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Climate Change Impacts and Adaptation in a Hill Farming System of the Himalayan Region: Climatic Trends, Farmers' Perceptions and Practices

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Abstract: Farming communities in the hills and mountains of the Himalayan region are some of the most vulnerable to the changing climate, owing to their specific biophysical and socioeconomic conditions. Understanding the observed parameters of the changing climate and the farmers' perceptions of it, together with their coping approaches, is an important asset to making farming communities resilient. Therefore, this study aimed to explore the observed change in climatic variables; understand farmers' perceptions of the changing climate; and document their adaptation approaches in farming systems in the mid-hills of the central Himalayas. Data on the observed change in climatic variables were obtained from the nearby meteorological stations and gridded regional products, and farmers' perceptions and their adaptation practices were collected from household surveys and from the interviews of key informants. The analysis of temperature data revealed that there has been a clear warming trend. Winter temperatures are increasing faster than summer and annual temperatures, indicating a narrowing temperature range. Results on precipitation did not show a clear trend but exhibited large inter-annual variability. The standardized precipitation index (SPI) showed an increased frequency of droughts in recent years. Farmers' perceptions of the changing climate are coherent with the observed changes in climatic parameters. These changes may have a substantial impact on agriculture and the livelihood of the people in the study area. The farmers are adapting to climate change by altering their farming systems and practices. Location-specific adaptation approaches used by farmers are valuable assets for community resilience.

Keywords: adaptation; climate change; farming community; hill farming system; Nepal; standardized precipitation index

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1. Introduction

Climate change is already affecting many aspects of human life and society, as well as the natural environment globally. While it affects all regions of the world, the Himalayan region has been identified as one of the most vulnerable regions due to the high sensitivity of the ecosystems and the low adaptive capacity of the local people [1–3]. Vulnerability in these areas is also exacerbated by their remoteness and marginalization [4]. The most widely reported impacts of climate change on the Himalayan regions include decreased agricultural production, reduced water availability [5–9], and an increase in weather/climate-induced disasters [10–13] with many other cascading effects of these changes [3,14,15]. Studies suggest that further increases in greenhouse gas concentrations will result in a substantial additional warming of the atmosphere and thereby accelerate climate change in the future [16].

Among the various sectors of human endeavor, agriculture is one of the most adversely affected sectors due to climate change in this region [17–19]. Climate change is expected to decrease agricultural production, which has a negative impact on food security [20]. Increasing temperature and changing precipitation patterns may change the growing season, crop duration, and soil moisture regime, inducing drought in the crop plants, thereby negatively affecting crop yield [21–23]. More frequent and heavy precipitation increases the risk of crop damage from flooding, soil erosion, and landslides. In recent years, such impacts are being observed [24] frequently and may become more prominent over the next couple of decades [25,26]. People of the Himalayan region are largely (about 70%) dependent on weather-based agriculture for livelihood making this region and people vulnerable [27].

Climate model studies at a global or regional scale exhibit a bigger picture of climate change but they are not very good at providing information about changes and their impacts at the local level [20,28,29]. Although climate change is a universal phenomenon, its indicators and impacts are local, and so are the adaptation choices, strategies, and practices [20,30,31]. Therefore, there has been increasing emphasis on the bottom-up approaches that climate change studies should be conducted at the local level where adaptations take place [32–34]. In recent years, there is an increasing realization that local people are valuable sources of such information [14,35,36]. Indigenous people are not only keenly observing the changing climate, but also actively reacting and trying to adapt to it [37,38].

Compared to other regions of the world, the Himalayas are less explored and examined in scientific literature that deals with climate change and its impacts on agriculture at the local level [20,39,40]. This lack of widely available scientific data related to climate change impacts at local levels, especially about agriculture in the Himalayas, has rendered governments' efforts to make communities more climate-resilient a difficult challenge. Therefore, it is important to explore both observed changes in climatic parameters at a local level and the farmers' perceptions about the changes, and their preferences for coping strategies towards adaptation to it. On the other hand, farmers also need to understand the actual changes and trends in climatic conditions, the associated risks, and how to cope with potential impacts [41]. The specific drive of this study, therefore, was to assess the trends of climate change and perceptions of local people to climate change issues and adaptation measures in practice among the farmers in the mid-hills of the Nepalese Himalayas.

We aimed to answer the following questions: (1) Are there significant changes in the climate in the mountainous area of central Himalayas, and if yes, what are the implications for agriculture? (2) How do farmers perceive climate change? (3) To what extent are the changes in farmers' agricultural practices toward climate adaptation? Hence, this study expects to enhance our knowledge on the impacts of climate change on agriculture in mountain communities and help develop, design, and implement effective adaptation strategies to reduce vulnerability and strengthen resilience.

Therefore, this study provides insight into how individuals view the issue and how their beliefs influence their behavior and actions on climate change. This type of research is particularly valuable for developing targeted strategies of communicating the risks of climate change and motivating people to act. Additionally, it helps to identify the areas of disagreement and misunderstanding, which can inform policy decisions. Another important aspect of this study is examining how people's perceptions of climate change vary across different demographics, such as age, gender, education level, and economic status. This can help policymakers and communicators tailor their messages to better resonate with different groups and promote more effective climate action.

2. Material and Methods

2.1. Study Area

The study area is in the central part of the Nepalese Himalayas (Figure 1), which lie in the mid-hill region, encompassing many villages settled in small, scattered clusters with diverse topography. All the villages are settled in the sloping lands. The basic feature of these villages is the high dependence on agriculture, which is of mixed type with crops, livestock, and forestry amalgamated. The climate of the study site is characterized by a hot and humid summer monsoon season with dry and cold winter, although various microclimates can be found within a short distance due to the drastically altering elevations.

Most of the farmers have both upland (around the settlements) and lowlands (at the basement of mountain slopes). There are two main crop-growing seasons: the summer season (June to September) and the winter season (October to May). In the lowlands, they cultivate rice in summer and potato, wheat, and vegetables in winter. The common cropping patterns with three or more crops in a parcel are maize (*Zea mays* L.), rice (*Oryza sativa* L.), vegetables; or rice, rice, fallow. The typical upland crops are maize and potato (*Solanum tuberosum* L.) in summer and mustard (*Brassica* sp. L.) and wheat/barley (*Triticum aestivum* L./*Hordeum vulgare* L.) in winter.

There is no reliable source of water for uplands except rainfall of which about 80% falls from June to September and the available water for farming depends on the onset, cessation, and amount of the monsoon rainfall. Irrigation facilities are available for lowlands, at least for the rice growing season from small streams flowing through the basement of settlements. As an attempt to sustain farming, commercial cultivation of tomato, cucumber, cabbage, and cauliflower is on the rise in the background of growing urbanization and good market in the vicinity. Most of the households have a few cows, goat and a few have buffalo and poultry, which are kept mostly for their domestic use, milk, meat, and manure. At the same time, small-scale poultry, vegetable farming, and dairy business are coming up commercially.

