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Farmer's perception and factors determining the adaptation decisions to cope with climate change: An evidence from rural India

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ABSTRACT

The farmer's adaptation decision to cope with climate change has drawn considerable attention and recognition of the local and global scale's human-environmental approach. In this paper, we tried to understand the human dimension of adaptation decision of farmers in rural India. We analyse the farmer's perception of climate change and socio-economic determinants of farm household which influence adaption decisions and adaptation strategies choices. We conducted a micro-level assessment of 700 farmers and farm households in seven districts of the Bihar state of northern India. The data is analysed through descriptive statistics and logistic regression. The study finds that 80 per cent of the surveyed farmers perceive and predict climate changes and choose to adopt. This study found that the key socio-economic variables such as the farmer's age, gender, household size, education level, off-farm income, and farm-size influence farmers' adaptation decisions. This study will help identify the critical household characteristics that may be integrated into future policy formulation and implementation to be integrated into future policy formulation and a successful adaptation future.

1. Introduction

Climate change impacts on agriculture impinge complex economic, social, and political crisis globally. The nexus of climate change, agriculture, and food security appear to be more intense and complicated with devastating impacts for developing countries (Rosenzweig and Parry, 1994; IPCC 2007; 2014; Pandey et al., 2017; Ojo and Baiyegunhi 2019; Omerkhil et al., 2020). Among all developing countries, India has been recognized as one of the most vulnerable developing countries towards climate change risks (IPCC, 2014; Guntukula, 2020; Praveen and Sharma, 2019). Climate change is a continuous process; without any counteracting responses, the magnitude and intensity will only increase in the future. Adaptation has been proposed as a critical policy option for combating the unavoidable consequences of climate change by several researchers (Huang and Sim, 2021; Khannal et al., 2021; Dorward et al., 2020; Turner-Walker et al., 2021; Holland et al., 2017; Smit and Skinner, 2002; Below et al., 2012).

Agricultural adaptation entails adjustments of agronomic and agro-management practices towards the prevailing or predicted climate conditions to reduce the vulnerability and ensure a climate-resilient farming system (Paudel et al., 2014; Jha et al., 2017). Food production can significantly increase under the adverse effect of climate change if appropriate region-specific adaptation measures are adopted (Bradshaw et al., 2004; Di Falco et al., 2011). Several researchers have conducted a micro-level assessment to examine factors determining adaptation behavior and estimated the impact on farmers' wellbeing under climate change (Di Falco et al., 2012; Singh, 2020). Success full adaptation will require multiple stakeholders, including farmers, policymakers, extension agents, NGOs, researchers, communities, and the private sector (Bryan et al., 2009, 2013; Below et al., 2010; Fraser et al., 2011). The policymakers can enhance the adaptive capacity of farm-household by providing credit, information, input, and extension and farm advisory services, among other measures (Maddison, 2007; Nhemachena and Hassan, 2008; Gbetibouo, 2009; Deressa et al., 2009; Hisali et al., 2011; Tambo and Abdoulaye, 2012; Gorst et al., 2018). In developing countries, several socio-economic, geographical, and meteorologicalconditions obstruct adaptation, and therefore, coping with climate change is often challenging (IPCC 2007; 2014; Patnaik and Das 2017; Singh et al., 2018; Khan et al., 2020; Omerkhil et al., 2020).

The human dimension of agricultural adaptation identifies a farmer's agency as a planner, performer, and innovator (Crane et al., 2010) working under a specific socio-economic, cultural and ecological setting (Bryan et al., 2013; Deressa, 2007). The human dimension approach of adaptation focuses on farmers' perception of climate change based on

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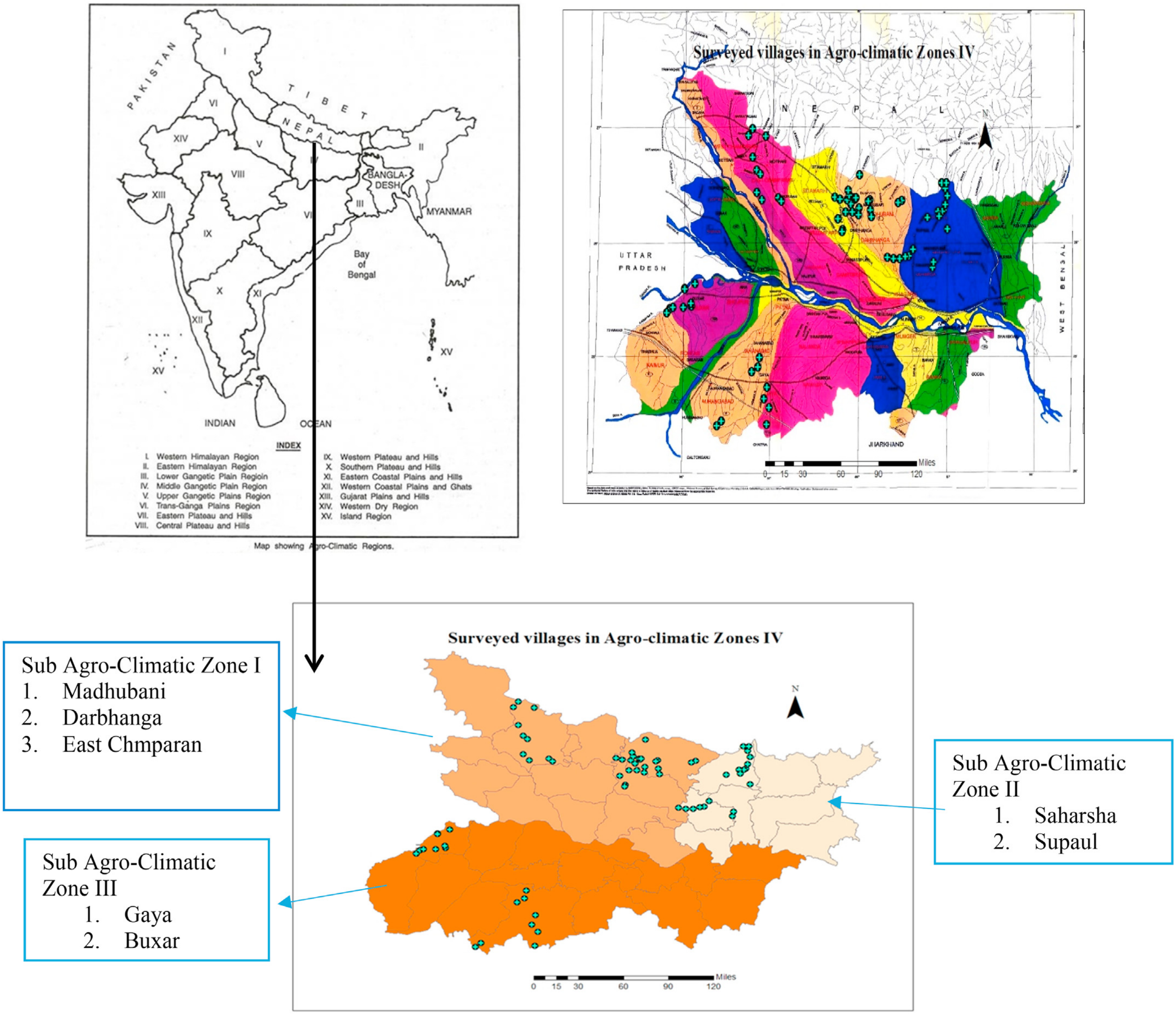

Fig. 1. Map of the selected villages' geographical location from seven districts along with the river basin of Bihar, India.

past experiences in dealing with risks and uncertainties. Accordingly, farmers develop their adaptive capacities and make decisions on local adaptation strategies. Farmer's perception of climate change and risk in the short and long run both impact the farmer's choice of adaptation strategies (Jodha et al., 2012; Ayanlade et al., 2017). The adaptation process encompasses the interdependence of agents through their relationships with each other at the micro-level, with the institutions in which they reside and the resource base on which they depend (Adger et al., 2003). An understanding of how farmers engage themselves in the decision-making process and the significant factors that induce and enhance adaptation responses is, therefore, imperative (Ojo and Baiyegunhi 2019).

