverse effects of climate change [6]. According to the Intergovernmental Panel on Climate Change [2], adaptation to climate change in human or natural systems in response to anticipated climatic consequences either mitigates harmful effects or takes advantage of beneficial opportunities. It mentions various types of adaptation, including anticipatory and reactive adaptation, public and private adaptation, and planned and autonomous adaptation [2]. According to Ref. [7], it is necessary to anticipate a long-term change and implement appropriate adaptation and resilience strategies to cope with changing climatic conditions. Many studies have reported that adaptation is widely recognized as a vital component of any policy to respond to climate change impacts. The degree of impact on the agricultural sector due to climate change depends on the adaptive capacity, which is the ability of a system to adjust to extreme climate variability, which again involves dealing with the effects of climate change by changing characteristics as per the prevailing external conditions [6,8]. Resilience and adaptation strategies form the cardinal quintessence in the agricultural sector when it comes to dealing with the adverse effects of climate change. Hence, the vulnerability of the system can largely be reduced with the effective implementation of adaptation strategies [9,10] such as weather forecasting, early warning systems, efficient water management techniques, different crop insurance schemes, biodiversity conservation, and enhanced risk management measures [11]. Adaptation refers to examining the ability of vulnerable

communities and people to adapt to climate change impacts, which will occur in human life in different sectors [12,13].

Afghanistan is an agrarian country; around 70 percent of the rural population is directly and indirectly involved in agriculture and 22 percent of the gross domestic product is derived from the agricultural sector [14–16]. The National Statistical Information Authority (2021–2022) reported that the area under cereals and pulses had decreased by 23% and 22%, respectively, due to drought and climate extremes [17]. In addition, drought and other climate change-related risks frequently affect Afghanistan due to increased temperature and reduced precipitation over most parts of the country [18].

Although there is inadequate data availability in Afghanistan, most sources concur that during the 20th century, the temperature in most parts of the country increased by more than 1 °C. The Berkeley Earth dataset confirms this, indicating an average change of about +1.5 °C between 1900–1917 and 2000–2017 [19]. According to Afghanistan's Second National Communication to the UNFCCC, hot days and nights are occurring more frequently [20]. According to [21], the central and southern parts of Afghanistan experienced the most warming, while the northeast, which is close to the country's greatest glaciers, experienced the least warming [22].

Over the past century, Afghanistan has experienced a shift in precipitation patterns and the severity of drought has significantly increased. The southern provinces of Kandahar, Helmand, and Nimruz experienced a notable increase in drought severity between 1901 and 2010 during the wheat growing season, from November to May, while western Afghanistan experienced significant drought during the corn and rice growing seasons, from July to September [22,23]. A study in [24] conducted in the seven agro-climatic zones of Afghanistan indicated that among the seven agro-climatic zones, the central agro-climatic zone of Afghanistan showed a trend towards higher temperatures and decreasing precipitation.

Moreover, the country has been experiencing drought for prolonged periods in recent years, with an increase in mean annual temperature of 0.13 °C and a decrease in rainfall of 2% per decade during the period spanning from 1960 to 2008 [15,25]. However, studies related to climate change impacts, adaptation, and mitigation strategies are limited in Afghanistan. Different regions follow different types of climate change adaptation strategies such as crop management practices, land use management practices, livestock management practices, etc., and some of these climate change technologies are region-specific too. Therefore, there is a need to understand location-specific determinants of adaptation to climate change [26]. It is important to identify both the generic and climate-specific elements of farmers' adaptation behavior and preferences to help respond not only to the current changes but also to future changes in climate and the possible impacts [27]. A better understanding of farmers' preferences for adaptation strategies and the factors driving their choices is important to inform policy for future adaptation of the agricultural sector to climate change [28].

There is a significant research gap, as a review of the existing literature suggests that there are limited studies on the impact of climate change in Afghanistan in the first place and employing a probit model of climate change study will be a novel idea in this arena. The study is essential because "Afghanistan is on the brink of climate catastrophe" [29] and former Afghan President Hamid Karzai highlights that Afghanistan "does not have the capability" [30], while other countries can manage to adapt to such climatic upheavals.

Hence, the present study identifies and explores the factors that influence the various climate change adaptation strategies that are followed by farmers in Afghanistan. The objective of this research is to identify the key determinants of farmers' strategies for adaptation to climate change in Afghanistan using a multivariate probit econometric model,

which will help to reduce the impact of climate variability in the central agro-climatic zone of Afghanistan, and to shed light on the prevailing adaptive strategies.

## 2. Materials and Methods

### 2.1. Study Area and Data

A well-structured interview schedule was designed to collect information on various climate change adaptation strategies followed by sample respondents in the study area. The questionnaire was pre-tested to check the expandability, relevance of information, and other related information about the study during the pilot study [31]. The data were collected from the highly vulnerable central agro-climatic zone of Afghanistan and the questions were designed aiming at dichotomous responses (yes or no answers), multiple choice questions, and open-ended questions [21]. The central agro-climatic zone encompasses the Kabul, Parwan, Kapisa, Panjsher, Bamyan, Wardak, and Ghazni provinces (Figure 1). The present study followed the Cochran formula for the selection of sample size and it predicted a sample size of 96 or more measurements or surveys would be needed to have a confidence level of 95% that the real value is within  $\pm 5\%$  of the surveyed value. Hence, the sample size of 105 respondents was fixed, ensuring that the respondents were equally distributed from the seven different provinces of the central agro-climatic zone. Each farmer was interviewed in person and fifteen sample farmers were randomly selected from each of those provinces of the central agro-climatic zone, with a total of 105 sample farmers. In addition to the primary data, secondary information was also collected from various published sources.

