Original Research Article

Farmers' perception, adaptation strategies to climate change, its determinants and barriers to climate change in Bundelkhand region of central India

ABSTRACT

This study is based on a farm house hold survey (811 households) collected from 4 districts of drought prone region of central India and examines that how farmers perceive the climate change and adaptation strategies adopted over the past few decades. Nearly, 80.9%, 93.6% and 95.2% farmers' perceived that the average temperature has increased, rainfall has decreased and occurrence of drought is more frequent, respectively during last 25–30 years. A significant decreasing trend was observed in annual rainfall at all the studied locations with a rate of 2.1 to 5.8 mm year^{-1}. In most of the locations both maximum and minimum temperature showed an increasing trend during winter season (July-October) in the range of 0.8 to 1.2 and 0.4–1.5 ºC per 100 year, respectively. However, only two locations viz., Jhansi and Banda district showed increasing trend in maximum temperature in the range of 0.8 to 2.3^{o}C per hundred years during rainy season. This study revealed that the perceptions of rural farmers on climate change and variability are consistent with the climate trend analysis. Econometric model suggested a positive influence of age, agriculture experience, educational qualification, size of land holding, adequate access to credit facility and crop insurance, intermittent dry spell and adequate extension services on climate change perceptions and adaptation. The results further revealed that 69.8% respondent have implemented adaptation measures in response to dry spell. Furthermore, analysis showed that agriculture experience, educational qualification and intermittent dry spell and access to extension services are the key factors for adoption of various adaptation strategies particularly, irrigations scheduling, use of high yielding improved varieties, pesticides and change of planting date. Inadequate availability of irrigation resources and frequent drought as well as intermittent dry spells were considered as the most critical barriers for adaptation measures to climate change by farmers.

Key words: Adaptation strategies, central India, climate change, trend detection, perceptions, logit and multinomial model

Introduction

Global warming is not a myth and that is easily distinguishable from natural climate variability (Abid *et al*. 2016). This phenomenon is mainly due to anthropogenic activities involved in agricultural production, transportation and industries. Since, last decade the climate change is a great challenge to mankind and for their livelihood and food security (Amjath-Babu *et al*. 2016; Ayanlade *et al*. 2017). Climate change; mainly changes in the scenario of temperature and rainfall affects crop, livestock and fish production through inducing metabolic and habited changes. Studies reported that yield of cereal crops will decline up to 30% per hectare in the period of 2001 to 2059 (Parry 2007). Temperature increase by 2°C and 0.5°C from the current scenario could decrease rice and wheat yield by 0.75 and 0.45 t ha^{-1} respectively, in India (Sinha and Swaminathan 1991). Saseendran *et al*. (2000) reported that each 1°C rise in temperature would decrease rice yield by 6%. Similarly, a study conducted by Ashalatha *et al*. (2012) found a negative growth rate in rainfed crops such as sorghum (-17.47%), maize (-6.0), pigeonpea (-8.44), groundnut (-13.06), wheat (-16.0), onion (-3.93), and cotton (-10.65) due to erratic monsoon and temperature in India.

Increase in atmospheric temperature and alteration in the hydrological cycle can affect the livestock production as compared to other climatic variables (Calamari and Mariani 1998; Sprott *et al*. 2001). For instance, Mader *et al*. (2009) reported that tripling the current atmospheric CO_2 has affected swine production from 22.4 to 70% in the United States (West and east side), furthermore the projected effect on the milk production is in the range of 1 to 7.2%. However, beef production has not been affected by increase in the temperature. The effect is more intense in the developing countries due to combined effect of poverty, poor infrastructure and technological facilities, and high dependency of agriculture on monsoon (Adger *et al*. 2013; Nelson *et al*. 2014; Adimassu and Kessler 2016)

In spite of progress in the atmospheric science, the effect of global warming on the farming sector at the local level is still crucial in developing nations (IFAD 2010). In developing countries the projection of climate change impact is very alarming (McCarthy *et al*. 2001). This is because of the low income and poor adaptive capabilities (Khan et al. 2020). Developing nations, including India are the most affected regions of the world. India ranked 5th and 14th in 2018 and 2017, respectively in climate risk index, 2020 (Bandyopadhyay 2020). Studies found that farmers of Africa and India are aware of the important climatic variables, for example onset of monsoon (Tennant and Hewitson 2002), period and distribution of rain (Mortimore and Adams 2001; Ndamani and Watanabe 2015), ground water depletion due to increase in heat (Kelkar *et al*. 2008), rising temperature and decreasing rainfall (Piya *et al*. 2013; Debela *et al*. 2015) in Africa and India. However, studies showed that the common people cannot easily distinguish the seasonal weather change pattern due to climate change (Greene *et al*. 2011). Perception of change in climate is a foremost thing for adaptation and implementation of suitable measures. In developing countries, several factors such as government policies, socio-economic status, land size, prevalent production systems, age of the grower, literacy, experience in farming, and capital investment can influence the grower's perception on climate change (Khan *et al*. 2020). For example, inverse relationship was found between age and perception level of growers on climate change (Hansen *et al*. 2004; De Jalon *et al*. 2013). Whereas, length of experience in farming has a positive effect on the level of awareness and attending training programmes on climate change in Argentina (Hansen *et al*. 2004).

Climate adaptation strategies are based on the level of perception of climate change and knowledge gained by growers. A common mitigation strategies of climate change are selection of suitable varieties, changing planting calendar, changing rate and type of fertilizers, crop insurance and diversification in farming activities (Budhathoki and Zander 2020; Khan *et al*. 2020). A study conducted in Nepal, Karki *et al*. (2020) reported that about 85% of growers have adapted one or two following strategies as a measure to tackle the climate change; high yield varieties, crop diversification, mixed cropping, inclusion of non-traditional crops in the traditional cropping system, crop rotation and exploitation of local varieties. Delay in planting time and drought resistant varieties are well established strategies during drought period in Indonesia (Rahayu and Suwitra 2020). Crop diversification is widely accepted and adapted coping mechanisms to lessen crop production risk associated with climate change in Niger (Mustapha *et al*. 2016). Mixed and intercropping (75.66% growers), integrated and mixed farming (71.11% growers) techniques are the main coping mechanisms of climate change in India (Ashalatha *et al*. 2012). Likewise, agroforestry and rainwater harvesting are also the major mitigation measures of climate change among Indian growers (Tripathi and Mishra 2017).

Some of the factors that affects adaptation strategies of climate change are poverty, poor education, lack of adequate and timely information on the change in climate, stringent land leasing system, customary farming practice, inadequate modern technologies, poor credit facility, lack of marketing facility, subsistence farming, insufficient infrastructure and poor government initiative (Rafiq and Blaschke 2012; Khan *et al*. 2020). In respect to India, Kimani and Bharadwaj (2015) reported that inadequate extension service, quality seeds, and irrigation facilities have felt as the major constraints to climate change adaptation. In Himachal hill region, 95.60% of growers felt that the investment cost of mitigation measures are very high compared to contemporary practices (Chunera *et al*. 2019). Moreover, lack of adequate and timely information on the change in climate and availability of farm inputs is the primary barrier of adaptation of climate change mitigation measures (Dupdal and Patil 2019).