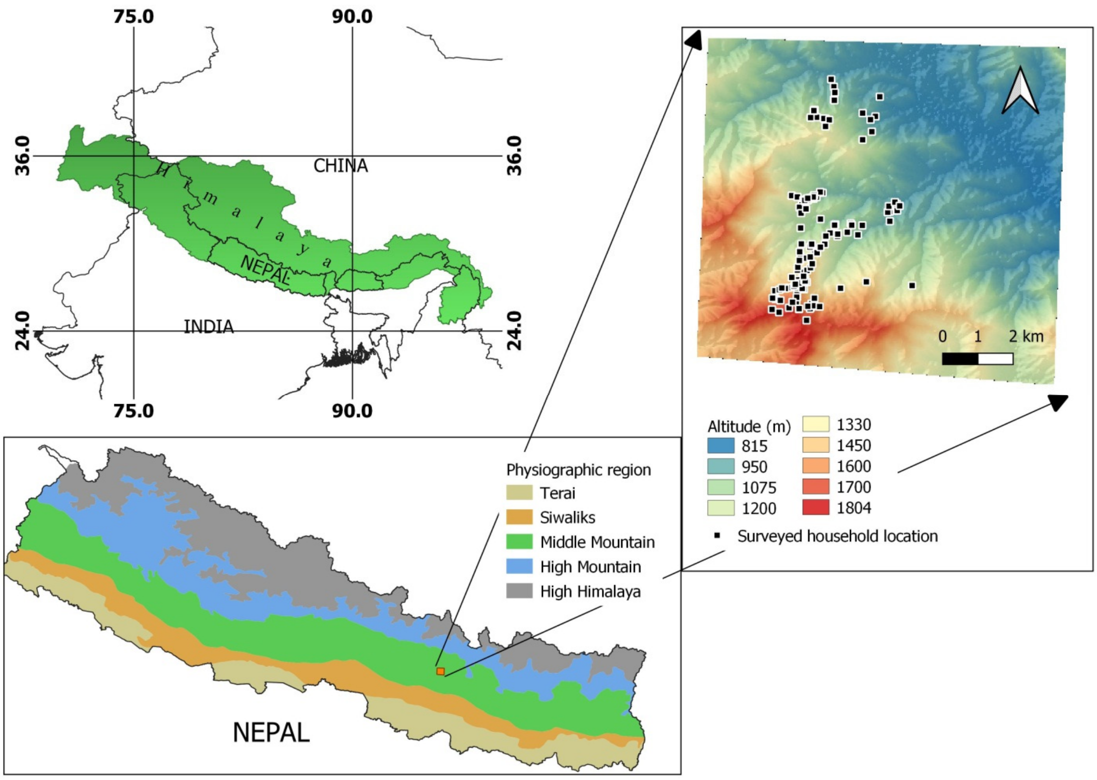

Figure 1. Location map of the study area in the mid-hills of central Himalayas, Nepal.

2.2. Climate Data

To analyze the climatic features and trends, daily precipitation data were obtained from the Department of Hydrology and Meteorology (DHM), Government of Nepal. There was no meteorological station inside the study area, and therefore, we used the data from the nearest station in Dhulikhel (6 km apart). The length of records for precipitation was 68 years (1948 to 2015). The missing precipitation data were then filled by using the gridded precipitation data produced by Asian Precipitation Highly Resolved Observational Data Integration Towards Evaluation (APHRODITE) [42]. For the temperature record, the station data contain a lot of missing values, and the quality of data was poor, therefore we used APHRODITE temperature data for the analysis [43]. We included temperature data from 1981 to 2015 in the current study.

2.3. Household Survey and Key Informant Interview

Assessment of farmers' perception of climate change, its impact on the farming system, and adaptation practices were carried out through a household questionnaire survey. We performed a cross-sectional survey in May 2017 using a multistage random sampling technique. In the first stage, Kavre district was purposively selected to represent the mid-hill farming system of Nepal. In the second stage, Patlekhet Village Development Council was selected randomly. Out of 9 wards of the village council, three wards and four small villages from each ward were randomly selected for the detailed household survey. Those twelve villages vary in altitude, ranging from 900 mm to 1800 m, as well as various other aspects and the slope. Among the total 510 households listed in the study area as the study population, a total of 153 households (30% of the population) were randomly selected as the study sample and surveyed using a semi-structured questionnaire with mostly open-ended questions to get the required information, at household levels. Researchers (and/or hired survey enumerators having at least a graduate degree and experience in similar surveys) visited each household to collect the information. The questionnaire included information on a wide range of variables, such as demography, cropping patterns, farming systems, farmers' perception of climate change, and practices adopted by them to cope with the impacts. The perception of climate change was based on the experience of changing temperatures, rainfall, and seasonality. We also collected the farmers' perceptions of the impacts of climate change on agriculture and their responses toward adaptation measures by using open-ended questions.

2.4. Data Analysis

We analyzed the annual and seasonal trends of temperature and precipitation. Mann–Kendall test (MK test) was applied to assess trends of the time series data [43,44]. The Sen's Slope Estimator [45] was used to determine the magnitude of the trend. The Standardized Precipitation Index (SPI) designed by McKee et al. [46] was used to quantify drought. To compute the SPI, [46] the suggested series of steps were followed with the equation of probability density to satisfy the gamma (Γ) distribution below:

$$f\ (x) = \frac{1}{\beta^x \Gamma(\alpha)} x^{\alpha - 1} e^{-x/\beta}, \qquad x > 0$$

where χ is the precipitation data series of the considered time scale, α (alpha) and β (beta) indicate the shape and scale parameters, which are estimated through the maximum likelihood method. Integrating the probability density function with respect to χ and inserting the estimated value of α and β, the gamma cumulative distribution function (cdf) is computed at each value of x and then the cdf is transformed into a standard normal distribution to compute SPI.

The SPI values can be interpreted as the number of standard deviations by which the observed anomaly deviates from the long-term mean. The SPI was calculated on the long-term precipitation record for a station and a long-term period (1948 to 2015). We calculated

SPI on 3-, 4-, and 12-month time scales, which correspond to the past 3, 4, 12 months of observed precipitation totals, respectively.

Following the research framework presented in Figure 2, the variables explaining the socio-economic characteristics of the respondents and the perception of climate change and adaptation practices were analyzed and presented in form of frequency and the mean. The level of association between the socio-demographic variables of the respondent farmers with the level of awareness of climate change impacts and the use of adaptation measures were presented in cross-tabulation and measured using the chi-square tests statistics. The Logit regression model was used to estimate the influence of different predictor variables on the farmers' decision to the adoption of climate change adaptation measures. IBM® SPSS® Statistics, version 20 was used for socio-economic data analysis.

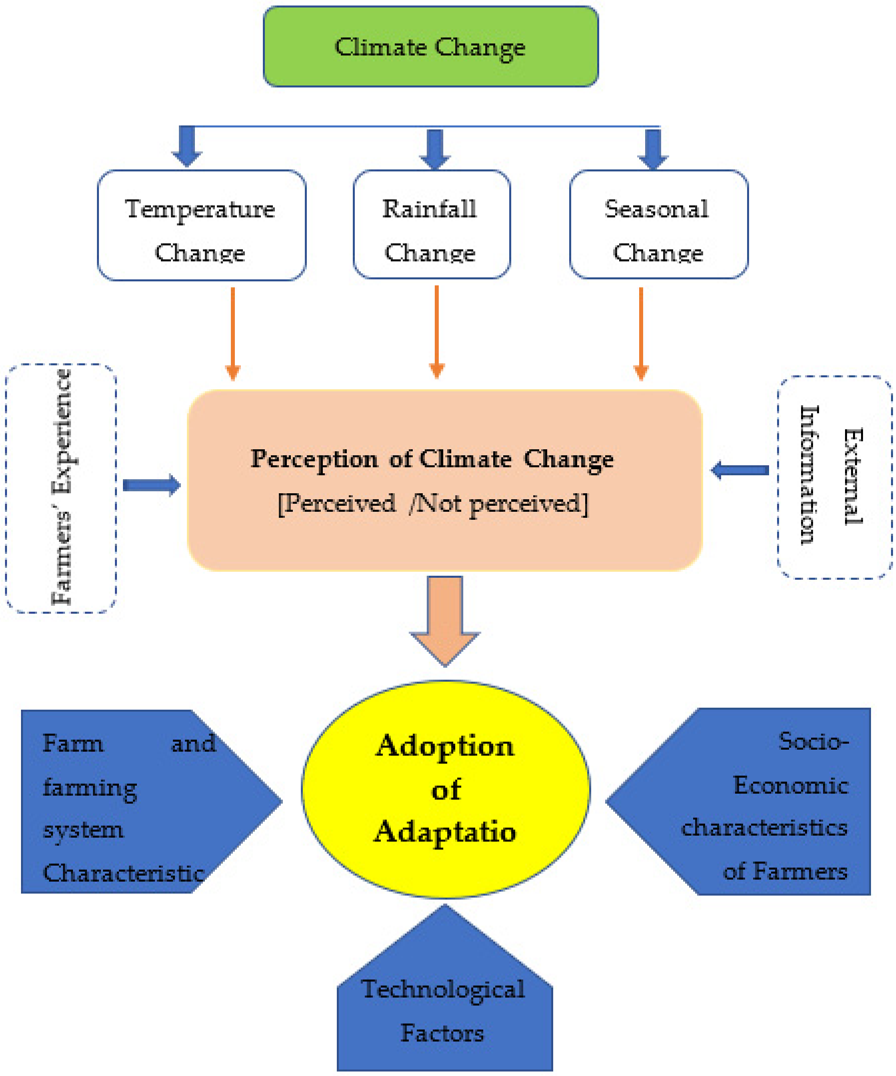

Figure 2. Research framework for climate change perception and adoption.