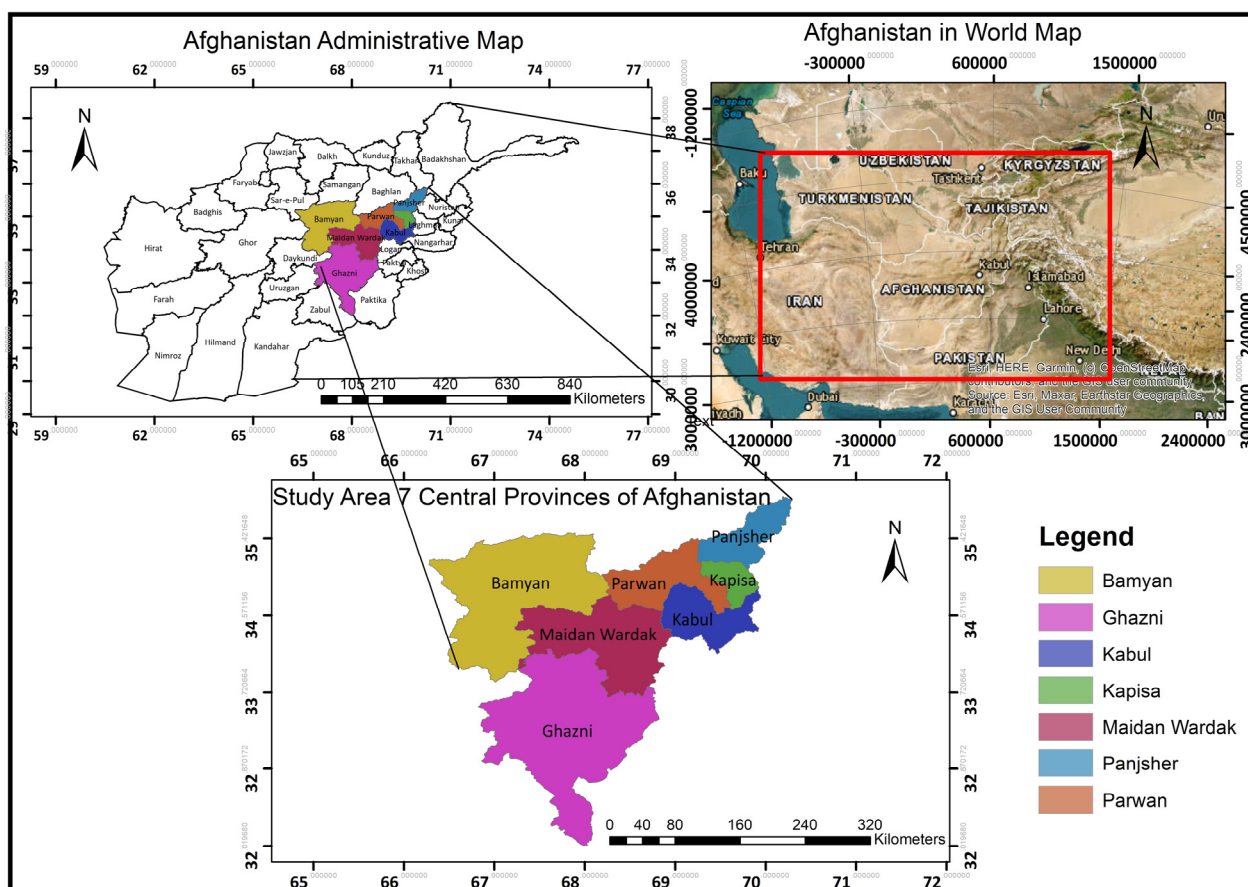


Figure 1. Map showing the study area and provinces of the central agro-climatic zone.

The distribution of arable land in the central agro-climatic zone (CACZ) according to the Afghanistan Land Cover Atlas, 2012 is given in Table 1. The CACZ has only 9.82% (6488 sq. km) as arable land among the total area of 66,065 sq. km, in which Ghazni province has the largest proportion of 49 percent arable land.

**Table 1.** Province-wise distribution of arable land in central agro-climatic zone (sq. km).

| Provinces               | Kabul | Kapisa | Parwan | Panjsher | Bamyan | Ghazni | Wardak | Total  |
|-------------------------|-------|--------|--------|----------|--------|--------|--------|--------|
| Geographical Area       | 4655  | 1882   | 5590   | 3730     | 17,878 | 21,751 | 10,580 | 66,065 |
| Arable Land (Rainfed)   | 64    | 15     | 115    | 8        | 159    | 623    | 296    | 1280   |
| Arable Land (Irrigated) | 702   | 230    | 373    | 94       | 608    | 2543   | 658    | 5208   |
| Arable Land (Total)     | 767   | 245    | 488    | 102      | 767    | 3166   | 954    | 6488   |

Source: Land Cover Atlas of Afghanistan, FAO, December, 2012.