However, very limited information's are available on grower's perception on climate change and constraints in adapting mitigation measures of climate change in Bundelkhand region of India. This region is holding around 18.5 million populations, whose economy and livelihood security is totally dependent on the agriculture and livestock rearing. Therefore, this study was initiated with following objectives 1) Growers perception regarding changes (long term) in climatic variables and factors affecting the probability of perceiving climate change, 2) to assess the grower's adaptation strategies to climate change and 3) constraints impeding climate change adaptation.

MATERIALS AND METHODS

Description of the study area

The Bundelkhand region consists of 13 districts in central India and lies between 23°8'to 26°30'N latitude and 78°11' to 81°30'E longitude (Fig 1). It is located in the hot semi-arid eco-system with alluvium derived soils. The Bundelkhand region has an area of 753700 square kms with a population of 18.6 million people. The higher percentage (78%) of population is lives in rural and the majority of population (69%) is dependent on agriculture and livestock rearing (Registrar General of India 2011). It accounts 3.6% of the total cultivated area and 1.8% of cereal production in the country. Bundelkhand region is characterized by various degrees of natural resource degradation, poor soil fertility, erratic rainfall with frequent droughts and crop failures (Palsaniya *et al*. 2009). Rain is crucial for the maturity of rainy season (July-October) crops and sowing of winter season (November to April) crops. The average annual temperature in this region is 25ºC. In summer, mean temperature is around 30ºC and can rise up to 47°C during May to June**.** The mean annual rainfall of the region is 895.8 ± 241.2 mm with coefficient of variation of 28.7%. The rainfall distribution pattern is uneven, and approximately 97% of the rain is received around 40–48 days of precipitation during the monsoon months (June to September) (Rai *et al*. 2018). The mean annual evaporation rate is found to be 1963.7 mm with lower (CV 7.3 %) variability (Rai *et al*. 2017). In this region, about 75% of the net cultivated area is under rainfed**.** Black soil and its variants (vertisol) comprise 44 % area while red soil and its variants (Alfisol and Inceptosol) are found in 56 % area of the Bundelkhand. The soils are inherently deficient in N, P and K. The red soils are gravelly and shallow in depth, and thus are unable to retain moisture well. The black soils extend up to 40 inches and are confined to low lying landscapes, with fine texture and possess the property of shrinking on drying and expanding when wet. Main enterprises of the region are mixed crop livestock production systems with major crops being sorghum, maize, green gram, groundnut, pigeon pea and rice. The black soils, found mostly in the southern part that retain water better and are thus preferred for wheat, gram and sugarcane cultivation.

Household surveys and interviews

Field surveys were conducted in 40 villages of Datia, Jhansi, Lalitpur and Mahoba district of Bundelkhand region during 2017 and 2018. A total of 818 farmers from 4 communities in a village were selected for sampling with the help of agricultural extension scientists and pradhan (elected chief by the villagers). Out of these communities, 15 to 20 farmers were randomly selected to take part in the survey done using semi structured questionnaires. A systematic random sampling was carried out until the desired sample size was achieved. Face -to- face single visit interview, discussion and observations were used to collect the information. Focus group discussions (FGDs) were also organized separately for 242 key informants comprising 20 participants from 2 agricultural extension agencies, 25 subject matter specialist from 5 krishi vigyan kendra (agriculture science centre), 150 farmers and 47 expert from 5 line departments of state government officials. The focus group discussions were used to solicit diverse views on issues surrounding adaptation strategies and constraints.

Long term climatic data

The weekly maximum and minimum temperature, and rainfall data of the study locations [Jhansi, 25.4° N, 78.6° E, 285m MSL, Banda, 25.5° N, 80.3° E,123m MSL, Mahoba, 25.4° N, 79.8° E, 214m MSL, Lalitpur, 24.6° N, 78.5° E 428m MSL, Jaluan, 26.1° N, 79.5° E,164m MSL and Hamirpur, 25.8° N, 80.0° E,80m MSL] for the period of 1937-2015 and 1901-2012, respectively have been obtained from India Meteorological Department (IMD), Pune, India to quantify the magnitude of climate change. Gaps in the data were left unfilled in order to avoid bias and only spurious values were eliminated. These data were converted into annual and seasonal series for further analysis.

Data Analysis

Long term climatic Data

Statistical characteristics were computed for annual (January to December) and seasonal viz., pre-monsoon (March to May), monsoon (June to September), post-monsoon (October to November), winter (December to February), rainy season (July to October) and winter season (November to April) for both rainfall and temperature series. The rainfall and temperatures data were subjected to low pass filter (WMO 1966) and 5-year moving average in order to smooth year to year variability, respectively. Then a linear regression was developed against time to find long term trends. Also, non-parametric, Mann-Kendall test was also performed (Mann 1945; Kendall 1975) to identify positive or negative trend in annual and seasonal time series. Non parametric Theil's Sen's slope estimator (Sen 1968) was used to calculate the change per unit time. The annual rainfall series of all locations were divided into three sub periods such as sub period I (1937 to 1967), sub period II (1968 to 1997) and sub period III (1998 to 2015). Statistical significance was analysed to compare sub period average rainfall with the long period average rainfall using Cramer's test (t_k) (WMO 1966).

The perception of model for climate change

The factors affecting the perception of climate change as well as farmer's decisions to adapt against climate change was evaluated using binary logit model (Bryan *et al*. 2013; Abid *et al*. 2015). The model can be expressed in its reduced form as follows:

$$Y = f\ (X_1, X_2, \ldots\ldots X_{11}) \qquad (1)$$

where, Y is status of perception or adaptation by the farmers (1 = perceive/or adapt, 0 = did not perceive/or adapt), Xi are explanatory variables (age of farmers in years, agriculture experience, qualification, weather information through mass media or internet, farm size, access to credit facility, intermittent dry spell, access to credit facility and crop insurance, adequate agricultural subsidies, access to extension services from government, soil health and high rate of temperature during crop growing season)

The coefficients of the binary logistic model only gives the direction of the effect of independent variables on binary dependent variable, similar to ordinary least square (OLS) coefficients (Peng *et al*. 2002). Whereas, marginal effect is interpreted as change in the probability of perceiving climate change in percentage, given a 1 unit change in the continuous explanatory variable of interest, setting other explanatory variables at their mean values (Abid *et al*. 2016). The factor which influenced the choice of farmer's to apply a particular adaptation measures (Fadina and Barjolle 2018)to climate change was determined by using multinomial logit model (Loko *et al*. 2013; Sani and Chalchisa 2014). The model can be written in reduced form as follows:

$$Y_i = f(X_1, X_2, \dots X_{11}) \quad (2)$$

where,Yi, the polychotomic dependent variable (adaptation method chosen by the farmers) and X_1 to X_{11} are the independent variables. Based on the data collected on the adaptation strategies chosen by producers. In the study area, the dependent variable (Yi) is coded 1 for "no adaptation", 2 for "Irrigation and method of irrigation", 3 for "Use of improved high yielding varieties, agro-chemical fertilizers, pesticides, and change of planting date", 4 for "Crop and farm diversification", 5 for "Agroforestry and perennial trees and shrubs (Orchard, tree species)", and 6 for "Other income-generating activities and copping strategies".