2.4.1. Specification of the Model

The decision to adopt any adaptation technology can be considered as a discrete binary dependent variable indicating either yes or no for the decision. The logit or probit models are the most commonly used for examining the factors affecting adoption decisions when it is a binary variable [47–53]. Though the choice between the logit and probit models largely depends on the convenience of the researchers, the logit model is often commonly used [47,54–59] due to its easiness and simple interpretation.

Following Gujarati [50] and Maddala [60], this study constructs the following form of the limited dependent variable regression model fits for this research, which was also adopted in similar research in the past [61,62].

$$y_i^* = \beta_0 + \sum_{f=1}^{k} \beta_j \chi_{ij} + u_i \quad (1)$$

where (y_i*) is the observed "latent" variable while X 's are the explanatory variables that affect the decision to adopt the adaptation measures or not, and u_i is the error term. The latent variable can only be observed as a dichotomous variable as (y_i) is defined by:

$$y_i = \begin{cases} 1 & if\ y^* > 0 \\ 0 & otherwise \end{cases}$$

where (y_i) is a variable measuring the adoption of adaptation measures or not. If the cumulative distribution of u_i is logistic, we have what is known as the logit model as follows:

$$log \frac{P_i}{1 - P_i} = \beta_0 + \sum_{f=1}^{k} \beta_j \chi_{ij} + u_i \quad (2)$$

where P_i is the probability of adoption. The left-hand side of this equation is called the log-odds ratio; thus, the log-odds ratio is a linear function of the explanatory variables.

2.4.2. Description of Independent Predictor Variables in the Model

Farmer's decision is influenced by a number of independent variables (Table 1). The **Gender** of the farmer would have a positive or negative influence on the decision. Although the male is said to have more freedom and influence in household decision-making, including the adoption of new practices, women are said to have more networks in social groups and thereby may have a role in the decision process. The level of farmers' **education** as an ordinal variable measured in a group of schooling years is expected to have a positive influence on farmers' decision to adopt the technology or practice. Other studies have revealed a positive effect [63,64].

Farmers' access to operational **landholding**, a continuous variable expressed in the number of units (ha), is another major determinant in the decision process. There are two thoughts to explain both positive or negative influences on decision-making. If the land holding is limited, farmers would be more concerned towards ensured production, and productivity from limited land by adopting technology or adaptation measures while surplus land may have a negative influence on adoption decision [36].

The **Age** of the responding farmer is a continuous variable in this model and is expressed in the number of years. Age would have positive or negative effects on a decision, however, it is expected that younger individuals are more likely to adopt technology or innovation adaptations. A similar study in Pakistan revealed the negative influence of age on adoption decisions [64,65]. On the other hand, young farmers may have higher education and more access to different sources of information, so more likely to adopt the technologies. The **distance** between the farm and the nearest market center is a continuous variable, which is expected to have a negative influence on the adoption decision. Farmers near towns or market centers are expected to adopt new technology to capture the market opportunity better than the farmers residing far from markets.

Similarly, if the farmer holds a higher number of **livestock**, he is expected to adopt the adaptation measures that complement the crop-livestock linkage in the Nepalese integrated farming system. Apart from the age of farmers, their length of engagement and **experience** in farming is another expectedly positive influence on the decision variable. The farms in higher **altitudes** might have limited access to production inputs and services, hence more likely to have a negative role in the adoption decision. The **purpose of farming**, expressed as a binary variable, either for market purpose or for subsistence, has a positive influence on adaptation measure adoption decisions.

Table 1. Key exogenous variables and their possible effect on the decision.

Variable	Measurement	Possible Effect
EDUCATION	Level of education of the farmer measured in years of schooling	+
AGE	Age of responding farmer measured in years	−
GENDER	Gender of farmer respondent as binary variable noted as 1 = male and 0 = female farmer	+
LANDHOLDING	Size of operational land holding by the farmer measured in hectare	+
DISTANCE TO MARKE	Distance to nearest market to sale of agricultural produce measured in kilometer	+/−
LIVESTOCK	Number of livestock holding measured in numbers	+
FARMING EXPERIENCE	Years of farming experience of the responding farmers	+
FARM ALTITUDE	Location of farm expressed as altitude meter above sea level (masl)	−
FARMING PURPOSE	Primary purpose of the farming activity as binary variable 1 = market purpose otherwise 0 = subsistence.	+

3. Results

3.1. Climatic Characteristics and Trend Analysis

3.1.1. Precipitation Characteristics and Trend

Average (1948 to 2015) annual precipitation was 1469 mm and around 80% (1165 mm) occurring in four months (June to September) of the monsoon season in the study area (Figure 3).

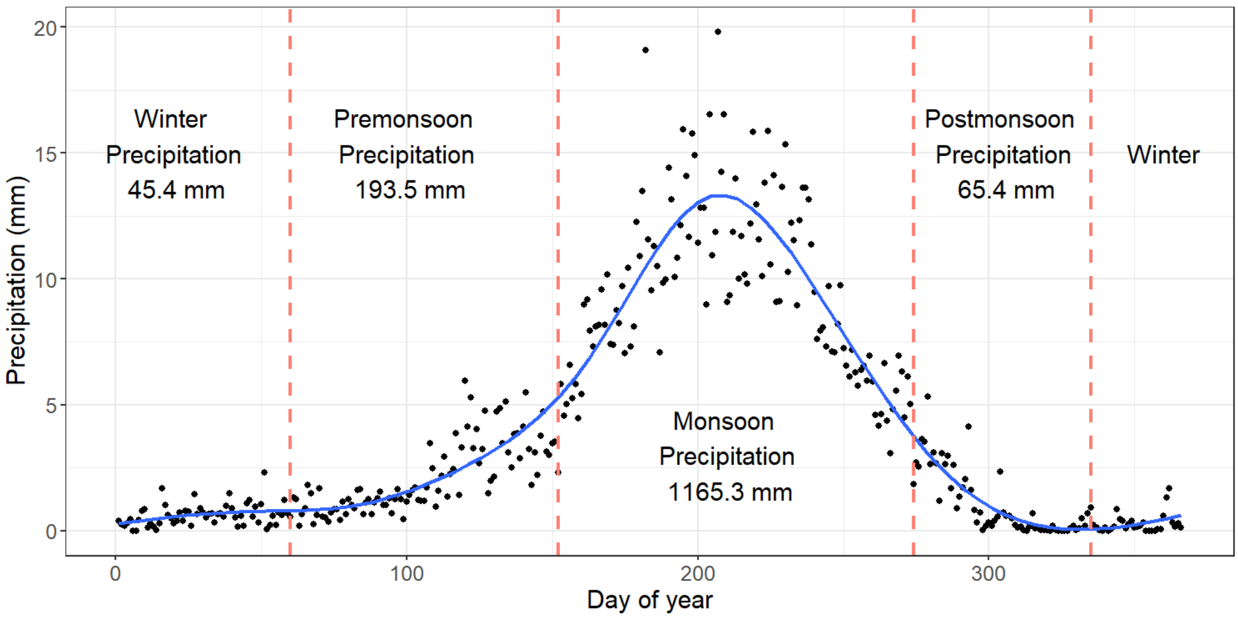

Figure 3. Mean daily (black dots) and smoothed average (blue line) precipitation in the study area over the years, averaged over 68 years (1948 to 2015).