## 2.2. Multivariate Probit Model

Linear regression is the procedure that estimates the coefficients of a linear equation, involving one or more independent variables that best predict the value of the dependent variable, which should be quantitative. Logistic regression is similar to linear regression but is suited to models where the dependent variable is dichotomous. Logistic regression coefficients can be used to estimate odds ratios for each independent model variable [32]. Since the current study comprises more binary dependent variables, the multivariate probit model has been used for the analysis.

The multivariate probit econometric model was used to examine the relationship between the explanatory variables and climate change adaptation strategies. The different climate change adaptation strategies followed by the sample respondents were used as dependent variables in the analysis. The nine adaptation strategies included in the study were chosen based on extensive field observations during the pilot study and a review of the previous literature on adaptation strategies in agriculture. These climate change adaptation strategies were identified as the responses most commonly adopted by farmers in the study area. The selection was further validated through pre-survey consultations with agricultural extension experts and local farmers, ensuring its relevance to the present study.

The explanatory variables included in the analysis are age, education, farming experience, farm size, household income, technical guidance from experts, and access to credit. The multivariate probit model permits error terms to freely correlate and reflects the effects of the set of explanatory variables on each of the different options [33,34]. Based on the farmers' responses, it can be inferred that they adapt various strategies in response to climate change in the study region and offer multiple choices which provide options that are highly interrelated and interdependent. Similarly, multiple adaptive strategies followed by farmers to mitigate climate change in agricultural production are correlative [35]. To address the correlations of the error terms among unobserved interdependent adaptation choices to climate change, the probit multivariate model was used to ensure statistical efficiency [33]. The proposed methodology derives insight into farmers' socioeconomic factors that play a role and are found to be instrumental in their adoption of various strategies to adapt to climate change extremes. The null hypothesis of this study is that there is no significant difference between the socioeconomic characteristics of sample respondents and their adapted strategies. This implies that farmers, irrespective of their age, education, farming experience, farm size, farmers income, technical guidance from experts, and access

to credit, used a variety of choices for adaptation to climate change extremes. The model can be specified as follows [34,36].

$$\begin{aligned}
 Y_{i1} &= X'_{i1}\beta_1 + \varepsilon_{i1} \\
 Y_{i2} &= X'_{i2}\beta_2 + \varepsilon_{i2} \\
 Y_{i3} &= X'_{i3}\beta_3 + \varepsilon_{i3} \\
 Y_{i4} &= X'_{i4}\beta_4 + \varepsilon_{i4} \\
 Y_{i5} &= X'_{i5}\beta_5 + \varepsilon_{i5} \\
 Y_{i6} &= X'_{i6}\beta_6 + \varepsilon_{i6} \\
 Y_{i7} &= X'_{i7}\beta_7 + \varepsilon_{i7} \\
 Y_{i8} &= X'_{i8}\beta_8 + \varepsilon_{i8} \\
 Y_{i9} &= X'_{i9}\beta_9 + \varepsilon_{i9}
 \end{aligned} \tag{1}$$

where  $i$  = farmer id;  $Y_{i1} = 1$  if the farmer changes the cropping pattern (0 otherwise);  $Y_{i2} = 1$  if the farmer delays the crop season (0 otherwise);  $Y_{i3} = 1$  if the farmer uses water-saving technologies (0 otherwise);  $Y_{i4} = 1$  if the farmer reduces the number of irrigations (0 otherwise);  $Y_{i5} = 1$  if the farmer drills new bore wells (0 otherwise);  $Y_{i6} = 1$  if the farmer uses water conservation technologies (0 otherwise);  $Y_{i7} = 1$  if the farmer adopts farm diversification (0 otherwise);  $Y_{i8} = 1$  if the farmer sells some livestock (0 otherwise);  $Y_{i9} = 1$  if the farmer migrates for employment to a non-agricultural sector (0 otherwise);  $X'_i$  = vector of factors of adaptation choices of the sample response to climate change extremes;  $\beta_j$  = vector of unknown parameters ( $j = 1, 2, 3, \dots, 9$ ); and  $\varepsilon$  = error term. The description of the dependent and independent variables used in the probit model is shown in Table 2. The econometric regression analysis was carried out by running nine different independent binary probit models of the following form in the STATA version 18 software.

$$Y_{ij} = X'_{ij}\beta_j + \varepsilon_{ij} \tag{2}$$

$Y_{ij}$  = climate change adaptation choices ( $j = 1, \dots, 9$ ) of  $i$ th farmer ( $j = 1, \dots, 105$ );  $X'_{ij} = 1 \times k$  vector of observed variables;  $\beta_j = k \times 1$  vector of unknown parameters to be estimated;  $\varepsilon_{ij}$  = unobserved error term.