Successful and efficient adaptation depends on three critical factors; timely recognition of the need, the incentive, and the ability to adapt (Fankhusher et al., 1999). Identifying the need for adaptation requires the farmer to perceive and realise the actual climate changes (Bryan et al., 2009) and alter the traditional farming practices to maximize returns in each new environment (Sanghi and Mendelsohn, 2008). Analysis of farmer's perception of climate change is a prerequisite for assessing their adaptation decisions. Decision-making by the farmer under constraints is quite challenging due to the time lag between gathering and processing information and realisation of adaptation (de Jalón et al., 2018). The importance of farmers' perception of climate change in farm-level adaptation literature is widely recognized (Madison, 2007; Bryant et al. 2000, 2009; Nhemachena and Hassan, 2008; Gbetibouo, 2009; Kawadia and Tiwari, 2017; Singh, 2020). The climatic factors include an increase/decrease of temperature and precipitation levels, regional monsoon variations, the local incidence of climate extremes (e.g., flood, drought, cyclones, and frosts). It is essential to understand and identify the climatic factors, considered by farmers for framing their perceptions on climate change (Khanal, 2014; Tripathi and Mishra, 2017; Zamasiya et al., 2017). Farmers give more significance to recent climatic events as information based on past personal experience and external sources differ significantly due to climate uncertainty (Hansen et al., 2004). Inter-annual variations in temperature and climate extremes are usually observed over the short term and are more erratic and uncertain. Farmers are traditionally concerned about seasonal climate forecasts as such changes leave very less response time and limited scope for efficient decisions.

Farmer's perception of climate events does not guarantee adaptation measures (Gbetibouo, 2009; Bryan et al., 2009) as several factors might jeopardies their ability to adapt. The ability to adapt depends on the cognitive skills of farmers, which varies across households and is influenced by demographic features such as age, educational qualification, gender, and geographic location, ethnicity, and other socio-economic parameters (Gbetibouo, 2009; Deressa et al., 2009; Maddison, 2007; Below et al., 2010; Dumenu and Obeng, 2016; Khanal et al., 2018; Khanal and Wilson, 2019; Funk et al., 2019; Mehar et al., 2016; Omerkhil et al., 2020). The adaptive capacity of farm-households depends on several socio-economic and demographic factors such as family size, age, gender, education level, and farm-size and vary at regions and local level (Opiyo et al., 2015; IPCC, 2014; Niles et al., 2015).

This study analyses farmers' perception of climate change and socio-economic factors in influencing farmers' decision to adopt strategies in the adaptation to climate change. The primary data was collected from 700 farm households in the districts of Bihar state, India, and analysed to assess adopting eleven adaptation strategies. The paper is structured into five sections. Section 2 discusses methods and materials, including questionnaire designing and the description of the survey area. Section 3 Analyses results and discusses the outcomes. Section 4 concludes the paper with policy implications.

2. Methods and materials

2.1. Study area

The study is conducted in the State of Bihar in Eastern India, where 89 per cent of the population and 77 per cent workforce live in rural areas, and involved in the agrarian and allied activities and contributed 18.1per cent of the gross domestic product (GSDP) in 2014-15 (Economic Survey of India, 2015–16). The State of Bihar extends from the 24° north to 27°' north latitude, hence fall under tropical to a subtropical region and characterised by high temperature, mild humidity, medium to high rainfall, and short and dense winter. The average annual precipitation is 1176.4 mm. The seasonal variation of atmospheric pressure over the State occurs systematically with a maximum in the winter and a minimum in the monsoon season. Bihar being an inland State, does not experience the full fury of severe storms/depression-like the coastal regions.

The total geographical area of Bihar is about 94.2 thousand square km, and the river Ganges divides the state into two, the south and the north Bihar. The state falls under Middle Gangetic plains and broadly characterised into three sub-sub-agro-climatic zones based on climatic and hydrophysical attributes such as North West Alluvial Plains, North East Alluvial Plains, and South Bihar Alluvial Plains. Our surveyed districts fall in all the above three sub-agro-climatic zones. The annual natural rainfall varies between 990 and 1700 mm. The major rainy season in the state is from July to September. The irony is that even though the State gets good precipitation and water reservoirs, it suffers from severe droughts intermittently that intrinsically leads to famine. The state categorized as a flood-prone area as 76 per cent of the north Bihar population was impacted by the threat of flood devastation. The State has started experiencing a decline in the volume of rainfall, rainy days and an increase in temperature (Giri, 2015). The climate change is likely to worsen the problem further with highly uneven and erratic rainfall, floods and severe droughts. The location of districts and villages chosen for our study are shown in Fig. 1.

2.2. Sample selection

In the first stage, we randomly selected seven districts out of 38 districts of Bihar. The randomly selected districts fall under the state's sub-agro-climatic zone, which has different climatic and hydrological attributes along with different soil characteristics. We randomly selected 72 villages from these seven districts based on the district headquarters' distance in the second stage. We tried to capture the close villages (less than 10 km) and far (10–70 km) from headquarters. The farm households from the first village category will always have an advantageous position in access to market and institutional support and vice-versa (Pandey and Jha, 2012). The farm households' preliminary information has been collected from the office of the head of the village. In the third stage, we selected 735 farm households randomly from these 72 villages for primary data collection. Finally, we statistically analysed data of 700 farm households after removing outliers and incompleteness. The sample size successfully captured the farm households from different landholding sizes, such as marginal, small, medium, and large. The location of districts and villages chosen for our study are shown in Fig. 1.

2.3. Questionnaire design

We developed a structured questionnaire to collect farm household level information related to their climate change perception, socio-economic attributes and adaptation strategies to cope with climate change. The structure of the questionnaire was based on the systematic framework. The adaptation decisions of the farm household are summarised in Fig. 2. The open-ended questions were asked to farm households to capture the alter in agricultural practices to minimise the impact of perceived changes in temperature and precipitation. We have identified eleven adaptation strategies listed in Table 1. The first category of strategies is at the farm level, which directly involved in improving agricultural yield based on farm households' perception of climate change and variability. The second category of adaptation strategies is for improving farm households' welfare. It, therefore, focuses on strengthening their income through income diversification, which includes measures of migration to an urban area, changing land from farm to non-farm activity, leasing land for commercial activity. These measures are expected to enhance the farm households' adaptive capacity and lessen their vulnerability to climate change. The third category of adaptation strategies is risk diversification and minimization, including crop insurance and diversification in agriculture through planting vegetable and horticultural crops. We also analyse farmers' responses to determine the socio-economic and demographic explanatory variables which influence their decisions to adopt or not to adapt. These variables are the education level of farmers, household size, ownership of livestock, gender, age, sources of the farm, and non-farm incomes.

For assessing farmer's perception of changes in precipitation levels, farmers were asked, 'Have you observed any long-term changes in the mean rainfall over the last 20 years? We have used mental map technique to quantify farmer's observation and perception of climate variation based on the ethnographic studies which confirm that individuals can correctly recognise the variation in climate over a decade or longer based on personal experience (Marin, 2010; West et al., 2003, 2008). Based on their answer (i.e., if, yes) they were further asked whether the rainfall levels have increased, decreased or remained the same? Also, farmers were asked to state their experience for the extreme weather events based on their impact on crops as per the number of occurrences of such extremes in the past 20 years. The types of extreme climate events identified for the study region are flood, drought, cyclone, frost, and sheer hotness. The magnitude of impact measured at different scales ranging from 1 to 5 (1 = No impact, 2 = low, 3 = medium, 4 = high, 5 = very high). The occurrence of climate extremes considered at every five-year interval.

2.4. Statistical analysis

We used descriptive statistics and statistical inference to analyse the socio-economic profile, farmers' perception of climate change and adaptation strategies of the surveyed household. We used cross-