Trend analysis of the annual and seasonal total precipitation recorded at Dhulikhel station showed a decreasing trend in annual (–3.55 mm year^{-1}), monsoon (–3.22 mm year^{-1}), and post-monsoon (–0.25 mm year^{-1}) precipitation and increasing trend in pre-monsoon (0.25 mm year^{-1}) precipitation (Figure 4) but none of the trends was significant at 95% confidence level indicating large inter-annual variability (Figure 5).

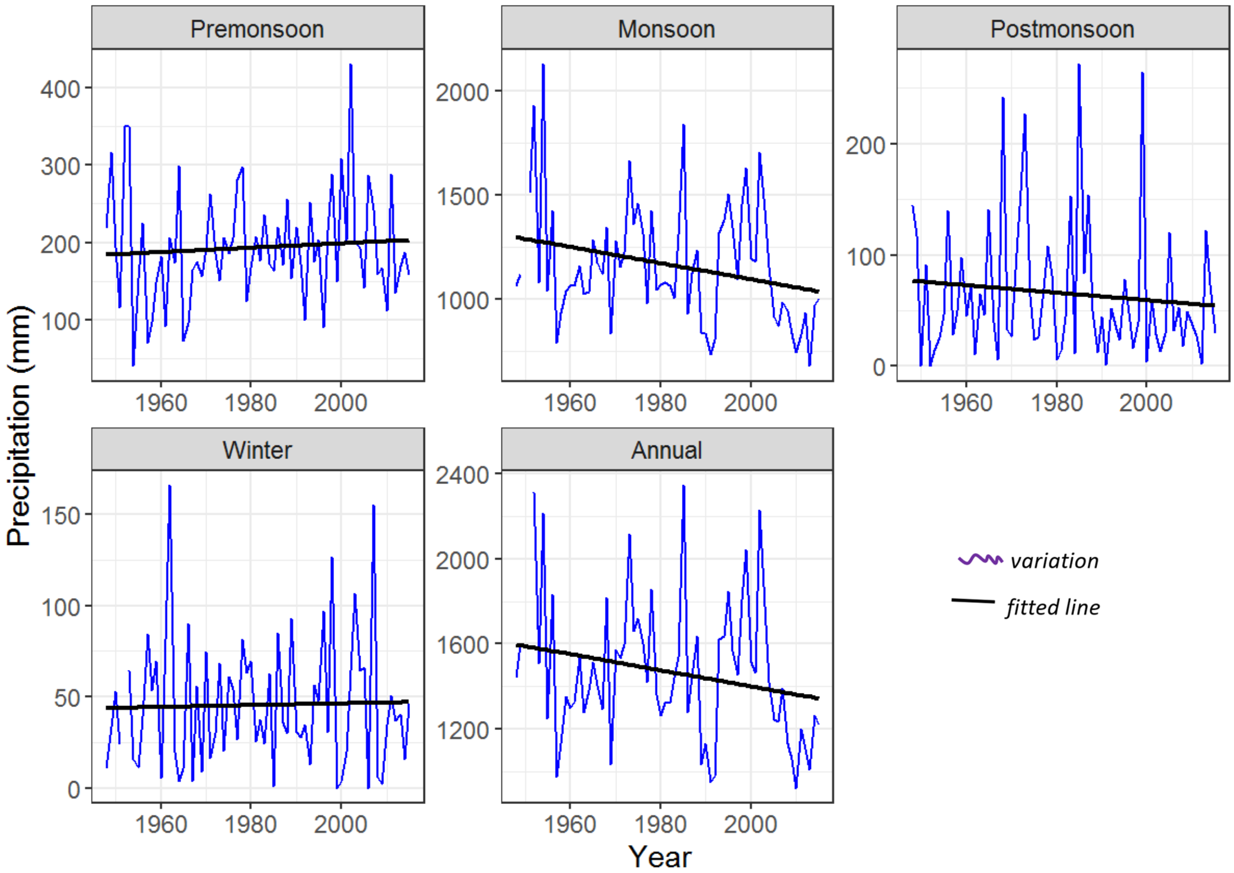

Figure 4. Trends of seasonal and annual total precipitation in the study area.

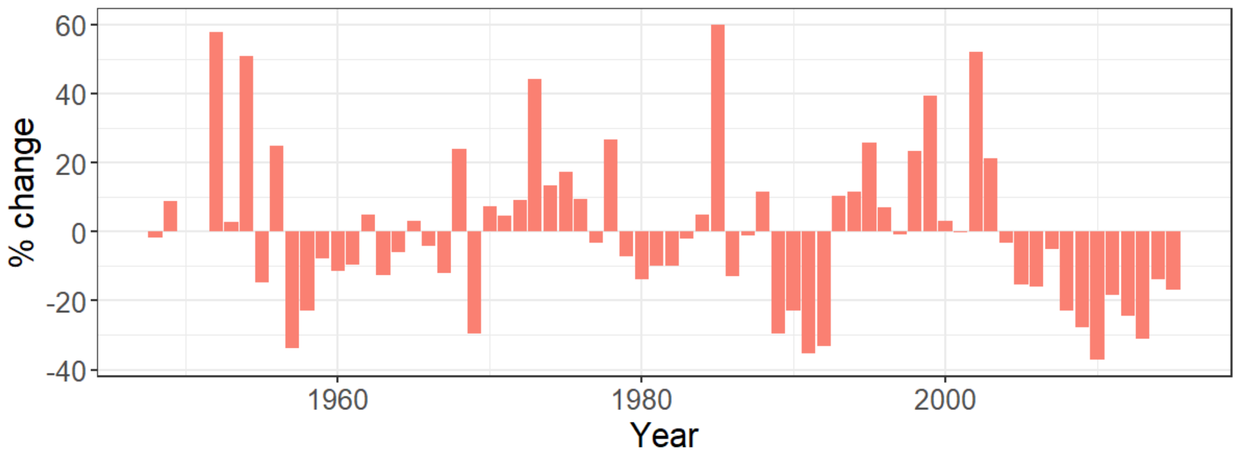

Figure 5. Deviation (%) of annual precipitation from the mean over 1948 to 2015 of 1469 mm in the study area.

Although there were no convincing trends in annual and seasonal total precipitation, significant decreases in the number of rainy days in the annual (3.3 day decade^{-1}) and monsoon season (3.2 day decade^{-1}) were observed (Figure 6). The results indicated that extreme precipitation events may increase in the monsoon season in the study area.