The explanatory variables include: X_1 = age in years, X_2 = Agriculture experience, X_3 = Education qualification, X_4 = information of weather through a mass media, X_5 = Information through internet, X_6 = Land/Farm size, X_7 = Adequate credit facilities and crop insurance, X_8 = Intermittent dry spell, X_9 = Proper access to agricultural subsidies, X_{10} = Soil health and X_{11} = Adequate government. extension services. The standardization of a category, defined as "base category" was used to estimate the model of multinomial logical regression. In this study, the category "no adaptation" has been considered as the base category.

The critical barriers/constraints (inadequate availability of irrigation resources, limited access to weather forecast, higher farm inputs cost, poor soil health, poor accessibility to agricultural subsidies, inadequate credit facilities and crop insurance, inadequate extension officers, be short of access to weather based agro-advisory services, and small farm size issues) were identified using equation-3, that hamper farmers from using adaptation practices. Farmers have been requested to score their perceived constraint based on a 0 to 3 likert scale of (i.e., ranging from "not a constraint" to "high constraint") and a ranking was made using constraint index (CI). The CI value was estimated using the formula below:

$$CI = C_N \times 0 + C_L \times 1 + C_M \times 2 + C_H \times 3 \quad (3)$$

where, C_N = Number of farmers graded barrier as "no constraint"; C_L = Number of farmers graded constraint as "low"; C_M = Number of farmers graded "moderate" constraint, C_H = Number of farmers grade the constraint as "high".

RESULTS AND DISCUSSION

Mean and variability of annual and seasonal rainfall

The mean annual rainfall has ranged between 781.7 ± 215.2 to 977.1 ± 352.8 mm, being lowest at district Jalaun and highest at district Lalitpur with coefficient of variation varied between 26.2 to 38.1 percent. This indicates that there was a high year to year variation in the annual rainfall in all the districts. Similar trend was observed in the rainy season rainfall (Table 1). However, high degree of variability was observed at Lalitpur followed by Mahoba and Banda districts. Mean winter rainfall varied from 54.7 to 94.7 mm being highest at Banda and lowest at Lalitpur districts and exhibited high inter-annual variation in rainfall in all the districts. It was attributed to coefficient of variation, which is varied in the range of 68.3 to 103.4 % (Table 1). Fisher statistic $g_1/SE(g_1)$ and $g_2/SE(g_2)$ with their respective standard error (SE) showed that mean annual rainfall series are normally distributed except at Banda and Lalitpur districts.

Trend analysis in annual and seasonal rainfall

Comparisons of short period average rainfall with the long period average rainfall

Data shows that in all the locations (Table 2), the sub-period (1969 to 1998) did not show any significant decrease in the annual rainfall from their corresponding long period average (LPA). However, in all the locations annual rainfall has decreased significantly ($p < 0.05$) in the range of 104.6 to 198.2 mm from their corresponding LPA during the current period (1999 to 2015). The maximum rainfall has decreased at Mahoba (198.2 mm), followed by Lalitpur (136.2 mm), Jhansi (133.5 mm), Hamirpur (132.3 mm), Jalaun (111.8 mm) and Banda (104.6 mm) district. The decreasing trend in the maximum rainfall in these districts will necessitate the selection of early and medium duration varieties in rainy season. Studies conducted by ICRISAT in semi-arid tropics, found that growing the early (CG12, 13, 14, and ICGV 9114, 90-110 days) and medium duration (CG 8, CG9 and CG 10, 120-130 days) varieties of groundnut was successful in Bundelkhand region under the decreasing rainfall condition (ICRISAT 2020). Similarly, Alam *et al*. (2016) reported that drought tolerant short duration varieties of sorghum (CSV-13 and 15, Bundela, CSH-23 and SPV 16160) and intercropping of cowpea with pigeon pea in rainy season is more feasible in this region. In case of delayed planting (in July) due to late onset of monsoon, varieties of sesame (Shekhar, Pragati, Tarun, T-78), black gram (Uttara, PU-31, Azad Urd3, N. Urd -1), green gram (Samrat, Narendra moong-1), pearl millet (BJ-104, Manupur), and maize (Ganga-1, 2 and 5, Hybrid) in rainy season could be an option for this region. Palsaniya *et al*. (2011) found that practice of integrated soil and water conservation measures (Check dams, and vegetative barriers) on watershed areas also an option to alleviate terminal drought experienced by crops even under 50% deficit rainfall in Bundelkhand region.

Low pass filter

In all the six locations, Gaussian low pass filter (LPF, WMO 1966) curves indicating that the trend in annual rainfall series were not linear but oscillatory in nature consisting for a period of 4 to 10 years (Fig 2 a-f). At Jhansi, an increasing trend was noticed from the year 1945 to 1960, 1974 to 1983 and 1994 to 1999, while rainfall during the period from 1962 to 1966 showed a decreasing trend. It is evident from the last section (1999 to 2015) of LPF curve that annual rainfall showed a significant steep declining trend in all the six locations with a rate ranging from 8.45 to 34.4 mm year^{-1}, being highest at Mahoba and lowest at Lalitpur districts ($p < 0.05$). The long term linear trend showed that the annual rainfall is declining with different rates in all the locations viz. Lalitpur (5.8 mm year^{-1}), Jhansi (4.21 mm year^{-1}), Jalaun (3.5 mm year^{-1}), Mahoba (3.3 mm year^{-1}), Hamirpur (3.3 mm year^{-1})

and Banda (2.1 mm year^{-1}). An overall maximum decrease of 457.4 mm was observed in annual rainfall for the period of 1939 to 2015 (77 years) at the district Lalitpur followed by Jhansi (324.2 mm), Jalaun (269.5 mm), Mahoba (260.7 mm), Hamirpur (260.3 mm) and Banda (161.7 mm). There was a significant declining trend in the rainy season rainfall in all the locations and the rate of decrease ranged between 1.7 mm year^{-1} in Banda to 5.4 mm year^{-1} in Lalitpur district, which are statistically significant ($p < 0.05$) as evident from coefficient of determination (R^2) values.

Trend analysis using Mann-Kendall rank (M_{KR}), Spearman Rank Statistics (S_{PR}) and Mann-Kendall tau test (M_{KZ})

All the three statistics revealed a significant ($p < 0.05$) long term declining trend in both annual and rainy season rainfall in all the locations except district Mahoba (Table 1).The slope (SL) values computed using least square method for annual rainfall are higher compared to Theil's Sen slope (Q)for Jhansi, Mahoba and Lalitpur. However, Sen's slope (4.0 mm year^{-1}) of rainy season rainfall was quite lower at Lalitpur as compared to least square (5.8 mm year^{-1}) method (Table 1). Long term significant trend was noticed in winter season rainfall in all the locations.