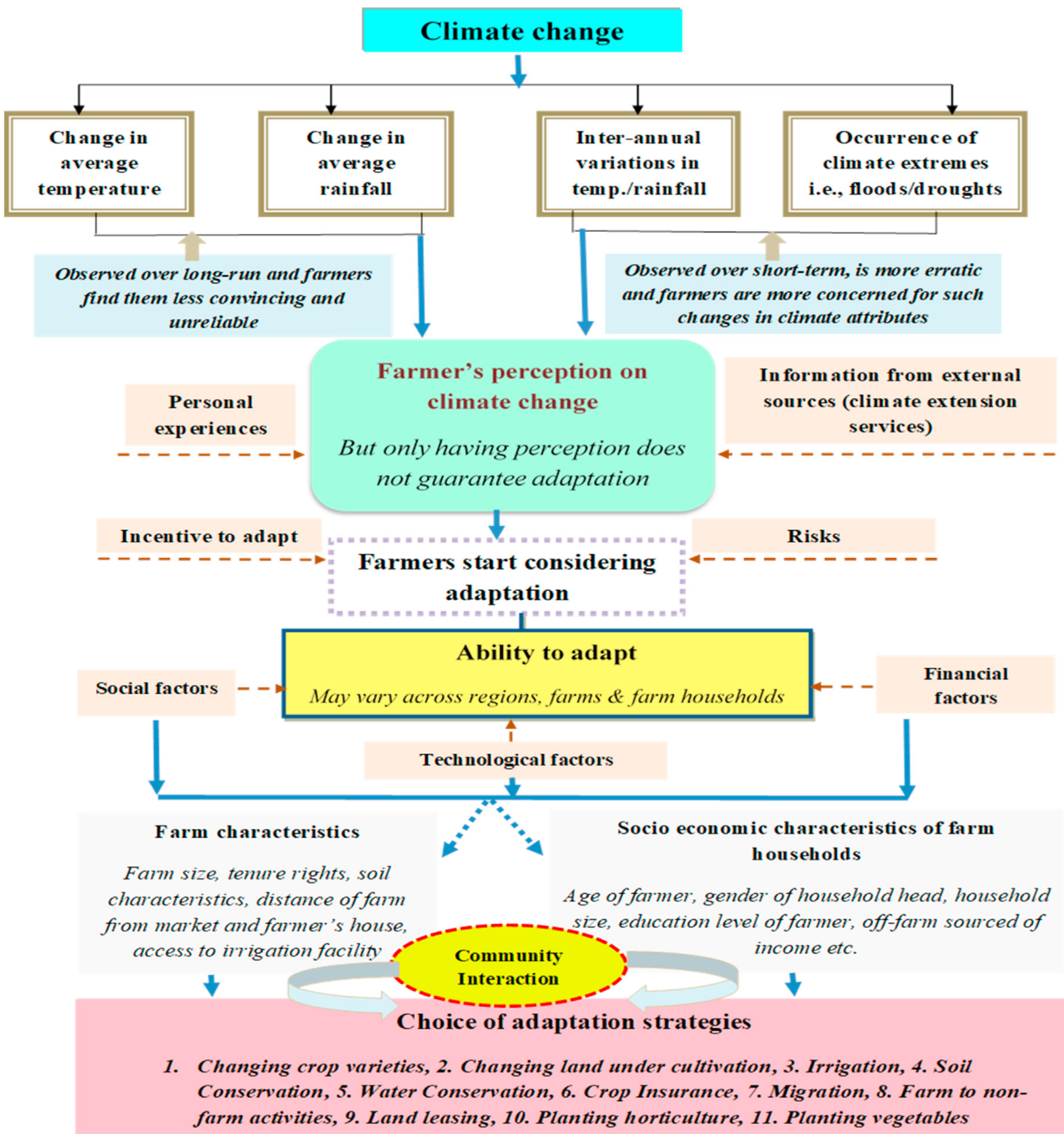

Fig. 2. Schematic conceptual frameworks of farmer's adaptation decisions.

tabulation and considered four cognitive cases to analyse the farmer's perception and adaptation. These are 1) perceive/predict climate changes and decide to adopt 2) perceive/predict climate changes yet not being able to adapt because of the constraints, 3) do not perceive/predict any climate changes and therefore do not adapt, and 4) do not perceive/predict any climate change yet undertake adaptation by choice.

In the first stage farmers first perceived the change in climatic parameters and at the second stage farmers decide to adopt coping strategies to minimise the impact of climate change. The farmer's decision to adopt the particular adaptation strategies is associated with the expected utility from those particular strategies. For example, the farmer will adopt water conservation strategies if he is aware that the expected utility to adapt is greater than utility derived in the case of no adaptation.

Let's assume the latent variable (***Y****$_{ij}$**),** which is equal to expected utility derived from the adoption of certain adaptation measures can be presented as the function of an explanatory variable

$$Y^*_{ij} = \alpha + \beta_j X_i + \varepsilon_{y^*_{ij}}$$

Where Y^*_{ij} is an expected outcome with subscript i which represent that ith farm household is adapting jth adaptation strategies. X_i represents the household characteristics i.e. explanatory variables affecting farmers' adaptation decision, and i represent the specific household characteristics. The denotes the model intercept, β_k is the vector of binary regression coefficient and $\varepsilon_{Y^*_{ij}} \cong$ N (0, σ^2) is the error term that normally is distributed and homoscedastic i.e. zero mean and constant variance) (W. Hosmer and Lemeshow, 2000).

We assume that,

$$Y_{ij} = \begin{cases} 1 \text{ if } Y^*_{ij} > 0 \\ 0 \text{ if } Y^*_{ij} < 0 \end{cases}$$

Where Y_{ij} is an observed expected outcome after adapting the jth

Table 1
Description of variables queried in the survey instrument.

Variables	Description	Data Type	Source
Age	Age of the farmer/household head	Continuous	Maddison, 2007; Nhemachena and Hassan (2008); Abid et al. (2016); Opiyo et al. (2015)
Gender	Gender of the farmer/household age (1 = male, 0 = female	Binary (1,0)	Maddison, 2007; Nhemachena and Hassan, 2008; Singh, 2020; Abid et al., 2016; Opiyo et al., 2015
Marital status	marital status of the farmer/household age (1 = yes, 0 = No)	Binary (1,0)	Nhemachena and Hassan, 2008; Gbetibouo, 2009 Abid et al., 2016;
Education	Year of education of the farmer(divided into four categories- 1. no education 2. primary education 3. secondary education 4. higher education	Continuous	Deressa et al., 2009; Abid et al., 2015; Patnaik and Das, 2017; Belay et al., 2017; Bryan et al., 2013
Household size	Total number of family members including male, female and children below 10 years of age.	Continuous	Nhemachena and Hassan, 2008; Abid et al., 2016; Opiyo et al., 2015; Khanal, 2018; Singh, 2020
Dependency ratio	No of dependents in the family e.g. non-workings women and children below 10	Continuous	Pandey and Jha (2012)
Secondary occupation	Whether a farmer is having any other non-climate sensitive occupation(other than agriculture and allied) along with agriculture (1 = yes, 0 = no)	Binary (1,0)	Gbetibouo (2009) Tenge et al. (2004) Shiferaw and Holden (1998)
Livestock	Whether the farm household possess livestock	Binary (1,0)	Falco et al., 2014; Belay et al., 2017
Land size(in Hectare)	Total cultivated land of the farmer in a hectare.	Continuous	Deressa et al., 2009; Patnaik and Das, 2017; Abid et al., 2016; Opiyo et al., 2015
Land right (ownership)	Land owned by the farmers or taken on rent	Binary (1,0)	Fosu- Mensah et al., 2012; Iheke and Agodike, 2016; Abid et al., 2016
Soil characteristics	Described as fertile = 1 and infertile = 0	Binary (1,0)	Tesfahunegn et al. (2016)
Farm distance(in Kilometer)	The distance of land from farmer's house in kilometer (km)	Continuous	Asrat and Belay (2018)
Farm mechanization	Whether farm household is having farm machine (1 = yes, 0 = no)	Binary (1,0)	Di Falco et al., 2011; Di Falco and Verones, 2013
Animal labour	whether farm household is using animal labour or not	Binary (1,0)	Di Falco et al., 2011; Di Falco and Verones, 2013
Family labour	If the household is having 2 or more than 2 family members engaged in agricultural activity	Binary (1,0)	Patnaik and Das (2017)
Adaptation Strategies Adopted by Farm Households			
Changing crop varieties	Planting different crops, drought-resistant varieties, high-yield varieties, water-sensitive crops, short-duration varieties	Binary (1, 0)	Di Falco and Verones 2013; Loria and Bhardwaj, 2016; Raghavendra and Suresh, 2018
Changing land under cultivation	Land rotation or altering the area under cultivation	Binary (1, 0)	Deressa et al., 2011; Gebru et al., 2020
Irrigation	Increase/decrease the intensity of irrigation to overcome shortage or excess rainfall by using tube well, water pump etc.	Binary (1, 0)	Brklacich et al., 1998; Bryant et al., 2000; Kabubo-Mariara, 2008; Raghavendra and Suresh, 2018
Soil conservation	For maintaining soil fertility-like zero-tilling etc.	Binary (1, 0)	Dumanski et al., 1986; Belay et al., 2017
Water conservation	Rainwater harvesting, building tanks or water reservoirs	Binary (1, 0)	Belay et al. (2017)
Crop insurance	Insure crops to overcome crop losses due to climatic disturbances	Binary (1, 0)	Aggarwal, 2008; Falco et al., 2014; Nambi et al., 2015; Mase et al., 2017; Raghavendra and Suresh, 2018
Migration	Migrating to the urban area to diversify their livelihood options	Binary (1, 0)	Murali and Afifi, 2014; Jha et al., 2018
Farm to non-farm activities	Changing land from farm to non-farm activities mainly in non-climate sensitive activities	Binary (1, 0)	Udmale et al., 2014; Nambi et al., 2015; Dhanya and Ramachandran, 2016
Leasing land	Leasing land for other non-farm activities	Binary (1,0)	Ampaire et al. (2017)
Planting horticulture crop	Planting fruits like- mango, litchi, banana, guava, nuts, seeds, herbs, sprouts, mushrooms, flowers, seaweeds and non-food crops such as grass and ornamental trees and plants.	Binary (1, 0)	Eriksen et al., 2009; Osbahr et al., 2010; Williams et al., 2020
Planting vegetables	Planting vegetables like potato, brinjal/eggplant, cauliflower, cabbage, tomatoes, chilli etc.	Binary (1, 0)	Eriksen et al., 2009; Osbahr et al., 2010; Williams et al., 2020

adaptation measure by the ith farm household to cope with climate change. If the expected output is greater than zero farm household adapt the particular adaptation strategies (1 *if* Y^*_{ij}). If the expected output is smaller than zero the then farm household will not adapt the jth adaptation strategies(0 *if* $Y^*_{ij} < 0$).