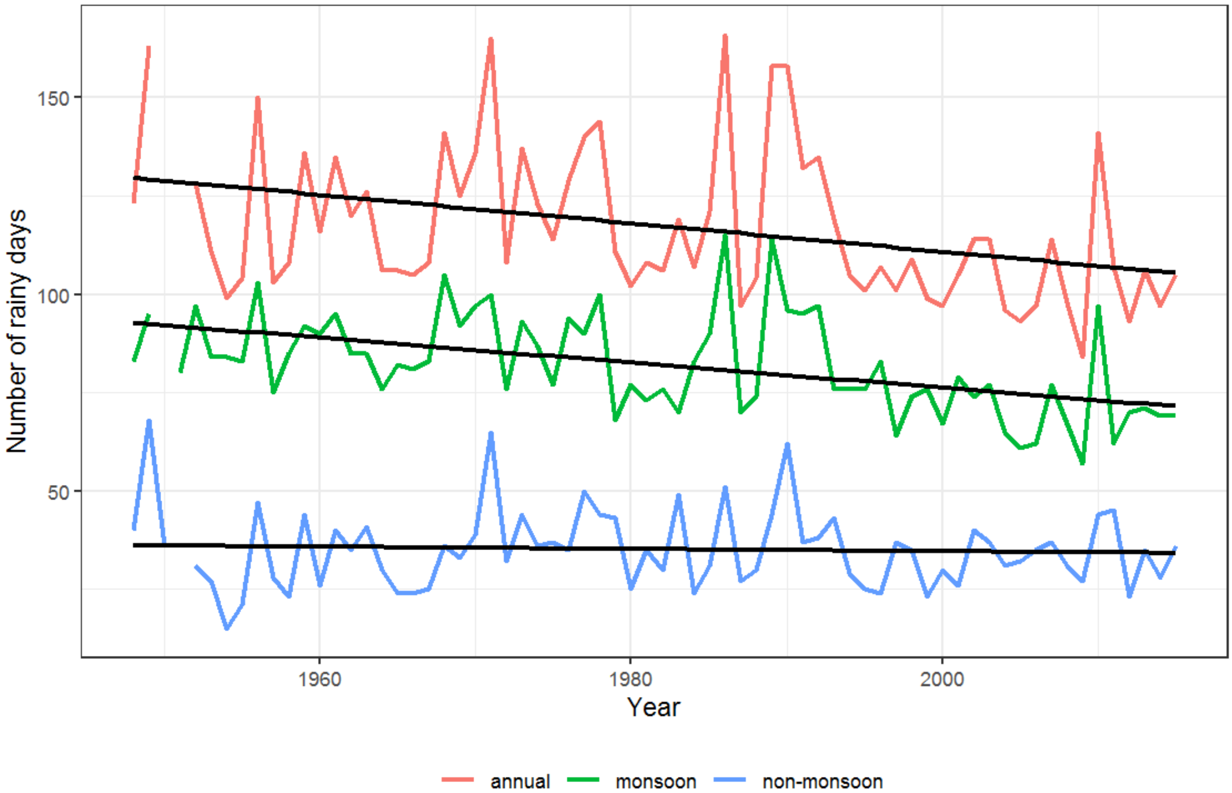

Figure 6. Trends in the number of rainy days (1948 to 2015) in the study area.

In the current study, the SPI was used to provide an indicator of drought severity (Figure 7). A drought is defined as whenever the SPI reaches a value below −1. Analysis showed that the study area has experienced droughts in terms of both severity and duration in recent decades. There were severe consecutive drought years from 2004. The result also showed that drought severity was stronger for longer drought time scales. The wet/non-drought conditions (SPI > 0) are indicated by shades of light blue to dark blue and drought conditions (SPI < 0) by shades of light red to dark red (increasing drought intensity).

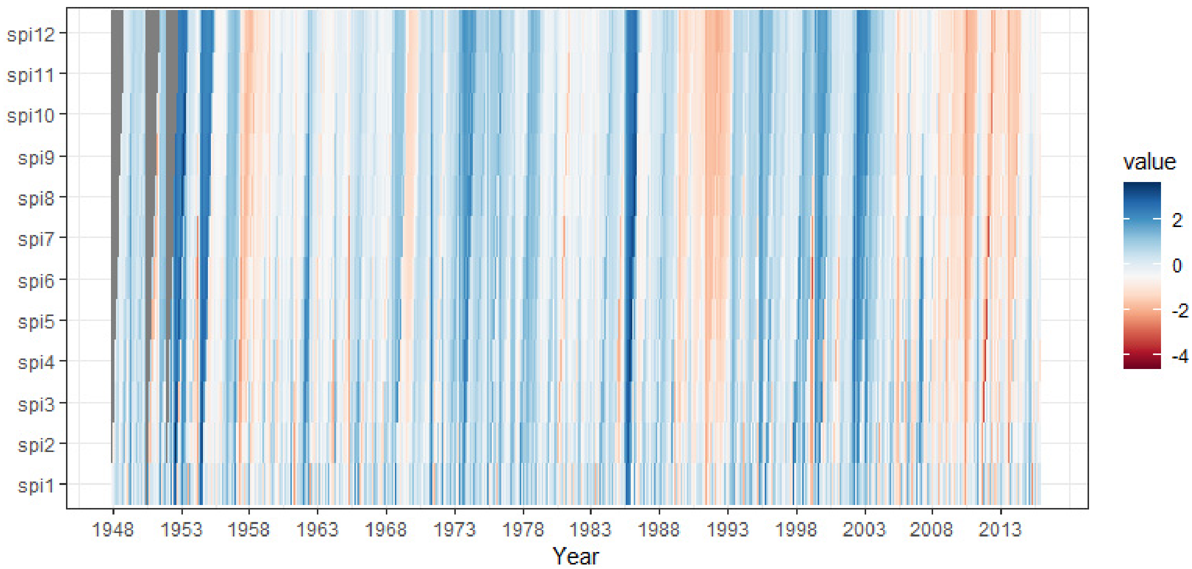

Figure 7. Drought heat map of Standard Precipitation Index SPI (SPI 1 to SPI 12) in the study area.

The drought heat map showed the monsoon drought (four-month SPI in September) and winter drought (three-month SPI in February) (Figure 8). Results suggested that both monsoon and winter droughts occurred on a periodic basis, and after 2004 there were consecutive monsoon drought years in the study area. The wet/non-drought conditions (SPI > 0) were indicated by shades of light blue to dark blue and drought conditions (SPI < 0) were indicated by shades of light red to dark red (increasing drought intensity).

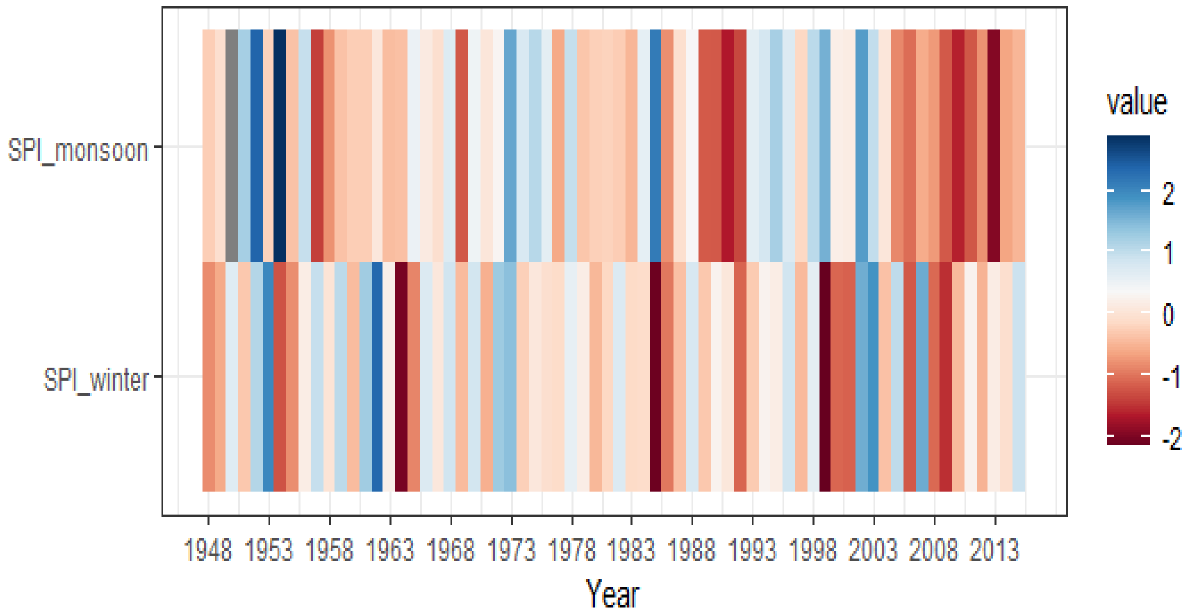

Figure 8. Drought heatmap monsoon and winter drought in the study area.

3.1.2. Temperature Characteristics and Trend

The annual mean temperature of the study site increased at the rate of 0.02 °C year^{-1} (Figure 9). Winter temperatures increased faster than summer and annual temperatures (Figure 10). The winter temperature increased at a rate of 0.03 °C year^{-1}. However, the trend of summer temperature was not significant in the study area.