**Table 2.** Description of the independent variables.

| Variables                                                     | Units  | Description              |
|---------------------------------------------------------------|--------|--------------------------|
| Dependent Variable                                            |        |                          |
| 1. Farmer changes cropping pattern.                           | Binary | Yes = 1, and 0 otherwise |
| 2. Farmer delays the crop season.                             |        |                          |
| 3. Farmer uses water-saving technologies.                     |        |                          |
| 4. Farmer reduces the number of irrigations.                  |        |                          |
| 5. Farmer drills new bore wells.                              |        |                          |
| 6. Farmers uses water conservation technologies.              |        |                          |
| 7. Farmer adopts farm diversification.                        |        |                          |
| 8. Farmer sells some livestock.                               |        |                          |
| 9. Farmer migrates for employment to non-agricultural sector. |        |                          |

Table 2. *Cont.*

| Variables                                 | Units    | Description                                                                           |
|-------------------------------------------|----------|---------------------------------------------------------------------------------------|
| Independent Variable                      |          |                                                                                       |
| Age ( $X_1$ )                             | Years    | Continuous: Representing actual age of the farmer                                     |
| Education ( $X_2$ )                       | Years    | Continuous: Number of years of schooling                                              |
| Farming experience ( $X_3$ )              | Years    | Continuous: Total years of experience in farming                                      |
| Farming size ( $X_4$ )                    | Hectares | Continuous: Land area owned by the farmer                                             |
| Household income ( $X_5$ )                | USD      | Continuous: Total annual income                                                       |
| Technical guidance from experts ( $X_6$ ) | Binary   | Information received from agricultural extension officials (Yes = 1, and 0 otherwise) |
| Access to credit ( $X_7$ )                | Binary   | Access to credit facility (Yes = 1, and 0 otherwise)                                  |

Technical guidance from experts indicates that a farmer receives information or advice about climate change issues, agro-advisory services, and adaptation strategies from local agricultural officials. Access to credit indicates how easy or difficult it is for a farmer to obtain an agricultural loan from institutional sources such as banks and other public financial institutions (formal sources of credit) and non-institutional sources like money lenders, brokers, commission agents, friends, and relatives (informal sources of credit).

### 3. Results and Analyses

#### 3.1. Inter-Annual Variations in Rainfall and Temperature

The data for rainfall and maximum and minimum temperatures in Afghanistan during the period from 1901 to 2023 were collected from the World Bank Climate Change Knowledge Portal. The year-to-year variations in rainfall and maximum and minimum temperatures in Afghanistan during the period from 1901 to 2023 are shown in Figure 2. The standardized rainfall anomaly provides more information on the magnitude and pattern of rainfall deviation from its long-term average, indicating the wet and dry periods [37]. However, the year-to-year rainfall departures are well pronounced, indicating the causes of extreme drought and floods, which significantly affect crop production in Afghanistan. Moreover, the maximum and minimum temperature anomaly illustrates a persistently increasing trend from 1995 to 2023, showing increasing heat waves, which aggravate soil moisture depletion and impact crop growth and development.

The maximum temperature slope of 0.054 indicates an upward trend, with the average maximum temperature having increased by 0.0154 °C annually over the period of 123 years. This indicates that the maximum temperature has risen by approximately 1.89 °C over the 123-year period, suggesting that extreme temperatures may cause more frequent and intense heatwaves, increased evaporation, drought risk, higher energy demand, and negative impacts on agriculture and water resources could further aggravate climate extremes. Similarly, the minimum temperature also showed an upward trend, with the average minimum temperature having increased by 0.0201 °C annually, with a cumulative effect of 2.47 °C over the 123-year period. The increasing temperature anomaly indicates the occurrence of global warming that leads to drought, which highlights the immediate necessity for sustainable farming methods and governmental initiatives to reduce the adverse effects of climate variability on the country's agriculture.