The dependent variable is binary as farmers have only two option i.e. to adapt (1) and not adapt (0). The logistic regression model helps to analyses the adaption decision by providing the relevant probabilities of the adaptation. Each adaptation strategy is independent and could not have any influential effect on selecting one over the other. Several studies have used the multinomial logit (MNL) or multinomial probit model. These are restricted to select only one adaptation strategy from a given set of adaptation strategies. Our study observes that the farm household adapt more than one adaptation strategies, making the use of MNL approach inappropriate. We use the logistic regression model to assess the role of socio-economic characteristics on adaptation strategies. The relationship between the binary dependent variable and a set of independent variables that can be either binary or continuous can be well expressed with the logistic regression model's help.

The logistic regression model is given by Green (2011):

$$\log\left(\frac{P_i}{1-P_i}\right) = \log(P_i) = \beta_0 + \beta_i X_i$$

Where P_i is the probability of adapting particular adaptation strategies from the set of given adaptation strategies, X_i is an independent variable. Therefore, the parameter β_i gives the log odds for the dependent variable, and β_0 is a constant. The odds ratio is the probability of an event happening related to not happening. It is given by Green (2011):

$$\frac{P_i}{1-P_i} = exp(\beta_0 + \beta_i X_i)$$

3. Results and discussions

3.1. Socio-economic and demographic profile of surveyed household

This section will provide descriptive statistics of the demographic and socio-economic characteristics of surveyed households in the villages of

Table 2
Descriptive statistics of socio-economic characteristic of farm household in survey region.

Variable Name	Mean	S.D.	Min.	Max.
Age	51	9.34	24	70
Gender	0.81	0.39	0	1
Marital Status	0.91	0.14	0	1
Education	8	4.40	0	17
Household Size	9	3.11	3	20
Dependency Ratio	5	1.92	1	17
Secondary Occupation	0.30	0.45	0	1
Livestock	1.70	1.39	0	9
Land Size(Ha)	1.78	1.723	0.125	12.5
Land Right	0.64	0.47	0	1
Soil Characteristics	0.90	0.30	0	1
Farm Distance(Km)	1.79	1.24	0.5	10
Farm Mechanization	0.24	0.42	0	1
Animal Labor	0.17	0.24	0	1
Family Labor	0.34	0.47	0	1

Bihar. Table 2 provide the descriptive statistics of households.

The farmer or household head parameters can influence farmers' perception, willingness to adapt, and adaptive choices. The average age of the farmer in the study area is 51 years. The youngest farmers were 24 years old, and the oldest was 70 years old. From the average age of the sample farmers, it can positively and negatively impact their adaptation decision. Usually, there exists a positive relationship between gender (male farmers or male head of the household) and a farmer's decision to adopt. Most of the sample in the study region was male farmer's. The percentage of male farmers is 81 per cent, and female farmers are 19 per cent.

Several studies have established a positive relationship between education and farmer's ability to perceive climate change and the likelihood to adopt strategies (Deressa et al., 2009; Gbetibouo 2009; Yegbemey 2013; Igodan et al., 1988; Lin, 2011; Maddison, 2007; Abid et al., 2016; Opiyo et al., 2015; Patnaik and Das, 2017). The average years of schooling of the surveyed household are 8 years. The maximum years of education are 17 years. The result shows that 12 per cent of farmers are not having any education (0 years of education). Among total farmers, 40per cent are found with primary education (1–6 years of schooling) i.e. 278 farmers in numbers. Overall numbers of farmers having a secondary education are 142 out of 700, i.e. 20 per cent of the total household. The number of farmers with higher education (12 years or more) was quite high as it was 193 of total surveyed farmers, i.e., 28per cent. It is expected that the farmers' education level will have a positive impact on their adaptation decision.

Farm-level adaptive response majorly depends on household size as it determines the feasibility of adopting any particular strategy. Average household size of the surveyed household is 9 members. The minimum household size is 3 members, and maximum household size is 20 members. The expected impact of household size is positive in their decision to adopt. The average dependent members are 5 members, including females and children below 10 years. The number of dependent members can have both positive and negative impact on their adaptive capacity. The household's occupational structure; both primary and secondary also has a significant implication on adaptation decisions and choices. In the study, very few farmers have had any other secondary occupation, i.e., non-climatic sensitive occupations. The secondary occupation is supposed to positively impact the adaptive capacity due to income from the different sources. Similar to secondary occupation livestock ownership also hypothesized to increase adaptation to climate change. Households' income is identified to play an essential role in enhancing climate change adaptation. Average Livestock held by surveyed household is very low in the study area, i.e., approximately 2 and ranging from 0 to 9.

Farm-size is often considered as a wealth indicator and can have both negative and positive consequence of adaptive decisions. The average land size held by the farm household is 1.78 ha. It is ranging from 0.125 ha to 12.5 ha. The detailed analysis of the distribution of land size is given in Table 2. It is observed (Table 3) that a higher number of farm households belong to the marginal group, i.e., 35 per cent and small land size group, i.e., 27 per cent. The medium-size farmers are 24 per cent, and large size farmers are 14 per cent.

Table 3
Land size group of the surveyed household.

Land Size Group	Marginal (0 > 1 ha)	Small (1–2 ha)	Medium (2–4 ha)	Large (≤ 4 ha)
Total households	245	190	170	94
Per centage (per cent)	35	27	24	14
Average land size (in ha)	0.48	1.24	2.29	5.33

Along with land size, ownership pattern is also found to be another critical determinant of adaptation decision. Bryan et al. (2009) found that creating stronger individual property rights would promote farm-level adaptation. This study found that farmer that has own title to their land are 6 per cent more likely to adapt. In our study, the number of households having land rights is 450 out of 700 surveyed households, and 250 was having only the user rights.

3.1. Farmer's perception of climate change

The preliminary results of this study indicate that about 91per cent (640 farm households) and 86 per cent (603 farm households) perceive changes in temperature and precipitation levels, respectively (Fig. 3). Most of the farmers perceive that in the past 20 years, the temperature levels have risen. About 87 per cent of the farmers noticed an increased number of hot days, while only 4 per cent observed a decrease in the number of hot days, and 9 per cent reported no change in it (Fig. 3). About 44 per cent of farmers felt an increase in the number of cold days; 47 per cent observed a decrease and 9 per cent reported no change. Similarly, around 86 per cent of the sample farm household perceived changes in precipitation. However, 47 per cent farmers noticed a decline while 39 per cent observed the rise, and the remaining 14 per cent did not observe any change in rainfall levels (Fig. 3). These results align with the Indian Meteorological Department (IMD, 2009) temperature record for Bihar, suggesting a significant increase in annual temperature levels by about 0.01C/year from 1951 to 2010. In the case of rainfall, the farmer's perception changes are in line with annual rainfall trends for 1951–2010, which records an increase of 1.41 mm/year. The summer and winter rainfall shows an increase of 0.59 mm/year and about 0.06 mm/year, respectively. Farmer's perception of climate change is influenced majorly by their recent changes in climate variables and climate extremes.