Trend analysis of seasonal maximum and minimum temperature

Trend in maximum and minimum temperature

For agriculture point of view both the rainy and winter seasons are important for this region thus climate variability and trends were also examined for these two seasons. The mean maximum temperature (T_{Max}) varied between 32.1 to 33.3ºC among the locations (Table 3). Temperature increased significantly ($p < 0.05$) during rainy season with a rate of 0.023ºC year^{-1}at Jhansi and 0.008ºC year^{-1} at Banda. The trends correspond to an increase of 2.3ºC and 0.8ºC over a period of 100 years for the respective locations. During the winter season, a significant increase ($p < 0.05$) in the T_{Max} trend was noticed at Banda (1.5ºC per 100 year), Mahoba (1.1ºC per 100 year), Lalitpur (1.0ºC per100 year), Jalaun (0.7ºC per 100 year) and Hamirpur (1.0ºC per100 year). M_{KZ} statistics confirmed that the presence of long term trend in both the seasons at different locations. A significant positive trend (1.74ºC per 47 year) in minimum temperature (T_{Min}) was noticed at Jhansi district during the rainy season. In winter season, T_{Min} exhibited significant increasing trend at five locations viz., Banda (0.8ºC per 100 year), Mahoba (0.98ºC per 100 year), Lalitpur (1.2ºC per100 year), Jalaun (0.93ºC per 100 year) and Hamirpur (1.1ºC per 100 year) (Table 3). Whereas, at Jhansi minimum temperature has decreased significantly ($p < 0.05$) to the tune of 2.21ºC over a period of 47 years.

Farmer's perceptions on climate change

The primary occupation of the family head was farming (81.6%) of which 59% were having primary or middle education, whereas 23.4% were illiterate. Farm size of individual varied from 0.4 to 5 hectare with a mean of 1.3 hectare. Length of agricultural experience of households lies between 10 to 20 years (45.5%); 21 to 40 years (35.7%) and > 40 years (18.8%). Survey analysis revealed that 80.9 % of the head of the household believed that there is an increase in temperature over the last 25 to 30 years. Most of the farmers (93.6%) were surveyed in the study had perceived a decrease in mean annual rainfall with high degree of variability. A total of 80.9 and 88.9% respondents perceived a delay in onset of the monsoon and early cessation of monsoon rains, respectively, during last 25 to 30 years. High proportion of respondents (95.2%) reported that drought and dry spells have become common during growing season. A total of 95.2% respondents have firmly opined that incident of unusual early rainfall followed by long dry spell is increasing which rarely occurred about 30 years ago. A significant and higher number of respondents (79.2%) perceived that rainy days with heavy rainfall were increasing and causing flood situation which was not prevailing in past years. As regards winter rain, 63% farmers perceived that winter rain has reduced and 31% speak out negligible rain in winter. The analysis of rainfall data of different districts of this region revealed that annual rainfall had decreased within the range of 158.6 to 444.25 mm as compared to 77 years ago.

Perceived effect of climate variability and change on crop production

The most important perceived effects (91.7 % respondents) of climate variability on crop production are long dry spells and drought, which ultimately reduce the yield or resulted into failure of crops. The second most perceived (87% respondents) impact was pest and disease including weed infestation leading to significant increase in crop damage (black gram, green gram, maize and groundnut). A high and significant number of farmers (70%) claimed that due to shortening of rainy season, they are deprived to grow some of the food crops such as rice, groundnut and sorghum. This implies that risk of crop failure increased due to reduction in the length of the crop growing season. Some respondent (51.7%) remarked that the temperature and frequent heavy rainfall resulted in accelerated erosion of top soil and lead to reduction in the soil fertility. A total of 46.3% of farmers perceived that high temperature particularly in the beginning of rains and during long dry spells usually affect the crop production in the region.

Factors affecting the perceived climate change probability

The econometric estimates of the logit model indicate that seven out of ten parameters estimated are statistically significant at least at the 10% level and the percentage of correctly predicted value is 67.6% (Table 4). Age (in years) and land holding size showed a negative and significant relationship with perception (Table 4), indicating that younger farmers and small land holding size (in acre) were more likely to perceive the climate change than the older ones and these findings are consistent with Roco *et al*. (2015). Agriculture experience variable showed a significant positive impact on perception; the likelihood perceiving climate change is 5.1% for each year of farming experience completed, which confirm the findings of Silvestri *et al.* (2012). However, Roco *et al.* (2015) reported that agriculture experience is not a significant variable in perceiving climate change in Mediterranean Chile region. On the other hand, educational qualification has a marked positive impact on perception and marginal effects showed that the likelihood of farmers perceiving climate change increases 13.5% for each year of schooling completed (Table 4).

Intermittent dry spell had a positive and significant ($p < 0.05$) impact on perceiving climate change in this region with the marginal effect of 54.1%. Access to credit facilities and crop insurance as well as access to adequate government extension service had a positive effect on perception of climate change. Both variables increased the likelihood of perception of climate change by 48% (Table 4). Inadequate access of weather information through internet did not have significant impact on perceiving climate among the farmers due to lack of internet connectivity. However, adequate availability of weather information through mass media had positive impact on perceiving climate change. Therefore, promotion of internet connectivity and use of weather apps among farmers is a good strategy, not only for accessing climatological data but also to improve the overall farm management practices.

Factors affecting adaptation strategies to climate change

In a total of 811 farmers, 69.8% respondent has adapted and implemented adaptation measures in response to dry spell and drought, whereas 31.2% of farmers still do not practice any adaptation practices or measures. Most of the farmers reported that with the adaptation measures there has been the reduced effect of dry spell (76.4% farmers responded) and drought (33.6% farmers responded). Farmers in Bundelkhand region generally practice rain-fed agriculture, but some are having a partial irrigation facility used to produce fresh vegetables on a small scale. In this region, the rainfall ranges between 600 to 950 mm and face the challenges of weather extremes such as frequent drought or long dry spell, high temperature and cold waves renders farmers greatly vulnerable to climate change. Under these situations, farmers are compelled to do off farm activities like providing services of their tractors in petty civil works, engaging farmers as casual labor in cities. Thus the study indicated that the above situation has the high tendency to influence farmers' decision adaptation strategies to climate change.

Analysis of binary logistic model and their marginal effect are presented in Table 4. The coefficient of logistic regression indicated the direction of effect of independent variables and marginal effects that explain the effect of unit change in explanatory variables on the dependent variables. The logit regression model was statistically significant ($p < 0.05$) and it is explaining 67% (Pseudo R^2) of the variance in farmers' decisions to adapt in response to climate change. The analysis showed that education qualification positively and significantly ($p < 0.05$) influence farmers' decisions in order to adapt climate variability and change. Due to their broad sense of knowledge and skill, the educated farmers have the ability to explore new avenues to curb the climate change. The marginal effect (Table 4) showed that one year increase in the years of schooling of household head would lead to an increase in the probability (5.5%) of adaption to climate change.