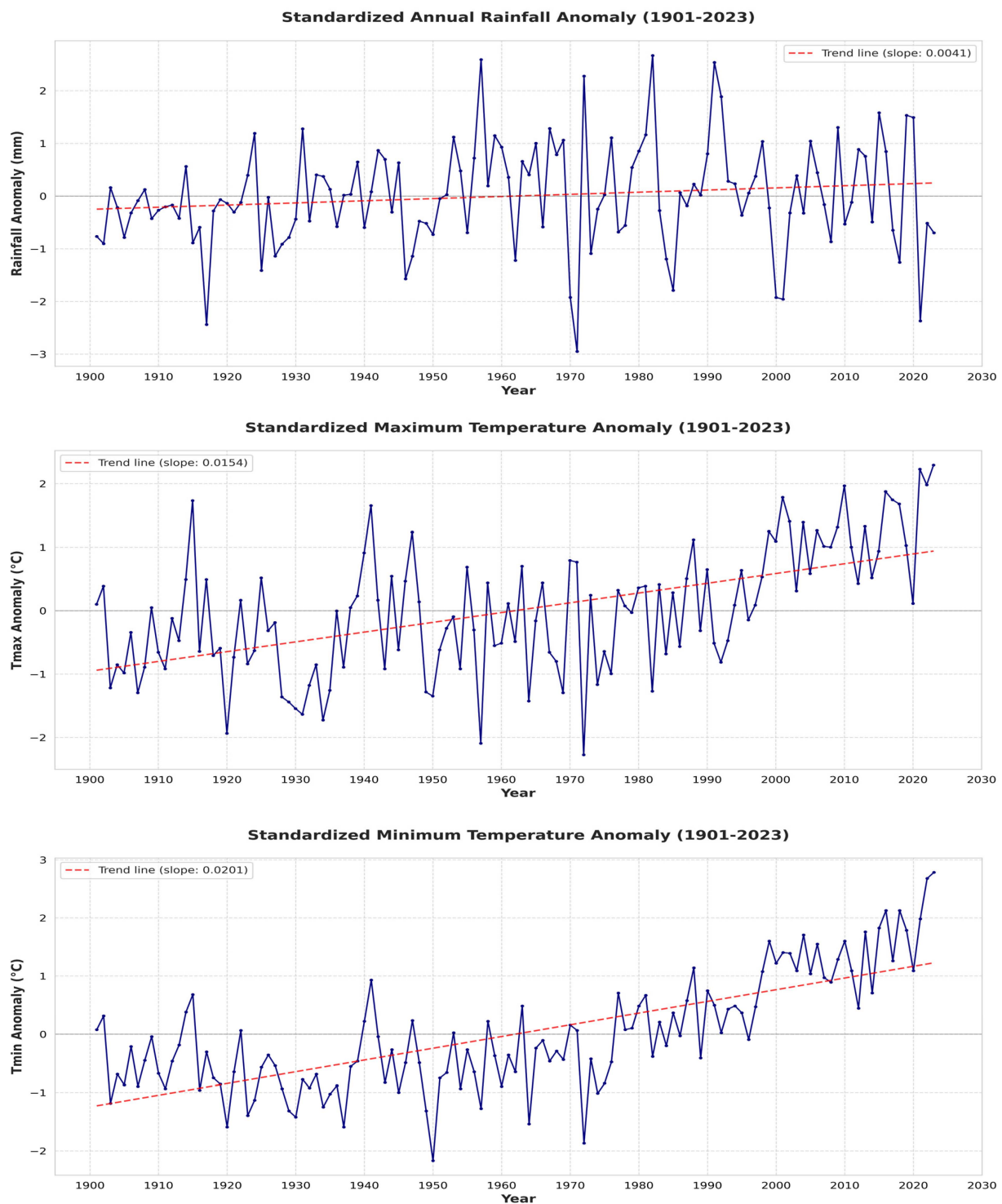


**Figure 2.** The year-to-year variations in rainfall and maximum and minimum temperature.

To strengthen adaptation plans and mitigate the adverse effect of climate variability on agricultural activities, climate-resilient strategies, viz., crop diversification, enhanced technical assistance and consulting services, crop insurance, water saving technologies, new irrigation methods, access to interest-free credit facilities from public financial institutions, might be promoted to improve the livelihood of the farming community in the country.

### 3.2. Descriptive Statistics of the Sample Respondents

The descriptive statistics of the sample respondents' demographic and socioeconomic features are shown in Table 3. The average age of the respondents was approximately 43 years with a farming experience of about 26 years, indicating that agriculture was relatively the primary occupation in the study region. The average land holding size was about 1.39 ha, with a standard deviation of 0.15 ha. The mean annual income of the sample respondents was approximately USD 2968 per household, with a wide variation in income.

**Table 3.** Descriptive statistics of the sample respondents.

| Independent Variable            | Mean     | Standard Deviation | Minimum | Maximum |
|---------------------------------|----------|--------------------|---------|---------|
| Age                             | 42.73    | 1.19               | 18.00   | 75      |
| Education                       | 5.79     | 0.63               | 0.00    | 16      |
| Farming experience              | 26.38    | 1.26               | 3.00    | 54      |
| Landholding size (Ha)           | 1.39     | 0.15               | 0.10    | 11      |
| Household income (USD)          | 2967.78  | 304.60             | 518.81  | 22,049  |
| Technical guidance from experts | Yes = 73 |                    | No = 32 |         |
| Access to informal credit       | Yes = 94 |                    | No = 11 |         |

### 3.3. Results of Multivariate Probit Model Regression

The results of the multivariate probit regression model for various determinants of climate change adaptation strategies are presented in Table 4. The Variance Inflation Factor (VIF) test confirmed that multicollinearity was not a concern, as all explanatory variables had values below 10. A positive and significant coefficient for age in the “change in cropping pattern” model (0.049, significant at 5%) suggests that older farmers are more likely to modify their cropping patterns as an adaptation strategy. The positive and significant coefficient for education in “sale of some livestock” (0.120, significant at 10%) and “migration to non-agricultural sectors” (0.044, significant at 5%) suggests that educated farmers are more likely to sell livestock or shift to non-agricultural jobs compared to their less-educated counterparts. A negative and significant coefficient for farming experience in “water conservation technologies” (−0.0406, significant at 10%) and “migration to non-agricultural sectors” (−0.035, significant at 5%) suggests that younger farmers are more likely to adopt water conservation measures or migrate out of agriculture as a climate coping mechanism. The positive and significant coefficient of land holding suggests that farmers with larger land areas reduced the number of irrigations and the negative and significant coefficient indicates that farmers with a smaller land holding size followed the advancement or delaying of the cropping season as a strategy for climate change coping.

The findings of the probit model revealed that age, income, expert guidance, and access to credit significantly (at 5% level) influenced the farmers to practice shifting cropping patterns toward less-water consuming crops. The model findings also showed that the low-income farmers adopted shifting cropping patterns as one of their adaptation tactics during extreme climate change. Information from extension professionals has a favorable and substantial influence on shifting cropping patterns and diversifying farms to reduce the effects of climate change. However, the selling of some cattle and drilling of new bore wells to ameliorate climate change are discouraged by the experts' technical guidance. Access to credit facilities has a statistically significant positive effect on changing cropping patterns and water-saving technologies as climate coping practices.