The farm households' experiences on climate extreme events are shown in Fig. 4. Farmer's experiences of climate extremes (flood, drought, cyclone, frost, and extreme hotness) have been captured distinctively through five categories i.e., no impact, low, medium, high, and very high impact. Experiences of climate extremes were investigated for four-time phases i.e., past 5 years, 10 years, 15 years, and 20 years' period. The results indicate that most of the surveyed farmers experienced floods (85per cent) and frost instances (76per cent) in the past 5 years. Farmers also experienced medium instances of the cyclone (60per cent) and hotness (45per cent) in 5 years. However, over the period i.e., for the previous 20 years, farmers' experiences of drought, cyclone, frost and hotness were 'low' (Fig. 4). These results reflect on the long-term memory retention of the farmers. The flood was the most prevalent climate extreme in the study area and highly vulnerable due to the recurrence of the flooding (Jha and Gundimeda. 2019). The farmers shared their experiences as high to very high even in the long-term period (for the past 20 years). The increased intensity and frequency of flooding in the survey area result from increased rainfall and the developmental

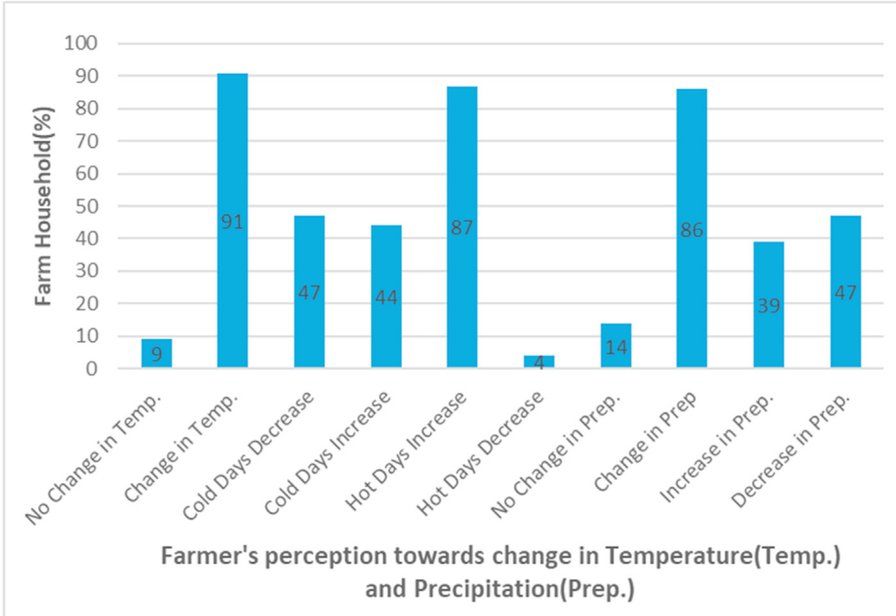

Fig. 3. Farmer's perception of change in temperature and precipitation.

and infrastructural issues in the state of Bihar (Jeganathan and Kumar, 2019).

3.2. Farmer's perception of climate change and the adoption of adaptation strategies

Farmers were enquired about their choices of adaptation strategies from 11 different adaptation strategies discussed in Table 1 for changes in temperature and precipitation and different seasons, i.e., Kharif and Rabi. The sample farmers expressed their choices for these strategies based on their perception of climate change or variability and their farming practices. It is found that 80 per cent and 89 per cent of the sample farmers (Table 4) perceive changes in climate for both temperature and precipitation in the Kharif and the Rabi seasons respectively. Therefore, the majority of them decided to adopt. We observe the positive influence of perception on their adaptation. However, the proportion of the farmers who perceive changes in a climate still do not/unable to adopt is in the range of 9–19 per cent and 8–12 per cent of the sample farmers who did not perceive any climate changes and still decided to adopt specific strategies. The proportion of sample farmers who did not perceive any climate changes and did not adapt is very low. The results reemphasize the findings of previous studies that observation over time shapes farmers' climate change perceptions and, accordingly, their adaptation (Maddison, 2007; Gbetibouo, 2009).

Farming seasons vary based on the climate conditions and accordingly, the choice of crops to be planted, and agricultural management practices also differ by seasons. Consequently, the choice of adaptation strategies is also likely to differ. One of the main objectives of this study was to assess whether the perception of climate change and farmer's adaptation decisions differ by agricultural season.

3.3. Farmer's adaptation strategies to climate change

Agricultural adaptation varies by time (short-term or long-term) and scale (farm level, regional level, national level) and types. Farm-level adaptation options can broadly be categorized into three main groups: farm management practices, farm-level technological developments, and financial management for farm protection (Smit and Skinner, 2002). Based on these broad categories, studies have identified several adaptation strategies. For instance, changes in farm management practices involve crop diversification, shortening or lengthening of growing seasons, changing planting dates, altering land under cultivation, and increase/decrease the use of irrigation. The technological developments may include using new crop varieties, adopting soil and water conservation techniques, adopting weather information and forecasts; and financial management for farm protection may involve switching from farm to non-farm activities, insuring crops, migration to urban areas for livelihood (Nhemachena and Hassan, 2008; Kurukulasuriya and Mendelsohn, 2006a; Gbetibouo, 2009; Below et al., 2009; Deressa et al., 2009; Hisali et al., 2011; Maddison, 2007). At micro-level, farmers' adaptation is often driven by their ability to predict climate while adaptation decisions are mainly influenced by their socio-economic, cultural and political conditions. Farmer's adaptation involves adjustment decisions usually taken quickly and mostly based on their perception and actual seasonal climate onset. Farmer's decision to adopt or not to adapt is based on four probable cognitive conditions- 1) perceive/-predict climate changes and decide to adjust to maximize their returns out of the changing conditions, 2) perceive/predict climate changes yet do not adapt because of the constraints faced in adaptation, 3) do not perceive/predict any changes in climate conditions and therefore decide not to adapt, 4) do not perceive/predict any climate change yet adapt new on-farm changes, influenced by their fellow farmers' choices which may be profitable.

Fig. 5 and Fig. 6 display the options of adaptation strategies for perceived changes in temperature and precipitation during Kharif and Rabi cropping seasons. The choices of adaptation strategies are not mutually exclusive, and therefore, farmers reported to choose more than one strategy at a particular time. Farmers go for both intra crop and intercrop strategies. For instance, farmers may change land under cultivation and change crop varieties, requiring an increase/decrease investment in irrigation. Farmers and some of their family members may also decide to migrate to urban areas for earning additional income for their livelihood requirements. Also, a farmer may decide to insure against crop failure by using crop insurance. The results of the study reveal that the most common adaptation strategies adopted by farmers in the survey region for the Kharif season for changes in rainfall and temperature are the increase irrigation (about 66–68 per cent), change crop variety (51–56 per cent), the area under cultivation (46–51 per cent), migration to urban areas (49–52 per cent) and crop insurance (43 per cent).

The other minor strategies adopted by farmers are growing vegetables

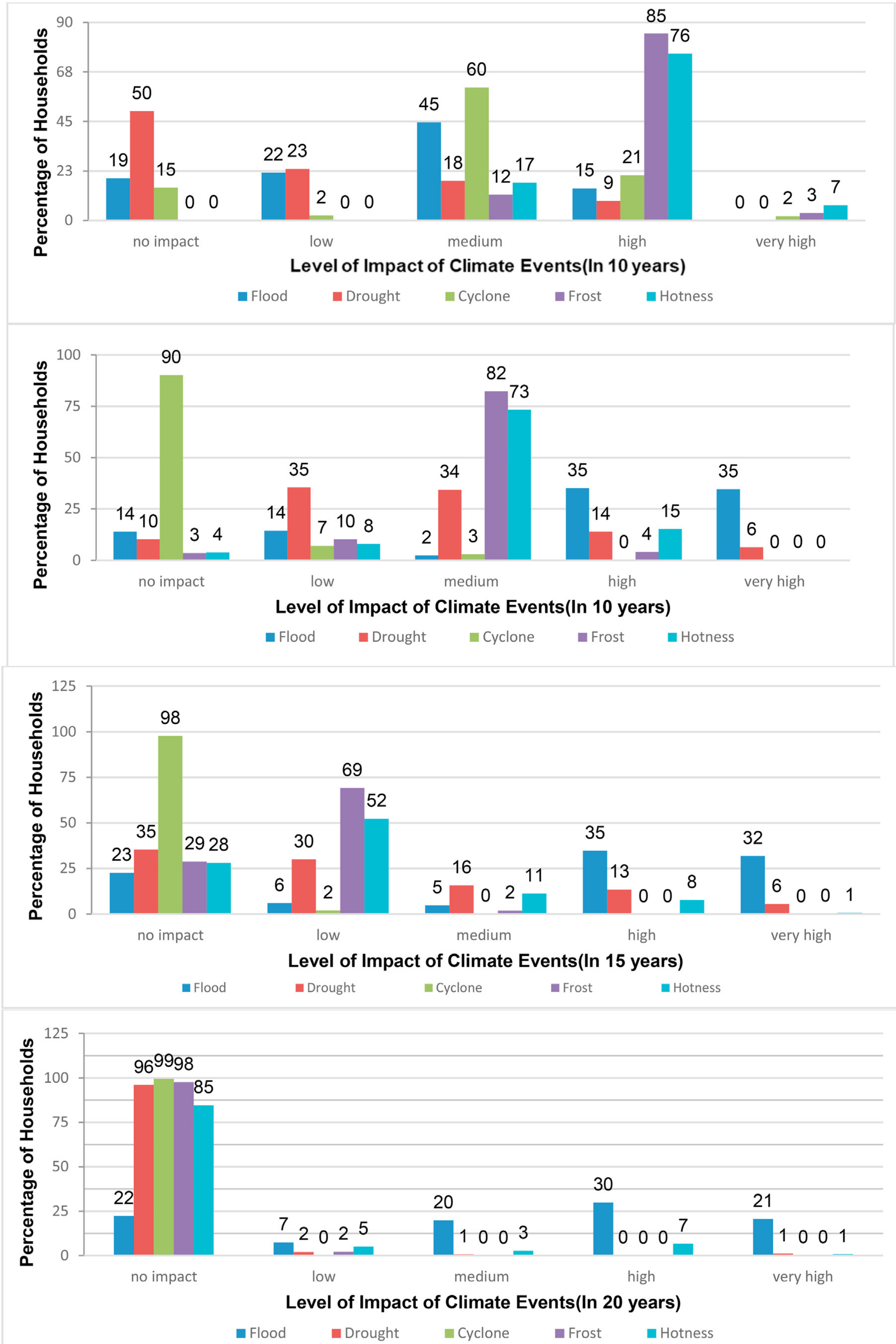

Fig. 4. Number of sample farm households experiencing extreme events.