Size of land holding as well as access to credit facilities and crop insurance had a negative correlation with climate change adaptation. A negative coefficient (β = -1.31) between land holding size and probability of adaptation (Table 4) further, indicating that a decrease by one acre in the average size of land holding would lead to increase (19.0%) the probability in adaptation measures. This might be attributed to the fact that farmers' having small size farm have more likely to spare their own time into their farm for adaptation measures to climate change. Adequate access to credit facility and crop insurance was highly significant and negative in the model with marginal effect of 22.4%. Farmers suggested that difficulties in accessing credit coupled with high interest rates and compulsion of crop insurance makes the credit facilities unattractive. Many farmers believed that their own earning is insufficient to purchase inputs such as seed, fertilizer and pesticides. Information gathered also revealed that easy access to credit without compulsion of crop insurance could facilitate the farmers to practice adaptation measures to climate change. A positive and significant coefficient (β = 1.75) of intermittent dry spell indicated that an increase by one dry spell in a year would result in to a 25 % increase in the likelihood of farmers' decision to adapt on climate change.

Government extension services in agriculture are an important way to disseminate useful and practical information related to agricultural technology to improve farm production and income. The marginal effect indicated that likelihood of adaptation to climate change increased by 21%, if they have got adequate access to government agricultural extension services (Table 4). Similar results were reported by Fagriba *et al*. (2018) and Neilson *et al*. (2010), who reported that poor availability of extension services could negatively affect farmers' climate variation adaptation when farmers' needs immediate attention to climate change.

High temperature affected crops and livestock production in the study region. According to the farmers, dry pastures and heat stress as a result of high temperature during dry season resulted in poor feeding, poor growth and death of their livestock. An intensity of temperature could influence farmers' decision on adaptation strategy to climate change. The analysis showed that high temperature had a positive correlation with climate change adaptation and it had the marginal effects of 23.2%. Several studies showed that farmers may not go for any climate change adaptation measures unless temperature pose threat to crops and livestock (Dhakal *et al.* 2016; Fagariba *et al*. 2018).

Factors influencing choice of adaptation measures

The parameters influencing the farmer's choice to use a distinctive method of adaptation to climate change using multinomial logit model is illustrated in Table 5.

Agriculture experience

Agriculture experience had a significant ($p < 0.05$) and positive (β = 0.18) impact on the use of high yielding improved crop varieties, chemical fertilizers or farm yard manner, use of pesticides and change of date of sowing. Agriculture experience helps in identification and implementation of any strategy and it had a positive (β = 0.12) and a strong impact on agro-forestry and perennial trees and shrubs plantation. Fadina and Barjolle (2018) also found in their studies that agroforestry as well as the perennial plantation may offer several economic and environmental benefits.

Educational qualification

The educational qualification had showed a positive and significant effect on the choice of various strategies (Table 5). Education qualification had a positive (β =0.43) effect on the implementation of irrigation methods and number. Literate farmers (32.5%) used to irrigate their crops through sprinkler and drip irrigation, whereas only 29.3 % farmers used to give irrigation through wells or check dam available in their villages. This was seen as a viable option that can help to improve the crop production in the areas with poor rain and long dry spell. Education qualification also helps to select improved high yielding crop varieties, locally available farm yard manure and change of sowing date (β =0.42). Crop and farm diversification (β =0.34) was also seen as a good climatic change adaptation strategy. Majority of the literate farmers' (82.5 %) followed agricultural practices such as balanced and integrated nutrient management, bio-fertilizer, herbicide, vermi-compost, farm yard manure etc., which has proved to be the pivotal adaptation strategies against the climate change.

Meteorological information

Adequate access to weather information from newspaper, radio and television was highly significant and positive (β =1.81, $p < 0.05$) in the model and affected the application of irrigation. Forecast of rainfall is an important parameter that helped farmers' for the irrigation scheduling and sowing operation. This study revealed that regular weather information assessed with high coefficient has a likelihood of influencing farmers in comparison to those with irregular or no access to weather information.

Land holding size

Land holding size was found to be helpful in determining the decision to combine multiple strategies to avert the impact of climate change and extreme events. Land holding size had a positive (β =0.11) and significant ($p < 0.05$) impact on crop and farm diversification. The farmers opted crop and farm diversification is a vital measure for climate change, the large farmers (52.3%) opted intercropping (*Sesamum indicum* L. + *Vigna mungo* L. Hepper), legume based rotations and inclusion of multi-purpose tree species (*Psidium guajava* L., *Tectona grandis* L., *Emblica officinalis* L.) and livestock based farming system irrespective of farm size. According Sani and Chalchisa (2016) and Abegunde *et al*. (2019), farmers' with larger land holdings are more likely to practice adaptation against climate change because it involves more capital and resources. However, small farmers tend to adopt the various other coping strategies (crop-livestock mixed farming, intercropping and additional profit generating activities (back yard poultry, mushroom, etc). Other known adaptation practices adopted are reduced tillage practices (21.8% respondents).

Intermittent dry Spell

The results indicated that intermittent drought spells had positively (β = 3.18) and significantly affected ($p < 0.05$) the choice of various adaptation strategies (63% respondent) like irrigation, improved crop varieties, change of planting date, multiple cropping and shifting to other income generating on farm or off farm activities.

Adequate government extension services

The analysis showed that government extension services showed a positive (β = 1.54) effect on adaptation measures (early maturing improved high yielding varieties, use of fertilizer and pesticides and change of sowing date). The government agricultural extension services provided to farmers indicated that the possibility of farmer's adaption to climate change has increased to avoid the impact of intermittent dry spell during the rainy season. Furthermore a total of 71% respondent adopted improved crop varieties particularly early maturing or drought tolerant varieties under the influence of extension services provided to farmers.

3.5 Constraints impeding climate change adaptation impediments

A result on constraints/barriers to use of adaptation practices is presented in Table 6. With a constraint index (CI) value of 556, inadequate availability of irrigation resources (Dams, Ponds, Check Dams, and Wells) was ranked the most critical constraint to use of adaptation measures. The erratic rainfall and long dry spell conditions were perceived as second ranked impediment (CI = 404) that affected farmers' efforts to restrain climate change impact on the crop and livestock. Various studies showed that unpredictable weather conditions and poor agriculture support are critical constraints for adaptation strategies (Fagriba *et al.* 2018) and in many areas farmers compelled to devise diverse strategies to cope with climatic conditions (Murthy *et al.* 2016; Juana *et al.* 2013). The analysis of FGDs showed that cost (CI=362) was ranked third in the order of constraints. Higher input cost involved (Labor cost, fertilizers, irrigation, herbicides, and insecticides) in their day to day farming affected farmers' purchasing power. The study also revealed that large number of the farmers' still use local varieties rather than short duration or improved varieties due to high cost. Poor soil health, inadequate access to weather based agro advisory services and inadequate extension services were ranked the third, fourth, and fifth most imperative problems (Table 6), respectively.