**Table 4.** Results of multivariate probit model for determinants of adaptation choices.

| Independent Variables           | Dependent Variables        |                                         |                           |                                    |                         |                                 |                      |                        |                                       |
|---------------------------------|----------------------------|-----------------------------------------|---------------------------|------------------------------------|-------------------------|---------------------------------|----------------------|------------------------|---------------------------------------|
|                                 | Change in Cropping Pattern | Delaying/ Advancing the Cropping Season | Water Saving Technologies | Reduction in Number of Irrigations | Drilling New Bore Wells | Water Conservation Technologies | Farm Diversification | Sale of Some Livestock | Migration to Non-Agricultural Sectors |
| Age                             | 0.049 **                   | 0.013                                   | 0.005                     | −0.0006                            | −0.014                  | 0.037                           | −0.043 **            | −0.827 *               | 0.0499 **                             |
|                                 | (0.023)                    | (0.020)                                 | (0.025)                   | (0.020)                            | (0.022)                 | (0.025)                         | (0.022)              | (0.497)                | (0.021)                               |
| Education                       | 0.0142                     | 0.004                                   | −0.043                    | 0.023                              | 0.005                   | −0.039                          | −0.027               | 0.120 *                | 0.044 *                               |
|                                 | (0.027)                    | (0.023)                                 | (0.031)                   | (0.023)                            | (0.024)                 | (0.034)                         | (0.024)              | (0.069)                | (0.025)                               |
| Farming experience              | 0.019                      | −0.002                                  | −0.010                    | −0.007                             | 0.013                   | −0.0406 *                       | 0.014                | 0.779                  | −0.035 *                              |
|                                 | (0.022)                    | (0.019)                                 | (0.026)                   | (0.019)                            | (0.021)                 | (0.024)                         | (0.021)              | (0.487)                | (0.020)                               |
| Farm Size                       | 0.183                      | −0.238 **                               | 0.143                     | 0.152 *                            | −0.111                  | −0.020                          | 0.008                | −1.072                 | 0.069                                 |
|                                 | (0.114)                    | (0.116)                                 | (0.163)                   | (0.090)                            | (0.150)                 | (0.126)                         | (0.106)              | (1.099)                | (0.109)                               |
| Household income                | −0.0002 ***                | 0.00007                                 | −0.00006                  | 0.00006                            | 0.00003                 | −0.00004                        | −0.00008             | 0.00062 *              | −0.00003                              |
|                                 | (0.00006)                  | (0.00005)                               | (0.00006)                 | (0.00005)                          | (0.00005)               | (0.00009)                       | (0.00006)            | (0.00034)              | (0.00005)                             |
| Technical guidance from experts | 0.683 **                   | 0.463                                   | −0.079                    | −0.205                             | −0.630 **               | −0.106                          | 0.613 *              | −2.942 *               | −0.396                                |
|                                 | (0.317)                    | (0.297)                                 | (0.398)                   | (0.296)                            | (0.297)                 | (0.382)                         | (0.323)              | (1.568)                | (0.313)                               |
| Access to credit                | 1.417 **                   | −0.990 **                               | 1.353 ***                 | −0.086                             | 0.418                   | −0.425                          | −0.438               | −5.262                 | 0.504                                 |
|                                 | (0.558)                    | (0.492)                                 | (0.519)                   | (0.450)                            | (0.507)                 | (0.501)                         | (0.476)              | (3.342)                | (0.503)                               |
| Constant                        | −4.005 ***                 | 0.138                                   | 0.447                     | −0.464                             | −0.224                  | −1.058                          | 1.201                | 12.445                 | −2.407 ***                            |
|                                 | (1.044)                    | (0.791)                                 | (0.939)                   | (0.796)                            | (0.845)                 | (1.032)                         | (0.840)              | (7.936)                | (0.877)                               |
| Log-likelihood                  | −50.819                    | −66.803                                 | −32.503                   | −63.610                            | −60.279                 | −31.494                         | −57.707              | −7.110                 | −53.379                               |
| LR $\chi^2$                     | 42.77                      | 11.72                                   | 9.63                      | 10.23                              | 6.86                    | 7.45                            | 12.01                | 25.98                  | 10.78                                 |
| Prob > $\chi^2$                 | 0.0000                     | 0.1103                                  | 0.2108                    | 0.1761                             | 0.4432                  | 0.3835                          | 0.1002               | 0.0005                 | 0.1485                                |
| Number of observations          | 105                        | 105                                     | 105                       | 105                                | 105                     | 105                             | 105                  | 105                    | 105                                   |

Figures in parentheses indicate standard error and \*, \*\*, and \*\*\* are at 10, 5, and 1 percent significance, respectively.