Table 4
Farmer's perception of climate change and adaptation decision. '(per cent of respondents).

Conditions	Kharif Season		Rabi Season	
	Temperature	Precipitation	Temperature	Precipitation
No adaptation total	20%	20%	11%	11%
Adaptation total	80%	80%	89%	89%
Perceive and adapt	72%	69%	82%	77%
Do not perceive and still adapt	8%	11%	8%	12%
Perceive and no adaptation	19%	17%	10%	9%
Do not perceive and therefore no adaptation	1%	3%	1%	2%

along with main crops (27–30 per cent), switch from farm to non-farm activities (12–14 per cent), soil (25–27 per cent) and water conservation (17 per cent), horticulture (9–11 per cent) and lease land (6–7 per cent).

Likewise, for Rabi (winter) season, the primary adaptation strategies which farmers in the survey region adopt are irrigation (76–81 per cent), use different crop variety (68–73 per cent), change area under cultivation (61-51 per cent), migration to the urban region (55–57 per cent), crop insurance, soil conservation (34–35 per cent). The other minor strategies are growing vegetables (28–31 per cent), water conservation (17 per cent), switch from farm to non-farm activities (13–14 per cent), horticulture (9–11 per cent) and lease land (7–8 per cent).

Agricultural activities in the study region are mainly rainfed, and therefore, it is apparent that any changes in temperature and rainfall will directly enhance the use of irrigation. Rice and maize are the principal crops of Kharif season, and what is the most significant crop grown in Rabi season. The monsoon rainfall is over by September–October, and therefore farmers need to adapt more during Rabi season. The increase in irrigation to cope with climate change is mainly because of the change in rainfall pattern. Farmers some time experience the delay in normal rain and start the cultivation of the crops by using the irrigation facility. This is also explained by the farmer's least confidence in shifting the cultivation period. We observed that in the study area the potential reason for using irrigation facility is subsidies provided by the government. The change in crop variety is another important strategy that has been found in practice in the study area. Farmers usually different crop varieties i.e. drought-resistant varieties, high-yield varieties, water-sensitive crops, short-duration varieties based on the climatic factors of the area and their perception of climatic variability of that particular season. Changing area under cultivation and land rotation is the conventional method to cope with climate change and one of the important soil conservation strategies based on how they predict the weather of the season. The knowledge and technology-intensive adaptation strategies such as buying insurance, soil conservation, and water conservation are low in practice in the study area because of the education and awareness level of the farm household. The lack of institutional arrangement to enhance the awareness and providing better knowledge of these strategies the barrier of adaptation. The other risk diversification strategies such as planting vegetables, horticulture and changing land from farm to non-farm strategies are also

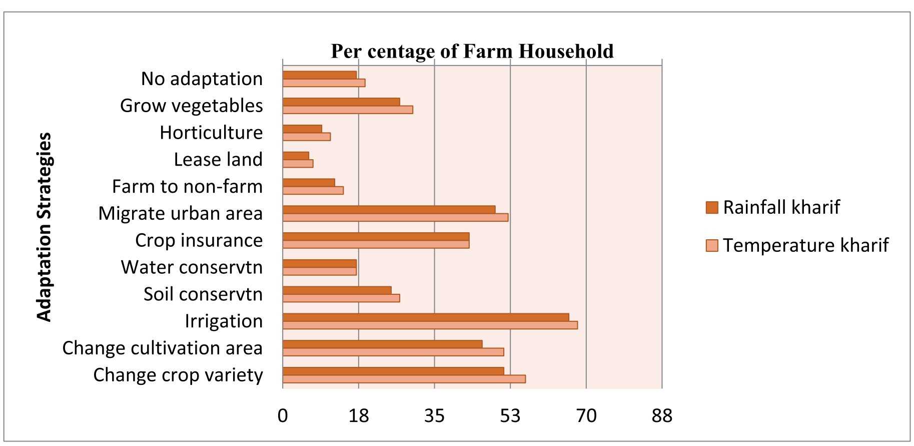

Fig. 5. Adoption of adaptation strategies in Kharif season.

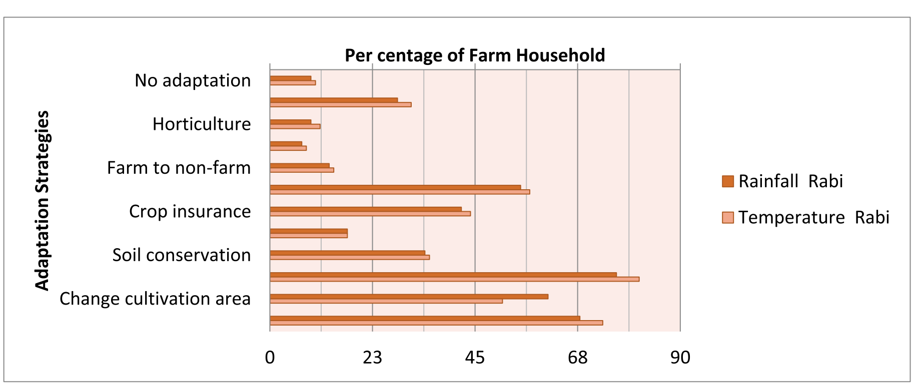

Fig. 6. Adoption of adaptation strategies in Rabi season.

low because of the small landholding size.

3.4. Role of socio-economic characteristics in adaptation decisions

The wide spectrum of literature focused on farm household's demographic and socio-economic characteristics as significant factors that determine the adaptive capacity and adaptation decision of farm households (Deressa et al., 2009; Below et al., 2010; Nhemachena and Hassan, 2008; Falco and Veronesi 2013). The study examines a range of socio-economic characteristics of farm households for assessing farmers' adaptation choices in the two cropping seasons i.e. 1) Kharif (Table 5) and Rabi season (Table 6). The application of logistic regression model helped to identify the factor that affects the choice of adaptation strategies to cope with climate change. We have run 11 different logit regression model separately to eliminate the interaction among the adaptation strategies for two different cropping season in the study area i.e Rabi and Kharif season. The rabi cropping season falls in winter season starting from October to March and the major Rabi crops in the study area are wheat, lentil, mustard, peas, linseed etc. The Kharif cropping season falls during the monsoon season starting from July to October and the major Kharif crops in the study area are rice, arhar (yellow pigeon peas), maize, groundnut etc. Further, we have analysed the farmer's adaptation strategies in response to change in temperature(TEMP.) and precipitation(PRECP). Several studies have emphasized farmer's household and socio-economic characteristics as an important factor in determining farm-level adaptation capacities and decisions (Nhemachena and Hassan, 2008; Deressa et al., 2009; Below et al., 2010; Falco and Veronesi 2013). Age represents the experience level of the farmers and therefore is a deciding factor in agricultural adaptation. The results presented for both seasons show the farmers' age as significant with the negative sign for on-farm adaptation strategies, livelihood diversification, and financial diversification strategies. The results emphasized that young farmers are keener on adopting adaptation strategies in all three farm-size groups. Aged farmers are expected to be emotionally attached to traditional farming practices and may show reluctance in adopting new agricultural practices and advanced technologically. The study results found that in response to sudden changes in climatic variations young farmers are more keen and open to adopting knowledge-intensive adaptation options such as soil and water conservation measures, insurance, income and livelihood diversification strategies and crop diversification strategies like the planting of horticulture and vegetables in both the agricultural seasons. This is mainly because young farmers are more risk-takers, while old farmers exhibit more risk-averse behaviour taking (Adesina and Zinnah 1993). The agricultural insurance found to boost the confidence of the household to use the new technology for a longer period (Wang et al., 2013). We found strong evidence of gender influence on the probability of adoption of adaptation strategies in both seasons.