CONCLUSION

In Bundelkhand region of central India, majority of the farming systems are rainfed. The study discerns farmers' perception of recent variability/change in climate i.e. change in the onset and withdrawal of rainfall, recent increase in intermittent long dry spell, increase in temperature and droughts. The rainfall analysis supported climate variability/change in the study area over the past 70 years and matches with farmers' perceptions that rainfall distribution pattern is much more unreliable in the recent years. The study showed a long term significant decreasing trend in annual and rainy season rainfall practically in all the locations with a rate of 2.1 to 5.8 mm year^{-1}. The latest sub-period (1999-2015) revealed that the rainfall has decreased within the range of 104.6-198.2 mm in the study region from their long period average. The trend is even more manifested in last 15 years (slope ranged between 8.45 to 34.4 year^{-1}), though the analyzed trends are significant in nature. This validated farmers' perception that rainfall has reduced and temperature has been rising in recent years. A total of 88.9 % respondents perceived early withdrawal of monsoon rains and 95.2 % respondents have gave firm opinion of incident of unusual early rainfall followed by long dry spell in the recent period. These findings have high practical significant effects in managing resources and agricultural activities over the region. A quantitative approach revealed that farmers' age, education qualification, their farming experience in agriculture, size of land holding, adequate access to government extension services and situations of intermittent dry spell have found to be important factors in climate change perception by the farmers.

This study revealed that farmers in the Bundelkhand region of central India are well aware of changing climate and have good perception of both its effects and impacts on agricultural production. Several factors such as farming experience, educational qualification, adequate government extension services, intermittent dry spell, size of land holding, and agriculture experience determine the choice of climatic change adaptation strategy. The main adaptation strategies identified by the farmers includes use of high yielding improved short duration varieties, change of sowing date, use of life saving irrigation, use of fertilizers, chemicals and insecticides. However, there are some barriers (inadequate availability of irrigation resources, erratic rainfall and long dry spell) which challenged the ability of farmers to manage with climate change. It has also been found that poor soil health of the study area and the inability to procure farm inputs increases farmers' susceptibility to climate change. Therefore, management practices such as quality seeds, change in date of sowing, drought hardy crops, short duration crops, soil mulching and residue compost could serve as a good intervention. Thus, for the adaptation measures, R&D efforts should be focused on the development of high yielding early maturing crop varieties (drought and thermal tolerant varieties), strengthening water resources (in-situ and ex-situ) and its efficient utilization with micro-irrigation and precision water management. Farmers' adequate access to timely weather based agro-advisory services also needs to be strengthened to help farmers in their production decision-making processes (eg, selection of adaptation options). The present studies have suggested that there is a call for farmers' capacity development programme to cope up with climate change.

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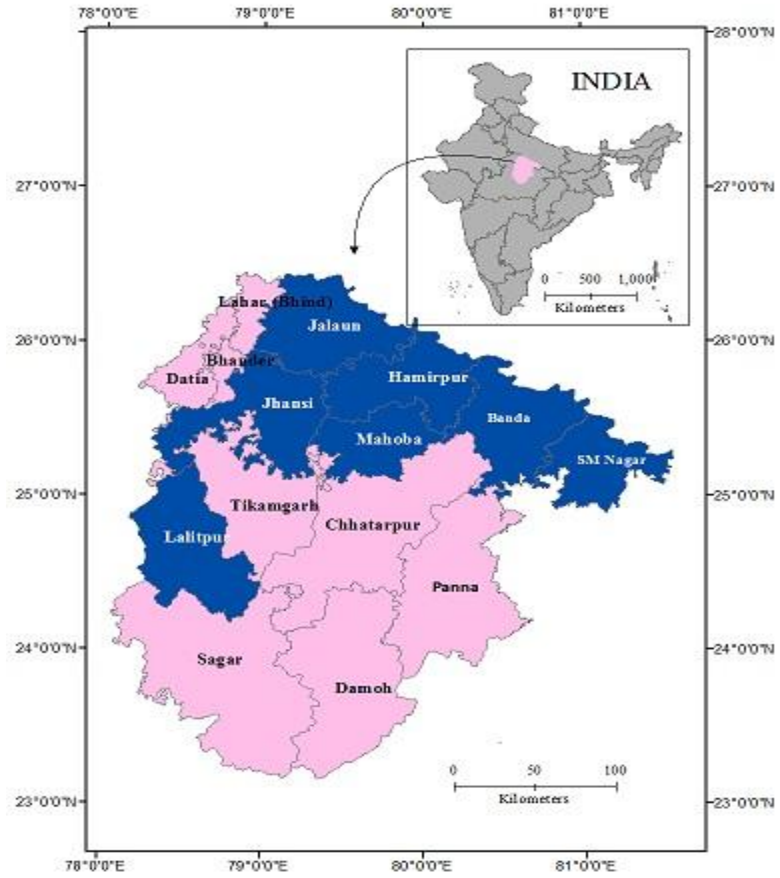

Fig 1 Location map of Bundelkhand region of central India.