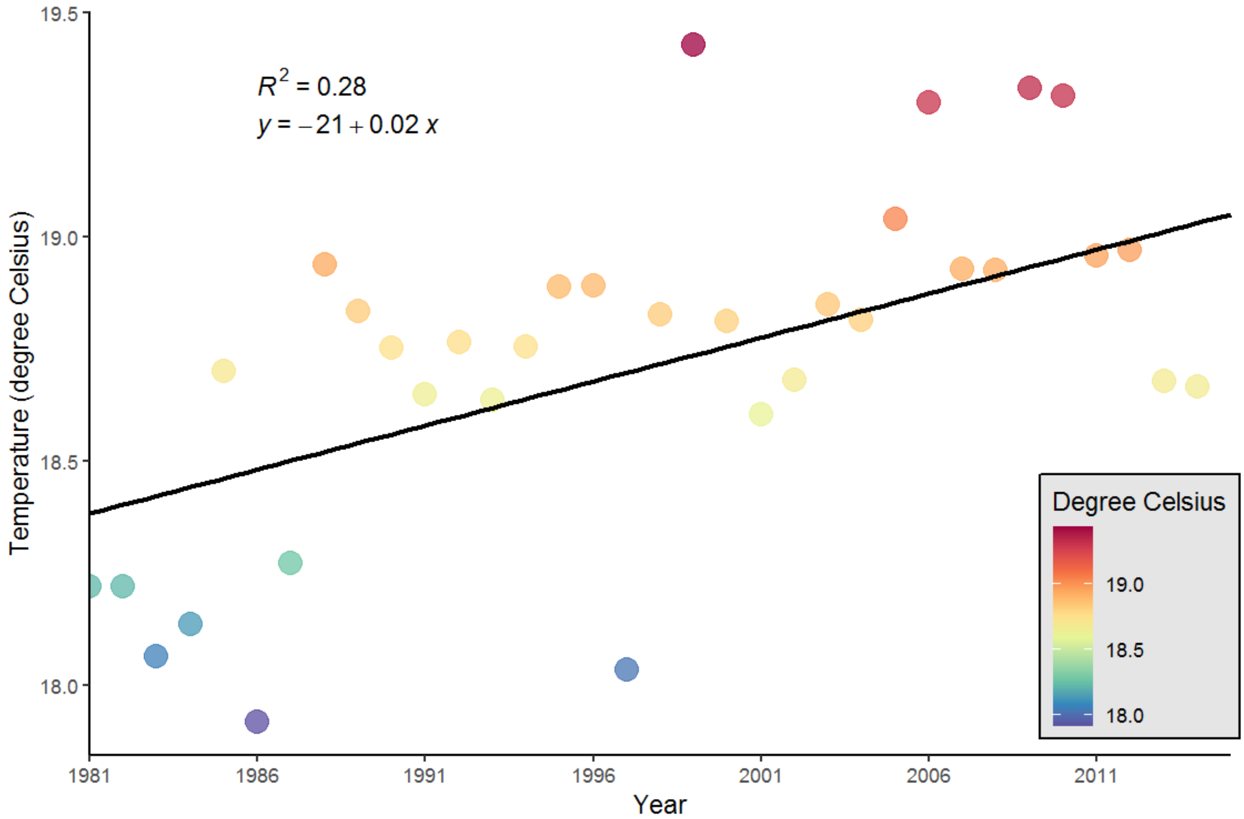

Figure 9. Trend of annual mean temperature in the study area.

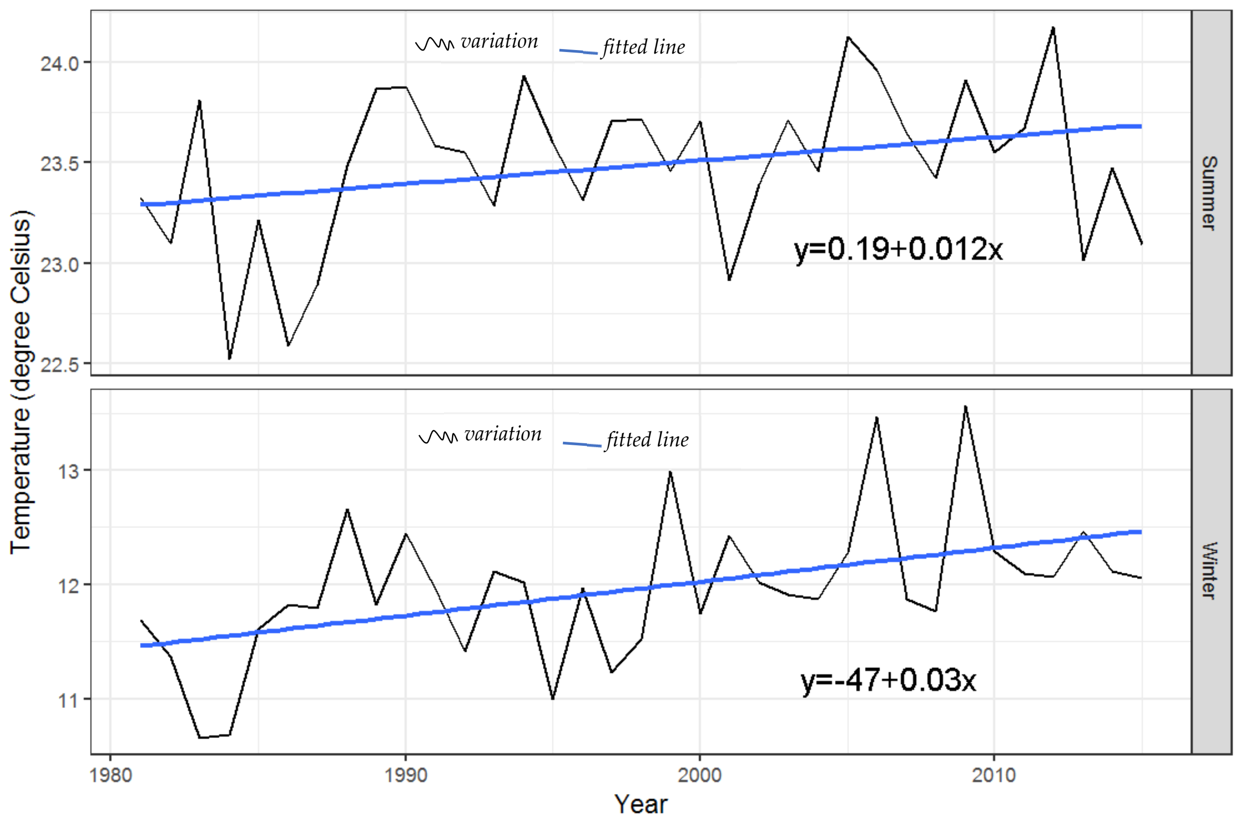

Figure 10. Trend of seasonal mean temperature in the study area.

3.2. People's Perception of Climate Change

3.2.1. Demographic Characteristics of Respondents

This study was conducted in 153 randomly selected respondent households from the study area. Among the total respondents, 78.4% were male and 21.6% were female. The average age of the respondents was 46.5 years with an average farming experience of 26.5 years. Only 2.6% of the respondents were under 20 years old (Table 2). This indicates that the respondents have substantial experience in observing weather events and climate over years. The average land holding of the respondent households was 0.64 ha. The result also showed that 31.4% of the respondents did not receive formal education while 51% obtained primary education, 15% obtained a secondary education and 2.6% of the respondents attained university (Table 1). About 79% of the respondents stated to have agriculture as their primary occupation.

Table 2. Socio-demographic characteristics of farmers.