The results indicate that the adaptive capacity of male-headed households is more strong to climate change than their counterparts due to their social networking and smooth interaction with the institutional arrangements for access to forecast, information and knowledge. The socio-economic culture and several other normative barriers and another source of income and family labour allocation determine the gender effect on adaptation strategies. In the developing country, land ownership also found to have a gendered bias, and user rights limit the adaptation decision of female farmers. In rural India, normative and institutional barriers hamper the female farmers' interaction in society and limit their adaptive capacity. The study has not found a strong unidirectional relationship between marital status and adaptation strategies across the cropping season as the observed relationship is significant only for water conservation and planting horticulture crops. Farmers' education level is always hypothesized to increase the probability of adaptation of new agricultural practices. Similar to previous studies (Norris and Batie, 1987; Nkonya et al., 1997; Deressa et al., 2009; Gbetibouo 2009; Yegbemey 2013), this study has also found the education level of the farmers increases the likelihood of adaptation in both the season for temperature and precipitation. The educated farmers are more aware of the access to information on climatic changes and on improved technologies, its understanding, acceptability, and adaptation, which leads to higher productivity. The education level of the farmer found to have a significant relationship with knowledge-intensive on-farm adaptation strategies such as using different crop varieties, changing land area, increasing irrigation, soil conservation and water conservation along with risk diversification strategies such as buying insurance, planting horticulture and vegetables. Despite the decentralized decision-making process, the education level of the farmers will have spill-over effect at an intra-household level in terms of the flow of knowledge along with the knowledge transfer from those who have migrated to urban areas. The results of this study have also shown the positive relationship between household-size and adaptation action across the cropping season. The strong significant relationship has been found for increasing irrigation, soil conservation, water conservation, buying insurance, migrate to an urban area, lease land, planting horticulture and vegetables. The large-sized households are forced and also can afford to divert (including migration to urban areas) part of the family members to non-climate sensitive occupation or off-farm livelihood to earn additional income that in turn, improve the adaptive capacity. The remittance from the off-farm livelihood help farm household to adapt the capital intensive adaptation strategies such as increasing irrigation, soil conservation, water conservation and planting horticulture. The awareness level is also high for the farm household which has an urban connection that helps them to adapt knowledge-intensive adaptation strategies. Connecting with dependency ratio, the relationship between several dependents in the family and adaptation strategies is observed as positive in the case of most of the strategies but found to be significant in the case of livelihood diversification and financial diversification strategies in the Rabi season. In the Kharif season, along with the previous two groups of strategies, on-farm adaptation strategies are also having a significant relationship with adaptation strategies. The farmers intended to produce more Kharif crops due to their higher market value and monsoon rainwater availability for irrigation than Rabi crops. India has a joint family system, particularly in rural areas with large family size with more number of dependent family members. The responsibility to feed dependents and to meet their expenditure requirement might be translated into their adaptation decision. On the other hand, the large-sized family's consumption needs hinder investments in adaptation strategies. This study has found a positive relationship between secondary occupation and the adoption of capital and knowledge-intensive adaptation strategies such as soil conservation, water conservation, planting vegetables and horticulture to cope with climate variability in both seasons besides consumption smoothening. The income from the other sources helps farm household to invest in new technology. The involvement in the secondary occupation also opens the different dynamics of social network which help them to explore the knowledge about the strategies and a way to implement them in practice. Livestock is usually considered as wealth for farm households and also provides key inputs like manure for the maintenance of soil fertility and ploughing services (Yirga, 2007). A household with larger livestock size is more likely to readily manage financial resources to uptake climate change adaptation (Opiyo et al., 2015). Sale of livestock and livestock products can help reduce farmers' distress from climate risks and therefore qualifies as a coping strategy (Bryan et al., 2009). In line with this literature, this study finds livestock ownership positively influencing the choice of adaptation strategies. The significant relationship has been found mainly with increasing irrigation, soil and water conservation and planting horticulture crops. On the contrary to this, animal labour is found to have a negative relationship with all adaptation strategies. Animal labour is used by farmers with weak financial capability and unaffordability of farm mechanization even partially. It is challenging for them to manage highly technologically intensive practices with animal labour. Farm-size is a critical factor determining the feasibility and efficiency of adaptation strategies.

Table 5
Logistic Regression Model of Households Characteristics- Adaptation-Rabi- Temperature(White colour row)/Rainfall(Grey colour row)..