### 3.4. Marginal Effects of Various Climate Change Adaptation Strategies

This study is the first of its kind to examine the climate change adaptation strategies in the central agro-climatic zone of Afghanistan using a robust econometric model, offering insights into rural development policies. The marginal effect shows the change in the likelihood of a climate change adaptation strategy for a unit change in the predictor variable; they are shown in Table 5. The coefficient of age for shifting cropping patterns and migration to non-agricultural sectors was significantly positive, indicating that one year in age increased the probability of migrating to non-agricultural sectors by 1.4 percentage points and the likelihood of shifting cropping patterns by 1.3 percentage points. The marginal effects of age indicated that, for every 1-year increase, the probabilities of practicing crop diversification and sale of some livestock were decreased by 4.3 and 8.2 percent, respectively, and these findings indicated that younger farmers are inclined towards asset-based climate coping strategies. A higher level of education supports movement towards non-agricultural sectors to strengthen climate-resilient activities. Experienced farmers are more likely to sell their cattle (2.9%) and less likely to leave the farm for non-agricultural employment. Respondents with larger land holdings are more likely to reduce the number of irrigations, by 5.2 percentage points, reflecting their efficiency in water management practices. However, smaller farms are more likely to advance or delay the cropping season, by 8.7 percentage points, indicating their ability to follow traditional climatic coping strategies. Lower-income households are more likely to change their cropping pattern, whereas high-income farmers are more inclined to sell their livestock to adapt to the changing climate. Farmers having access to technical guidance from extension officials significantly (at 5% level) increases the likelihood of them changing their cropping pattern, by 18.6 percent, and diversifying their farms, by 19.2 percentage points. The results on crop diversification and changes in cropping patterns on technical guidance from experts were similar to the findings of a study on determinants of climate change adaptation strategies in South India [38]. Another study, conducted in [39], also obtained similar findings on receiving technical guidance from experts positively influencing crop diversification as a climate change adaptation strategy. On the other hand, expert guidance reduced the likelihood of drilling new bore wells by 20.5 percentage points and decreased the probability of selling livestock by 10.8 percentage points. These findings clearly indicate that effective use of extension services can enhance the adoption of climate-resilient strategies. Access to credit is essential, making farmers 23.2 percent more likely to invest in water saving technologies and 38.7 percentage points more likely to shift the cropping pattern. However, farmers having access to credit reduced the likelihood of them delaying cropping seasons by 36.0 percentage points and decreased the probability of selling livestock by 19.3 percentage points. These findings show that the farmers who had access to credit were able to take proactive approaches and had a reduced measure of dependence on reactive measures.

**Table 5.** Results of marginal effect for determinants of adaptation choices.

| Independent Variables           | Dependent Variables        |                              |                           |                                        |                         |                                 |                      |                        |                                                      |
|---------------------------------|----------------------------|------------------------------|---------------------------|----------------------------------------|-------------------------|---------------------------------|----------------------|------------------------|------------------------------------------------------|
|                                 | Change in Cropping Pattern | Delaying the Cropping Season | Water Saving Technologies | Reduction in the Number of Irrigations | Drilling New Bore Wells | Water Conservation Technologies | Farm Diversification | Sale of Some Livestock | Migration for Employment to Non-Agricultural Sectors |
| Age                             | 0.013 **                   | 0.005                        | 0.001                     | 0.000                                  | −0.004                  | 0.006                           | −0.013 **            | −0.030 **              | 0.014 **                                             |
|                                 | (0.006)                    | (0.007)                      | (0.004)                   | (0.007)                                | (0.007)                 | (0.004)                         | (0.006)              | (0.014)                | (0.006)                                              |
| Education                       | 0.004                      | 0.001                        | −0.007                    | 0.008                                  | 0.002                   | −0.006                          | −0.008               | 0.004 **               | 0.013 *                                              |
|                                 | (0.007)                    | (0.008)                      | (0.005)                   | (0.008)                                | (0.008)                 | (0.006)                         | (0.008)              | (0.002)                | (0.007)                                              |
| Farming experience              | 0.005                      | −0.001                       | −0.002                    | −0.002                                 | 0.004                   | −0.007 *                        | 0.004                | 0.029 **               | −0.010 *                                             |
|                                 | (0.006)                    | (0.007)                      | (0.004)                   | (0.007)                                | (0.007)                 | (0.004)                         | (0.007)              | (0.014)                | (0.005)                                              |
| Farm size                       | 0.050                      | −0.087 **                    | 0.024                     | 0.052 *                                | −0.036                  | −0.003                          | 0.003                | −0.039                 | 0.020                                                |
|                                 | (0.030)                    | (0.040)                      | (0.028)                   | (0.030)                                | (0.049)                 | (0.020)                         | (0.033)              | (0.037)                | (0.031)                                              |
| Household income                | −0.00004 ***               | 0.00002                      | −0.00001                  | 0.00002                                | 0.00001                 | −0.00001                        | −0.00002             | 0.00002 ***            | −0.00001                                             |
|                                 | (0.000)                    | (0.000)                      | (0.000)                   | (0.000)                                | (0.000)                 | (0.000)                         | (0.000)              | (0.000)                | (0.000)                                              |
| Technical guidance from experts | 0.186 **                   | 0.169                        | −0.013                    | −0.071                                 | −0.205 **               | −0.017                          | 0.192 **             | −0.108 ***             | −0.113                                               |
|                                 | (0.081)                    | (0.104)                      | (0.068)                   | (0.101)                                | (0.091)                 | (0.062)                         | (0.096)              | (0.038)                | (0.088)                                              |
| Access to credit                | 0.387 ***                  | −0.360 **                    | 0.232 ***                 | −0.030                                 | 0.136                   | −0.069                          | −0.137               | −0.193 **              | 0.144                                                |
|                                 | (0.138)                    | (0.169)                      | (0.087)                   | (0.155)                                | (0.164)                 | (0.081)                         | (0.147)              | (0.097)                | (0.142)                                              |

Figures in parentheses indicate standard error and \*, \*\*, and \*\*\* are at 10, 5, and 1 percent significance, respectively.