Variables and Category		**Measures**	**Value**
Gender [BIN]	Female	Frequency	33 (21.6%)
	Male	Frequency	120 (78.4%)
Age [CONT]	Overall, in years	Mean	46.5 ± 14.9
	Up to 20 years	Frequency	4 (2.6%)
	21–40 years	Frequency	59 (38.6%)
	41 to 60 years	Frequency	57 (37.3%)
	61 and above	Frequency	33 (21.6%)
Farming experience (years) [CONT]		Mean	26.5 ± 14.9
Land Area (ha) [CONT]		Mean	0.64 ± 0.43
Education [ORDINAL]	No Schooling	Frequency	48 (31.4%)
	Primary Education	Frequency	78 (51.0%)
	Secondary education	Frequency	23 (15.0%)
	College/University	Frequency	4 (2.6%)
Primary occupation [ORDINAL]	Only agriculture	Frequency	102 (66.66%)
	Agriculture with local grocery and tea shop	Frequency	12 (7.84%)
	Agriculture with service	Frequency	6 (3.92%)
	Others	Frequency	33 (21.56%)
Livestock holding [CONT]		Mean	5.8 ± 3.6
Distance to market [Ordinal]	<1 KM	Frequency	36 (23.5%)
	1–5 KM	Frequency	50 (32.7%)
	5–10 KM	Frequency	19 (12.4%)
	>10 KM	Frequency	48 (31.4%)
Farming purpose [BIN]	Market purpose = 1	Frequency	124 (81%)
	Subsistence = 0	Frequency	29 (19%)
Altitude (masl) [CONT]		Mean	1278.11 ± 223.8

3.2.2. Farmers' Perception of the Indicators of Climate Change

To study the farmers' perception of climate change, the indicators of climate change were categorized into three broad categories; change in rainfall, change in temperature, and change in season. The changes in rainfall included the changes in rainfall amount, intensity, and timing. Similarly, changes in temperature included increases, decreases, and changes in extreme events. The season was treated just as one variable, change in seasonality. Out of 153 respondents, the majority (81.7%) revealed that they have perceived at least one or more indicators of climate change in recent years. Among the respondents who perceived the change in climate, 77.6% were male and 22.4% were female. Out of three major indicators of climate change, there was a significant association of gender with the perception of temperature change ($n = 55$, $p < 0.05$) and rainfall change ($n = 100$, $p < 0.10$) while there was no significant association with the perception of season change ($n = 32$, $p > 0.1$) (Table 3).

Table 3. Climate change perception by gender of the respondent in the study area.

Perception Parameter	Perception Category	Gender of HH Head		p-Value (χ^2-Test)
		Female (n = 33)	Male (n = 120)	
Rainfall Changes (pool)	No	21.2%	38.3%	0.049
n = 100; f = 65.4%	Yes	78.8%	61.7%	
Temperature change (pool)	No	39.4%	70.8%	0.001
n = 55; f = 35.9%	Yes	60.6%	29.2%	
Season Change (pool)	No	81.8%	78.3%	0.434
n = 32, f = 20.9%	Yes	18.8%	21.7%	
Overall climate change (frequency)	No (18.3%)	17.9%	82.1%	-
	Yes (81.7%)	22.4%	77.6%	

Note: "n" refers to the number of responses to the indicator while "f" indicates the frequency in the percentage of respective responses.

There was no significant ($p > 0.1$) relationship between the level of education with changes in rainfall and temperature perceived by the respondents, but a significant ($p < 0.05$) association was observed with the perception of season change (Table 4).

Table 4. Climate change perception by education category of the respondent in the study area.

Climate Parameters	Perception Category	Education of HH Head				p-Value (χ^2-Test)
		No Schooling	Primary Education	Secondary Education	College/ University	
Rainfall change	No	33.3%	35.9%	34.8%	25.0%	0.968
	Yes	66.7%	64.1%	65.2%	75.0%	
Temperature Change	No	58.3%	65.4%	73.9%	50.0%	0.561
	Yes	41.7%	34.6%	26.1%	50.0%	
Season Change	No	93.8%	71.8%	78.3%	50.0%	0.013
	Yes	6.2%	28.2%	21.7%	50.0%	

Similarly, a significant association was found between the age of the respondents and the perception of climate change parameters at a 10% level of significance (Table 5).

Table 5. Climate change perception and age of respondents in the study area.

Climate Parameters	CC Perception	HH Age				p-Value (χ^2-Test)
		Upto 20	21–40 Years	41 to 60	61 and above	
Rainfall change	No	0.0%	45.8%	29.8%	27.3%	0.081
	Yes	100.0%	54.2%	70.2%	72.7%	
Temperature Change	No	100.0%	67.8%	66.7%	48.5%	0.100
	Yes	0.0%	32.2%	33.3%	51.5%	
Season Change	No	50.0	78.0	73.7	93.9	0.058
	Yes	50.0	22.0	26.3	6.1	

3.2.3. Farmers' Perception of Impacts of Climate Change on Agriculture

Among 125 farmers who reported that they have perceived at least one indicator of climate change, 124 (99%) claimed that they have been experiencing the impact of climate change on agriculture (Table 6).

Table 6. Farmers' perception of major impacts of climate change in the agriculture sector (n = 124) in the study area.

Impact	Number of Respondents
Decrease soil moisture/need more water for irrigation	103 (83%)
Increase disease, insect, pest and weeds	99 (80%)
Low yield/crop failure	63 (51%)

In the current study, farmers identified many impacts of climate change on agriculture (Table 7). The farmers perceived that a decrease in soil moisture and a deficit of water for irrigation (83%), increased disease, pests, and weeds (80%), and low yields or crop failure are the most prominent impacts of climate change on agriculture. Table 6 summarizes the impacts perceived by the farmers in agriculture based on the indicators of climate change in the study area.

Table 7. Different problems of climate change on agriculture based on climate change indicators as perceived by the farmers in the study area.

Climate Change/Variability	Change Observed in Agriculture
Change and variability in rainfall	Difficult to puddle to transplant rice
	Decreased crop yield
	Decreased soil moisture
	Delayed in time of sowing of crops
	Increase mortality of seedlings
	Witlings crop in the field
Change and variability in temperature	Increased incidence of pest and diseases
	Appearance of newer pests and disease
	Increased weeds
	Change in crop phenology; time of flowering and fruiting
	Burning younger new leaves of crop plants
Change in surface water availability	Drying natural water sources.

3.3. Local Adaptation Practices

Out of the total respondents, 115 (75.2%) were adopting one or more measures to cope with the problems brought about by changing climate. The adaptation measures were categorized into four groups, namely related to changes in crops and variety, technological changes, the input used, and farm structure. The results showed that 28.8% of the respondents have practiced crop and variety-related adaptation measures, 20.3% have practiced a technological shift, 57.5% have practiced input change, and 54.2% had practiced changes in the farm structure (Table 8). The results also revealed that there was no significant association between the gender of the household head and all climate change adaptation measures, however, a significant association ($p < 0.05$) was found with technological adaptation.

Table 8. Gender and climate change adaptation measures in the study area.

Adaptation Measures	Adaptation Decision	Gender of HH Head		p-Value (χ^2-Test)
		Female	Male	
Crop and variety adaptation	No	78.8%	69.2%	0.280
	Yes	21.2%	30.8%	
Technological adaptation	No	93.9%	75.8%	0.022
	Yes	6.1%	24.2%	
Input adaptation	No	54.5%	39.2%	0.113
	Yes	45.5%	60.8%	
Farm structural adaptation	No	36.4%	48.3%	0.222
	Yes	63.6%	51.7%	

This study investigated the influence of different predictor variables on respondents' decision for adaptation practices on climate change measures. The logit regression analysis (Table 9) revealed that gender, distance to market, livestock number, age, and altitude had an inverse influence on adaptation practices while education, land holding, farming experience, and farming purpose had a positive influence on adaptation. Out of these nine decisive variables, the education level of the household head and the distance to the market were found to be significant contributors to the decision on adopting adaptation measures. The negative coefficient of the gender variable indicates the greater possibility of climate change adaptation by female-headed households. Similarly, a significant negative coefficient ($p < 0.05$) of the distance to the market may indicate that farmers near a market have better access to information and inputs, as well as a market opportunity for their produce and help to practice different adaptation measures.

Table 9. Adoption of climate change mitigation measures in the study area.