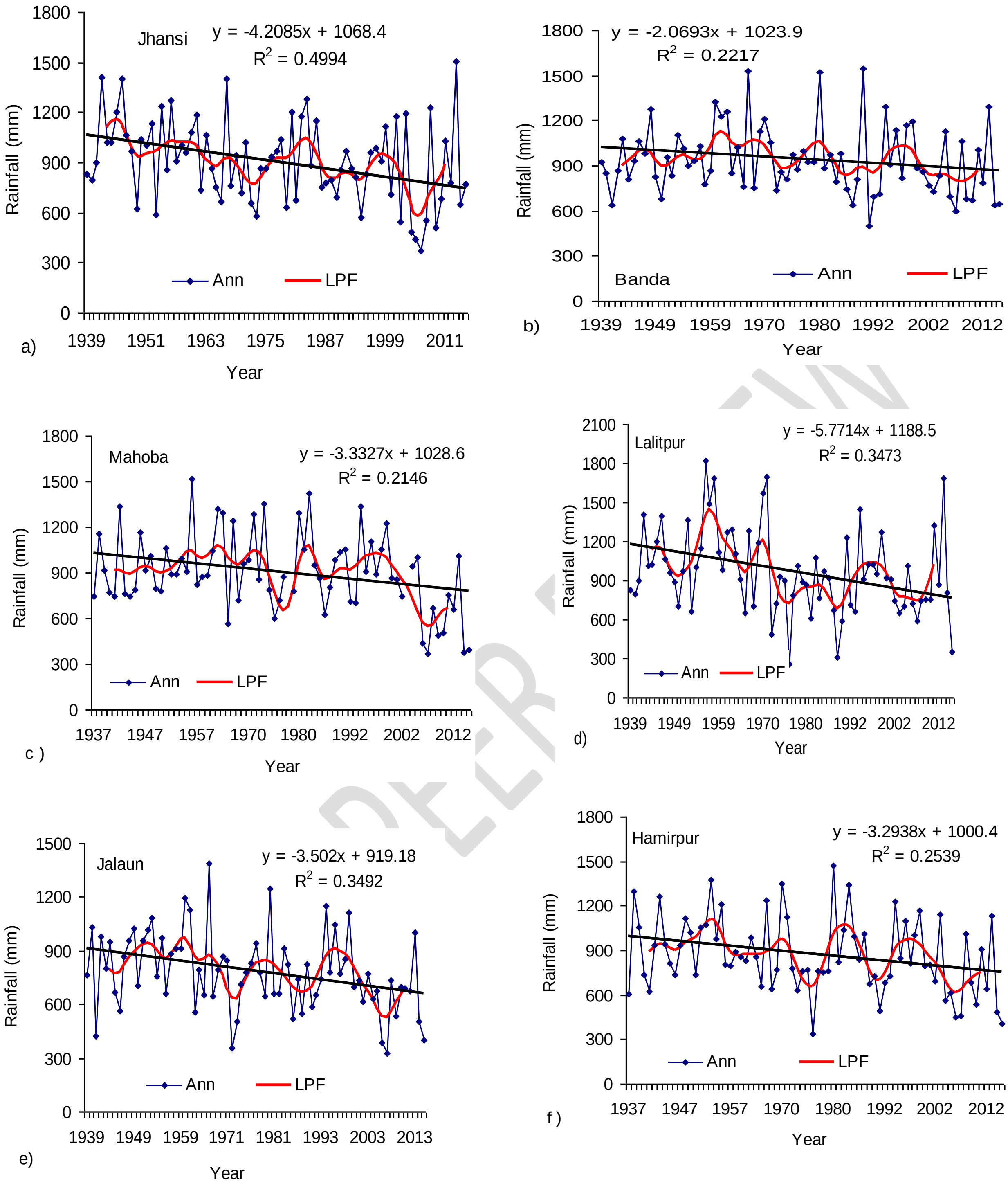

Fig 2 Mean annual (Ann) rainfall along with low pass filter (LPF) curve at different locations of Bundelkhand region of central India.

Table 1 Statistical parameters of annual and seasonal rainfallalong with different trend statistics in Bundelkhand region of central India

Districts	Seasons	Mean (mm)	SD (mm)	CV (%)	CS	CK	g1/ SE(g1)	g2/ SE(g2)	High (mm)	Low (mm)	M_{KR}	S_{PR}	M_{KZ}	Q
Jhansi	Annual	909.1	245.6	27.0	0.22	-0.41	0.75	-0.70	1510.0 (2013)	375.2 (2006)	-0.23#	-2.7#	-2.6##	-3.5#
	Rainy	826.7	220.1	26.6	0.03	-0.49	0.09	-0.84	1299.9 (1967)	346.2 (2006)	-0.20#	-2.6#	-2.5#	-3.4#
	Winter	82.8	85.6	103.4	1.94	4.32	6.7*	7.3*	434.5 (1985)	0.0 (1977)	-0.10	-1.2	-1.2	-0.3
Banda	Annual	934.9	224.2	24.0	0.80	0.40	2.6*	0.7	1549.1 (1990)	502.0 (1991)	-0.19#	-2.1#	-1.64	-2.1#
	Rainy	846.3	219.4	25.9	0.70	0.60	2.2*	1.1	1494.0 (1990)	399.2 (2014)	-0.17#	-2.0#	-1.42	-1.9#
	Winter	94.7	66.4	70.1	1.60	3.30	5.5*	5.6	346.8 (1960)	7.5 (1972)	-0.07	0.9	0.87	0.30
Mahoba	Annual	907.0	253.8	28.0	0.13	-0.11	0.46	-0.2	1516.0 (1956)	369.0 (2007)	-0.19#	-2.2#	-2.04#	-2.75#
	Rainy	829.8	225.9	27.2	0.10	-0.14	0.36	-0.2	1311.0 (1956)	258.8 (2014)	-0.17#	-2.3#	-2.12#	-2.62#
	Winter	82.3	56.2	68.3	1.30	1.92	4.5*	3.3*	265.1 (1985)	15.6 (1977)	-0.01	-0.4	-0.23	-0.06
Lalitpur	Annual	977.1	352.8	36.1	1.0	2.40	3.5*	4.0*	2344.7 (1971)	255.4 (1976)	-0.18#	-2.4#	-2.5#	-4.0#
	Rainy	812.6	313.2	38.5	0.90	1.70	3.2*	2.9*	1859.8 (1971)	175.4 (1976)	-0.24#	-3.0#	-2.9##	-4.0#
	Winter	54.7	49.8	90.9	1.90	4.60	6.4*	7.8*	258.0 (1946)	0.0 (2007)	-0.10	-1.1	-1.4	-0.33
Jalaun	Annual	781.7	215.2	27.5	0.26	0.11	0.91	0.18	1385.8 (1967)	323.4 (2007)	-0.28#	-2.2#	-3.11##	-3.8#
	Rainy	705.2	197.7	28.0	0.32	0.50	1.11	0.85	1263.6 (1967)	305.7(2007)	-0.30#	-2.4#	-3.29##	-3.31#
	Winter	74.6	62.26	83.5	1.58	2.65	5.4*	4.4*	283.3 (2013)	0.00 (2007)	-0.15	0.23	-0.42	-0.11
Hamirpur	Annual	867.6	250.0	28.8	0.29	-0.36	0.98	-0.6	1474.8 (1980)	337.7 (1976)	-0.20#	-2.4#	-2.62##	-3.54#
	Rainy	780.5	238.2	30.5	0.40	0.05	1.38	0.1	1452.8 (1980)	337.7 (1976)	-0.21#	-2.6#	-2.60##	-3.34#
	Winter	87.2	27.4	31.5	0.13	6.67	0.44	11.3*	205.0 (2013)	0.0 (1978)	0.83	-1.3	-0.70	-0.04

* Significance at 5% level; SD: Standard Deviation, CV: Coefficient of Variation, CK: Coefficient of Skewness, CK: Coefficient of Kurtosis, g1/SE(g1) and g2/SE(g2): Fisher statistics, M_{KR}: Mann-Kendall rank,S_{PR}:Spearman Rank Statistics, M_{KZ} : Mann-Kendall tau test; # and ## , Trend statistics and Slope (Q) significant at 5% and 1 % probability level respectively.

Table 2 Comparison of short and long period annual rainfall at different locations of Bundelkhand region in central India

Sub-period	Jhansi		Banda		Mahoba	
	Mean (SD) mm	Crammer t_k test	Mean (SD) in mm	Crammer t_k test	Mean (SD) in mm	Crammer t_k test
1939 - 1968	991.6 (245.3)	2.46**	968.6 (205.0)	1.01	954.7(226.3)	1.31
1969 - 1998	879.3(245.1)	-0.90	951.3(246.6)	0.58	972.3(223.1)	1.76
1999 - 2015	775.6(327.8)	-2.8**	830.3 (212.1)	-2.06*	708./8(255.4)	-3.8**
	Lalitpur		Jalaun		Hamirpur	
1939 - 1968	1092.4(295.5)	2.65**	867.8 (213.9)	2.77**	933.4 (212.4)	1.87
1969 - 1998	921.5(408.9)	-0.84	770.1(190.4)	-0.33	879.2(259.9)	-0.31
1999 - 2015	840.9(235.9)	-1.99*	669.9 (201.4)	-2.51**	735.3(255.5)	-2.58*

*,**Significance at 5 % and 1% probability level respectively

Table 3 Statistical parameters of seasonal maximum and minimum temperature along Mann-Kendall test