#### 4. Conclusions and Policy Recommendations

Changing climatic conditions greatly influence a country's agriculture directly and indirectly due to increasing temperature and variability in precipitation, which affects food production and farmers' livelihoods. The inter-annual variations in the maximum and minimum temperatures during 1901 to 2023 revealed that they have increased annually by 0.0154 °C and 0.0201 °C, respectively. This indicates that the average maximum temperature has increased about 1.89 °C and the average minimum temperature has increased by 2.47 °C over the period of 123 years. Furthermore, the average maximum and minimum temperature anomalies indicate a consistent upward trend during the recent years from 1995 to 2023, suggesting that heat waves intensively deplete the soil moisture and have an impact on crop growth and development. The year-to-year rainfall difference also significantly caused drought and floods, which have a significant impact on agricultural productivity in Afghanistan. The objective of this research was to identify the key determinants of farmers' strategies for adaptation to climate change in Afghanistan using a multivariate probit model to reduce the climate variability and adverse impact of climate change on agricultural production. The investigation attended to the explanatory variables such as age, education, farming experience, land-holding size, household income, technical guidance from experts, and access to informal credit. The average age of respondents was approximately 43 years with farming experience of about 26 years, indicating that agriculture was the primary source of occupation in the study area.

The results from the multivariate probit model indicate that the coefficient of age for shifting cropping patterns and migration to non-agricultural sectors was significantly positive, indicating that every one year in age increased the probability of migrating to non-agricultural sectors by 1.4 percentage points and the likelihood of shifting cropping patterns by 1.3 percentage points. Farmers with higher levels of education are more likely to sell their livestock and move to non-agricultural sectors for employment and these two were found to be the prime adaptation strategy to climate change. Experienced farmers are more likely to sell their cattle (2.9%) and less likely to leave the farm for non-agricultural employment. A negative and significant coefficient of farming experience with water conservation technologies suggested that younger farmers have a 4 percent higher probability of adopting water conservation measures as a coping strategy.

Respondents with larger land holdings are more likely to reduce the number of irrigations, by 5.2 percentage points, reflecting their efficiency in water management practices. However, smaller farms are more likely to advance or delay the cropping season, by 8.7 percentage points, indicating their ability to follow traditional climatic coping strategies. The guidance from technical experts suggests changing cropping patterns and farm diversification as adaptation strategies. The marginal effect for determinants of adaptation strategies indicated that farmers having access to technical guidance from extension officials have an increased likelihood of changing their cropping pattern, by 18.6 percent, and diversifying their farms, by 19.2 percentage points. Also, farmers having access to credit reduced the likelihood of them delaying cropping seasons by 36.0 percentage points and decreased the probability of them selling livestock by 19.3 percentage points.

The study further provides empirical evidence on the marginal effects of key socio-economic factors on climate change adaptation techniques among farmers in the central agro-climatic zone of Afghanistan. The findings of the study show that younger and more educated farmers have a higher probability of using asset-based and proactive adaptation strategies, such as shifting cropping patterns and looking for non-agricultural occupations. In contrast, older and more experienced farmers are more dependent on traditional techniques like selling livestock. Access to extension services and loans has emerged as a critical enhancer of climate-resilient practices such as crop diversification

and investments in water saving technologies. These findings significantly highlight the necessity of targeted support and policies to improve adaptive capability among the vulnerable farming communities in Afghanistan.

Based on the findings of the study, the following recommendations might be followed by the government and agricultural producers to mitigate future implications of climate change. In dealing with the effects of climate change, Afghanistan can strive to enhance rural farmers' adaptability, guarantee food security, and sustain rural livelihoods by promoting community participation and bringing in innovative methods in the research and development of drought-tolerant varieties. In Afghanistan, presently farmers are more dependent on informal sources of credit like money lenders, brokers, commission agents, friends, and relatives. The government could initiate an effort to provide access to agricultural loans from institutional sources such as banks and other public financial institutions, which would likely reduce the burden on the farming community and boost agricultural production.

The government may invest in providing subsidies to drip and sprinkler irrigation technologies, the adoption of precision farming technologies, rehabilitation of existing ponds and canals, providing training to farmers, capacity building programs on climate-smart sustainable practices for extension officials, creating awareness about new technologies, expanding public extension networks, mobile-based agro-advisory services, and public–private partnership to cope with climate change and enhance farm production.

There are limitations to this study; however, it offers important insights into key determinants of climate change adaptation strategies for the changing climate in Afghanistan. Recall bias may have an impact on survey replies and inconsistencies in climate information on various adaptation strategies may compromise the results of the study. Furthermore, by concentrating on socioeconomic and environmental determinants, the study leaves out elements such as institutional support, market access, and policy initiatives. To improve Afghanistan's agricultural resilience, future studies should evaluate the long-term efficacy of adaptation tactics and use larger datasets.

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