Explanatory Variables	B	S.E.	Sig.
Gender (Male = 1, Female = 0) BIN	–0.403	0.577	0.485
Education ORDINAL	0.747	0.369	0.043
Landholding (ha) CONT.	0.535	0.540	0.322
Distance to market (km) CONT.	–0.751	0.222	0.001
Livestock number (number) CONT.	–0.008	0.063	0.898
Age (years) CONT.	–0.034	0.023	0.151
Farming experience (years) CONT.	0.020	0.027	0.460
Farm Altitude (masl) CONT.	–0.001	0.001	0.551
Farming purpose [Market = 1 Subsistence -0) BIN	1.579	0.530	0.003
Constant	3.279	1.691	0.052
Log likelihood = 129.201, Cox and Snell R Square = 0.242, Nagelkerke R Square = 0.358			

4. Discussion

Our finding of no long-term significant trends in precipitation in the study area is consistent with the studies in other parts of the Himalayas. Dahal et al. [11] reported that there was no distinct long-term trend in the precipitation records in the Gandaki Basin of central Himalaya, though there was increased frequency and severity of drought in recent decades. Shrestha et al. [66] found considerable fluctuation, but no significant long-term trend in regional precipitation in Koshi Basin in central Himalaya. However, Sigdel and Ma [67] found an increasing trend in observed precipitation based on nine stations on the northern and southern slopes of the central Himalayas. Another study by Khatiwada et al. [68] reported a decreasing trend of precipitation in the Karnali Basin of central Himalaya.

Though there is no significant change in annual precipitation, inter-annual variability is large and there is a clear reduction in precipitation from 2004 onwards, and all years from 2004 experienced extreme drought conditions in the study area. This large inter-annual variability in rainfall and consecutive drought may have a serious impact on the agriculture system in the mid-hills of the Himalayas. Selvaraju [69] studied a relationship between Indian summer monsoon rainfall (SMR) and food grain production (FGP) in India and stated that inter-annual variability in SMR and total food grain production anomalies are closely related. Many researchers have pointed out the impact of drought on agriculture and farming system in different parts of the mid-hills of the Nepaesel Himalayas [70]. Ref. [71] reported that drought in recent years has emerged as a cause of household-level vulnerability in rainfed hill agriculture in the central Himalayas.

As the results of the analysis of the temperature record clearly showed a warming trend in the study area, other studies also support this result showing the increasing trend of temperature in the central Himalayas [72–76]. This increasing trend of annual and winter temperatures may have an impact on crop growth and production. Wheeler et al. [77] stated that variability of temperature plays a key role in crop growth. For example, doubling the standard deviation of temperature daily, while keeping the same mean temperature will reduce grain yields by 7%. Sinha and Swaminathan [78] reported that an increase of 0.5 °C in the current mean winter temperature would shorten wheat crop duration by 7 days and reduce wheat yield by a significant amount. For wheat and rice, an increase in minimum temperature increases the rate of respiration of the crop and shortens the time to maturity and thus reducing net growth and productivity [79]. Maharjan and Joshi [80] reported a significant negative relationship between an increase in maximum summer temperature and maize yield. Increased temperature can also have significant effects on pathogens, insects, and weeds. The cold temperature in winter suppresses much of the pathogen population whereas warm winter can enhance pathogenic activities and negatively affect the crop yield. Increased temperature changes the population growth and metabolic rates of insect pests, as well as their damaging activities. This may cause yield losses of major grains to increase by 10 to 25% per degree of mean surface warming [81]. Dukes and Mooney [82] reviewed the relation of global change and dispersal of invasive weeds and stated that increase in temperature may help to wider migration of invasive weeds.

Regarding the people's perception of climate change, changes in rainfall and temperature were identified as the most frequently used climate change indicators. Most of the respondents have noticed the rising temperature, change in rainfall time and amount, and decrease in surface water availability as common indicators of climate change. Regarding the gender of respondents, females were found closer to available climate change parameters. A comparison of farmers' perceptions with observed trends in temperature and precipitation finds that farmers' understanding of changing climate is in line with the actual trend. These indicators of climate change mentioned by the farmers in our study are in line with that identified by previous studies in various parts of the Himalaya [83–87]. People's perceptions are similar to those reported by studies done in other parts of the Himalayas, where the majority of the respondents have perceived increasing overall temperatures, changes in rainfall patterns, and a decrease in surface water availability [86–91]. Regarding the changes in rainfall, people have perceived that the total rainfall has decreased, and in terms of timings, respondents have perceived rainfall to arrive later. These local perceptions about climate change are also supported by scientific data. The results of the present study collected from the local level contribute to the knowledge in the field of documenting perceptions of climate change in the Himalayan region. This information is very crucial for formulating site-specific adaptation and mitigation strategies.

Location-specific people's perception of climate change is essential for adaptation planning [33,35] and farmers also need to understand the actual changes and trends in climatic conditions, associated risks, and measures to adapt to the potential impacts [41]. Haq et al. [92] and Barrett and Bosak [93] suggested that the perception of climate change differs depending on the physio-cultural condition and socio-demographic dimensions such as gender, religion, age, etc. Therefore, site-specific perception of people regarding the changing climate is essential to know the exact extent and dimension of climate change at the local level.

Since agriculture is highly dependent on the weather and climate of any location, changes in their parameters may have a serious impact on agricultural production. A decrease in soil moisture increased the need for water for irrigation, an increase in insect pests and diseases, and weed infestation resulting in low crop production and even crop failure are the biggest impacts of the changing climate on agricultural activities in the study area. Farmers felt that rainfall variability has a bigger impact on agricultural production than the change in temperature. Other studies also have reported the potential impact of climate change on the decline in crop yield—both short-term and long-term—due to rainfall variation, increase extreme events (mainly drought), and proliferation of weeds and pests [9,81,94–96]. A study by Chaudhary and Bawa [14] stated that approximately 73.6% and 54.2% of individuals have seen new crop pests and new weeds in their fields in recent years in the central Himalayas, respectively. In our study, local people reported that the rainfall pattern has been irregular, and the rainy season has shifted which has adversely affected their agricultural practices and production. Many people have replaced the cultivation of food crops with cash crops, mostly vegetables, in the study area. The traditional varieties of maize, paddy, and potato have been replaced by new "improved" varieties. Studies conducted in other parts of the Himalaya have also reported similar changes in rainfall patterns, and it is the main driving factor for change in farming practices [97–99].

As climate change is happening and is perceived by local people, they have to some extent developed adaptation strategies to cope with its adverse impact. Farmers reported that rainfall variability is the most essential determinant of adaptation decisions in farming. Adaptation measures in the community were shaped by both social and demographic factors. The level of education of farmers, purpose of farming and distance to market were found significant contributor for choosing the adaptation practices. Regarding the gender of respondents, female was found to have more decisive role for choosing the adaptation practices. The local communities have vast amount of knowledge and experience in coping with climatic change and variability, and these coping strategies are important elements of successful adaptation plans [30,100,101]. At the same time, adaptation practices being adopted in farming communities differ according to household economic status and are dependent on access to education, information, and resources within the community [102]. This traditional knowledge helps to provide efficient, appropriate, and time-tested ways of coping mechanisms in the changing climate. Therefore, this analysis helps to enhance our understanding of the status of climate change and its impact on the hill farming system of the central Himalayas.

5. Conclusions

Understanding people's perceptions of climate change and their response to such changes are important to design location-specific community-based adaptation strategies. We assessed the local level climate change information along with the farmers' perception of climate change indicators, broadly temperature change, rainfall change, seasonality change, and adaptation measures by using both observed climate records and perception-based approaches. This study revealed ample strong and clear evidence of changing climate in the study area, which is also perceived by the local farming communities. They are adopting various measures to cope with the impacts of climate change by making changes in their farming practices including cultivation time and methods; cropping patterns and seasons; farm inputs, crop, and variety; farm structures. The education of the farmers, distance to the market, and purpose of farming were found to be important socioeconomic factors for choosing adaptation measures for the farmers. This study will help policymakers to formulate suitable policies to lessen the adverse impact of climate change at the farm level and can contribute to the development of an appropriate strategy for designing climate-resilient farming systems in the mid-hill of the Himalayan region. The results derived from this study are based on a relatively small area of the hilly farming systems of the Himalayan range, taking into consideration of limited socioeconomic variables, the generalization of the conclusion is subject to similar geophysical, socio-cultural, and agro-ecological assumptions. So, further extensive research covering multi-locations is suggested.

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