Season	Mean(°C)	SD(°C)	CV(%)	High(°C)	Low(°C)	SL	In	R^2(%)	M_{KZ}	TS
Maximum temperature										
Jhansi										
Rainy	33.3	1.0	3.0	35.4	31.1	0.023	32.7	30.5**	2.56*	0.031
Winter	29.6	0.8	2.5	31.1	27.3	-0.002	29.7	NS	-0.85	-0.007
Banda										
Rainy	32.6	0.7	2.2	34.8	31.2	0.008	32.1	22.1*	2.56*	0.006
Winter	29.1	1.0	3.4	31.7	26.9	0.015	28.3	22.7*	4.53***	0.015
Mahoba										
Rainy	32.1	0.5	1.6	33.3	30.7	-.001	32.1	NS	1.75+	0.003
Winter	28.9	0.7	2.4	30.4	26.9	0.010	28.3	55.7#	4.76***	0.011
Lalitpur										
Rainy	32.9	0.5	1.6	34.2	31.2	-0.002	32.9	NS	-0.21	0.000
Winter	29.0	0.7	2.3	30.5	27.0	0.010	28.5	56.1#	4.09***	0.010
Jalaun										
Rainy	33.0	0.9	2.7	35.2	29.5	-0.007	33.4	26.1*	-3.16**	-0.007
Winter	28.7	0.8	2.9	30.4	26.1	0.004	28.5	21.2*	2.50*	0.007
Hamirpur										
Rainy	32.9	0.5	1.6	34.2	31.6	-0.002	32.9	NS	0.03	0.000
Winter	29.0	0.7	2.3	30.7	27.0	0.010	28.5	51.5#	3.78***	0.010
Minimum temperature										
Jhansi										
Rainy	22.0	1.0	4.6	23.5	18.3	0.0373	20.9	69.7#	3.46***	0.026
Winter	12.3	1.4	11.4	15.4	9.4	-0.047	13.6	42.8#	-2.75**	-0.044
Banda										
Rainy	23.1	0.6	2.6	24.9	21.6	0.0002	23.1	NS	0.37	0.001
Winter	12.4	0.9	7.4	14.4	9.7	0.008	12.0	23.1*	2.89**	0.010
Mahoba										
Rainy	22.5	0.5	2.2	23.8	21.4	0.0	22.5	NS	-0.21	0.000
Winter	12.6	0.7	5.4	14.3	10.6	0.008	12	59#	3.97***	0.091
Lalitpur										
Rainy	22.0	0.5	2.5	23.4	20.8	0.002	22.0	NS	1.53	0.003
Winter	14.3	0.7	4.8	16.1	12.1	0.012	13.5	64.1#	4.91***	0.013
Jalaun										
Rainy	23.1	0.9	3.9	24.9	18.8	-0.007	23.5	17.3*	-2.39*	-0.006
Winter	12.4	0.7	5.7	13.9	10.4	0.009	11.8	42.4#	3.55***	0.009
Hamirpur										
Rainy	23.0	0.5	2.2	24.5	21.2	-0.004	23.3	14.7	-2.04*	-0.004
Winter	12.3	0.7	5.4	13.9	10.2	0.011	11.7	66.6#	4.47***	0.011

*,**,*** or #, Significance at 5, 1 and 0.1% level respectively; NS: Non significant; SL:Slope;In: Intercept; TS:Theil's slope; R^2: Coefficient of determination.

Table 4 Parameters estimates, marginal effects from the binary logistig models or logistic regression model results of factors influencing perception and adaptation to climate change (N= 818)

	Factors influencing perception to climate change			Factors influencing adaptation to climate change		
Explanatory variable	Coefficient	Standard error	Marginal effect(dy/dx)	Coefficient	Standard error	Marginal effect(dy/dx)
Age in years	-0.30**	0.08	-0.075	-0.091**	0.04	-0.13
Agriculture experience	0.20**	0.09	0.051	0.021	0.06	0.003
Education qualification	0.51**	0.18	0.135	0.38*	0.14	0.055
Access to weather information through mass media	1.25*	0.91	0.31	0.76	0.83	0.11
Access to weather information through internet	-1.34	1.31	-0.33	-1.10	1.1	-0.16
Size of land holding	-1.95**	0.81	-0.49	-1.31**	0.55	-0.20
Adequate access to credit and crop insurance facility	1.96*	1.2	0.49	-1.54**	0.75	-0.22
Intermittent dry spell	2.1*	0.95	0.54	1.75*	0.80	0.25
Proper access to agricultural subsidies	0.15	0.95	0.039	-0.68	0.73	-0.10
Adequate government extension services	1.91**	0.87	0.47	1.48**	0.81	0.21
Soil health	-	-	-	-0.16	0.79	-0.02
High rate of tempearture	-	-	-	1.60**	0.74	0.23
Psedo R^2	0.76			0.67		
Log likelihood	-20.2			-0.31		
N	881					
Classified by the model	Original data					
	No.of respondent percieved climate change (%)					
	Yes	No				
Yes	349(73.3%)	154(38.1%)				
No	127(23.7)	251(61.9%)				
Correctly classified (%)	67.6 %					

*p <0.10;** p <0.05 ; Robust standard error estimated with STATAV.14.2

Table 5 Determinants of farmers choice to use a specific climate change adaptation strategy

Explanatory variables	Co-efficient of adaptation strategies				
	2*	3	4	5	6
Age in years	0.05	-0.068	-0.063	-0.04	-0.05
Agricultural experience	0.074	0.18*	0.074	0.12*	-0.02
Educational qualification	0.43*	0.42*	0.34*	0.13	-0.1
Access to weather information through mass media	1.81*	0.85	0.57	0.28	0.19
Access to weather information through internet	-0.80	-1.5*	0.10	-15.0	-0.75
Size of land holding	-0.11	-0.24	1.1*	0.07	-2.6*
Adequate access to credit and crop insurance facility	1.32	0.87	1.31	0.27	0.08
Intermittent dry spell	3.19*	3.7*	1.30	2.11	1.6*
Proper acess to agricultural subsidies	-1.01	-1.0	1.32	0.19	-0.58
Soil health	0.47	0.51	1.47	0.20	-0.92
Adequate government extension services	-0.13	1.54*	0.79	1.6	1.1
Base category			No adaptation		
N			818		
LR Chi^2			156.24		
Log likelihood			-138.4		
Prob>chi2			0		
Pseudo R^2			0.36		

*2 for "Irrigationand methods of irrigation", 3 for "Use of improved high yielding varieties, chemical fertilizers and pesticides, and change of date of sowing", 4 for " Crop and farm diversification", 5 for "Agroforestry and perennial trees or shrubs (Orchard, tree species, leucaena, sesbania, desmanthus, gliricidia)", 6 and for " Other income generation activities and copping strategies ".

Table 6 Barriers affecting implementation of adaptation practices in study region(FGD;N= 242)

	Degree of constraints					
Adaptation practices	High	Moderate	Low	No problem	CI	Ranking
Inadequate availability of irrigation resources	154	38	18	32	556	1
Frequent drought and intermittent dry spell	78	60	50	54	404	2
Higher inputs cost	86	38	28	90	362	3
Poor soil health	66	42	26	108	308	4
Inadequate weather based agro-advisory services	62	34	24	122	278	5
Limited agricultural extension officers	40	50	22	130	242	6
Poor credit facilities	32	20	10	180	146	7
Poor accessibility to agricultural subsidies	14	32	18	178	124	8
Small farm size	16	26	8	192	108	9