Variable Name		Crop Variety	Change Land	Increase Irrigation	Soil conservation	Water Conservation	Buy Insurance	Migrate Urban Area	Farm to non-Farm	Lease Land	Horticulture	Vegetables
Age	TEMP.	0.012 (0.405)	0.026 (0.095)*	0.012 (0.504)	-0.015 (0.025)**	-0.115 (0.006)***	-0.223 (0.036)**	-0.044 (0.003)***	-0.535 (0.032)**	-0.031 (0.169)	-0.226 (0.046)**	-0.005 (0.015)**
	PREC.	0.009 (0.502)	0.031 (0.053)*	0.007 (0.682)	-0.006 (0.010)**	-0.110 (0.005)***	-0.183 (0.032)***	-0.060 (0.000)***	-0.513 (0.035)**	-0.027 (0.224)	0.332 (0.040)**	-0.006 (0.011)**
Gender	TEMP.	0.255 (0.390)	0.685 (0.023)**	1.741 (0.001)**	0.986 (0.041)**	0.152 (0.084)*	0.750 (0.030)**	0.251 (0.007)**	0.495 (0.389)	2.873 (0.069)*	0.752 (0.046)**	0.025 (0.035)**
	PREC.	0.324 (0.274)	0.526 (0.077)*	1.096 (0.013)**	1.135 (0.070)*	0.187 (0.088)*	0.665 (0.053)*	0.041 (0.003)**	0.555 (0.333)	3.297 (0.050)**	0.113 (0.041)**	0.006 (0.033)**
Marital Status	TEMP.	-0.466 (0.689)	-0.471 (0.607)	0.410 (0.753)	-0.357 (0.763)	2.400 (0.036)**	-1.300 (0.169)	-1.214 (0.083)*	0.269 (0.766)	-1.445 (0.130)	18.057 (0.996)	0.529 (0.495)
	PREC.	-0.609 (0.603	-0.361 (0.690)	0.140 (0.904)	-0.801 (0.506)	2.767 (0.019)**	-1.246 (0.187)	-1.271 (0.078)*	0.300 (0.742)	-1.485 (0.119)	15.056 (0.976)	0.460 (0.554)
Education	TEMP.	0.241 (0.030)**	0.171 (0.075)*	0.465 (0.016)**	2.217 (0.005)**	0.385 (0.001)**	0.428 (0.000)***	0.111 (0.007)**	0.006 (0.949)	0.164 (0.231)	0.410 (0.002)**	0.341 (0.085)*
	PREC.	0.252 (0.022)**	0.183 (0.061)*	0.428 (0.007)**	0.272 (0.045)**	0.473 (0.000)***	0.425 (0.000)***	0.098 (0.007)**	0.046 (0.642)	0.206 (0.137)	0.427 (0.003)**	0.345 (0.071)*
HH Size	TEMP.	0.186 (0.095)*	0.144 (0.075)*	0.559 (0.019)**	0.211 (0.091)*	0.133 (0.037)**	0.027 (0.813)	0.842 (0.000)***	0.094 (0.445)	0.112 (0.056)*	0.114 (0.054)*	0.090 (0.054)*
	PREC.	-0.194 (0.080)*	0.170 (0.095)*	0.272 (0.097)*	0.210 (0.024)**	0.091 (0.020)**	-0.064 (0.583)	00.77 (0.000)***	0.089 (0.465)	0.335 (0.046)**	-0.080 (0.069)*	0.110 (0.061)*
Dependency Ratio	TEMP.	0.259 (0.120)	-0.020 (0.895)	0.559 (0.224)	-0.055 (0.800)	0.200 (0.337)	-0.160 (0.347)	0.672 (0.000)***	-0.046 (0.802)	0.163 (0.015)**	0.266 (0.005)**	0.289 (0.057)**
	PREC.	0.282 (0.089)	-0.007 (0.960)	-0.229 (0.320)	0.088 (0.674)	0.134 (0.528)	-0.067 (0.706)	0.561 (0.001)**	-0.055 (0.762)	0.531 (0.039)**	0.236 (0.002)**	0.313 (0.040)**
Family Type	TEMP.	-0.098 (0.746)	0.152 (0.580)	-0.601 (0.239)	-0.178 (0.618)	0.461 (0.234)	-0.664 (0.025)**	0.414 (0.004)***	0.086 (0.793)	-0.422 (0.348)	1.408 (0.001)***	0.458 (0.003)***
	PREC.	-0.020 (0.989)	0.041 (0.882)	-0.243 (0.562)	-0.380 (0.282)	0.570 (0.151)	-0.631 (0.032)**	0.834 (0.000)***	0.309 (0.924)	-0.643 (0.182)	1.015 (0.013)**	0.340 (0.005)***
Secondary Occupation	TEMP.	-0.005 (0.994)	0.359 (0.305)	-0.802 (0.443)	1.195 (0.005)**	1.066 (0.001)***	0.387 (0.237)	0.392 (0.209)	0.537 (0.001)***	1.525 (0.725)	1.204 (0.007)***	0.635 (0.020)**
	PREC.	-0.156 (0.795)	-0.317 (0.369)	-0.895 (0.277)	1.179 (0.002)**	1.168 (0.000)***	0.461 (0.154)	0.398 (0.225)	0.564 (0.007)***	0.327 (0.941)	0.868 (0.022)**	0.685 (0.012)**
Livestock	TEMP.	0.437 (0.005)***	0.101 (0.913)	0.704 (0.008)***	0.199 (0.168)	0.273 (0.023)**	0.223 (0.069)*	0.211 (0.054)*	0.238 (0.024)**	0.223 (0.072)*	0.600 (0.000)***	0.373 (0.000)***
	PREC.	0.448 (0.003)***	0.004 (0.971)	0.653 (0.003)***	0.167 (0.190)	0.276 (0.025)**	0.140 (0.229)	0.239 (0.038)**	0.187 (0.070)*	0.124 (0.323)	0.440 (0.000)***	0.368 (0.000)***
Land Size	TEMP.	1.707 (0.014)**	0.954 (0.018)**	3.219 (0.006)***	0.827 (0.059)*	0.141 (0.437)	0.363 (0.303)	-0.476 (0.014)**	0.294 (0.089)	0.570 (0.006)***	0.627 (0.013)**	0.352 (0.115)
	PREC.	1.302 (0.049)**	1.002 (0.016)**	1.983 (0.030)**	0.087 (0.642)	0.132 (0.479)	0.322 (0.326)	-0.438 (0.042)**	0.217 (0.201)	0.547 (0.010)**	0.540 (0.016)**	0.393 (0.079)*
Marginal (0 > 1 ha.)	TEMP.	5.636 (0.028)**	3.564 (0.023)**	-3.359 (0.998)	3.727 (0.034)**	2.234 (0.020)**	1.871 (0.189)	-1.592 (0.079)*	0.470 (0.577)	1.194 (0.405)	-1.607 (0.178)	-1.115 (0.249)
	PREC.	3.934 (0.111)	3.769 (0.019)**	5.984 (0.086)*	.465 (0.605)	2.407 (0.014)**	1.598 (0.223)	-1.679 (0.103)	0.402 (0.627)	0.876 (0.554)	-1.465 (0.179)	-1.266 (0.192)
Small (1-2 ha)	TEMP.	4.923 (0.021)**	3.742 (0.004)***	-6.023 (0.996)	2.99 (0.040)**	2.325 (0.005)***	1.650 (0.166)	-1.474 (0.067)*	0.382 (0.591)	2.272 (0.016)**	-1.410 (0.157)	-1.201 (0.148)
	PREC.	3.579 (0.081)*	3.934 (0.004)***	4.348 (0.136)	2.263 (0.074)*	2.613 (0.002)***	1.535 (0.173)	-1.989 (0.029)**	0.197 (0.780)	1.755 (0.069)*	-1.327 (0.149)	-1.353 (0.104)
Medium (2-4 ha)	TEMP.	2.814 (0.063)*	2.918 (0.002)***	-9.123 (0.994)	2.076 (0.052)*	1.298 (0.035)**	0.508 (0.567)	1.095 (0.095)*	-0.030 (0.944)	1.985 (0.005)***	1.107 (0.129)	1.028 (0.106)
	PREC.	1.826 (0.211)	3.046 (0.002)***	2.183 (0.303)	0.251 (0.694)	1.456 (0.022)**	0.569 (0.501)	1.755 (0.018)**	-0.262 (0.626)	1.690 (0.019)**	1.1809 (0.082)*	1.165 (0.068)*
Large (≤ 4 ha)	TEMP.	1.255 (0.019)**	4.645 (0.000)***	16.080 (0.085)*	0.568 (0.074)*	1.298 (0.077)*	0.815 (0.006)***	0.914 (0.002)***	1.525 (0.000)***	0.886 (0.009)***	0.787 (0.008)***	0.219 (0.006)***
	PREC.	1.294 (0.016)**	4.407 (0.000)***	2.124 (0.037)**	0.271 (0.080)*	0.418 (0.035)**	0.742 (0.012)**	1.325 (0.000)***	1.516 (0.000)***	1.198 (0.000)***	1.044 (0.000)***	0.233 (0.007)***
Land Right	TEMP.	0.108 (0.699)	0.041 (0.872)	0.427 (0.337)	.0681 (0.054)*	0.938 (0.102)	0.798 (0.003)***	-0.037 (0.888)	1.288 (0.012)***	0.508 (0.531)	0.588 (0.323)	1.033 (0.000)***
	PREC.	0.096 (0.728)	0.090 (0.725)	0.552 (0.146)	0.831 (0.020)**	1.043 (0.074)*	0.839 (0.002)***	-0.206 (0.441)	1.600 (0.004)***	1.047 (0.331)	0.859 (0.158)	1.026 (0.000)***
Soil Characteristics	TEMP.	.465 (0.201)	2.070 (0.003)***	0.506 (0.284)	2.008 (0.005)***	13.730 (0.994)	2.069 (0.058)**	0.882 (0.055)*	0.362 (0.742)	13.691 (0.997)	13.343 (0.991)	2.114 (0.045)**
	PREC.	.234 (0.523)	1.728 (0.006)***	0.222 (0.602)	1.236 (0.307)	13.943 (0.995)	2.137 (0.050)**	0.547 (0.205)	0.396 (0.721)	12.814 (0.995)	13.343 (0.146)	2.004 (0.057)*
Farm Distance	TEMP.	-0.442 (0.008)***	0.091 (0.532)	-0.474 (0.056)*	-2.220 (0.024)**	-0.059 (0.672)	0.022 (0.881)	0.093 (0.485)	0.013 (0.912)	0.083 (0.564)	0.107 (0.440)	-0.719 (0.000)***
	PREC.	-0.487 (0.023)**	0.184 (0.221)	-0.580 (0.008)***	-0.162 (0.023)**	-0.065 (0.653)	0.005 (0.972)	0.086 (0.533)	0.056 (0.647)	0.139 (0.350)	0.122 (0.359)	-0.688 (0.000)***
Farm Mechanization	TEMP.	1.535 (0.164)	0.072 (0.858)	0.930 (0.003)***	4.530 (0.023)**	1.642 (0.000)***	0.615 (0.113)	0.154 (0.666)	0.359 (0.315)	0.915 (0.052)**	2.152 (0.000)***	1.136 (0.000)***
	PREC.	0.858 (0.307)	0.040 (0.920)	0.455 (0.001)***	0.080 (0.041)**	1.711 (0.000)***	0.379 (0.322)	0.140 (0.703)	0.407 (0.249)	0.357 (0.446)	1.912 (0.000)***	1.090 (0.001)**
Animal Labor	TEMP.	-1.054 (0.000)***	-1.570 (0.000)***	-1.444 (0.003)***	-1.325 (0.110)	0.173 (0.876)	-16.243 (0.977)	-1.366 (0.000)***	-0.492 (0.550)	-14.840 (0.996)	-14.484 (0.990)	-0.800 (0.000)***
	PREC.	-1.080 (0.000)***	-1.537 (0.000)***	-1.410 (0.001)***	-2.217 (0.046)	0.243 (0.827)	-16.179 (0.977)	-1.410 (0.000)***	-0.491 (0.553)	-13.515 (0.994)	-0.724 (0.509)	-0.955 (0.033)***
Family Labor	TEMP.	0.206 (0.585)	-0.024 (0.929)	2.28 (0.036)**	0.850 (0.004)***	0.939 (0.002)***	0.744 (0.005)***	-0.143 (0.580)	0.411 (0.155)	1.509 (0.002)***	1.100 (0.004)***	0.411 (0.075)*
	PREC.	0.221 (0.551)	-0.009 (0.997)	0.686 (0.223)	0.671 (0.021)**	0.989 (0.002)***	0.805 (0.002)***	-0.202 (0.441)	0.431 (0.129)	1.580 (0.002)***	1.097 (0.002)***	0.468 (0.042)**
Prob. LR stat		***0.001***	***0.000***	***0.001***	***0.001***	***0.000***	***0.000***	***0.000***	***0.001***	***0.000***	***0.001***	***0.000***
S.D. Dependent Variable		***0.581***	***0.526***	***0.544***	***0.492***	***0.515***	***0.478***	***0.401***	***0.486***	***0.570***	***0.410***	***0.500***
R^2 Count		***0.71***	***0.71***	***0.80***	***0.77***	***0.75***	***0.78***	***0.71***	***0.70***	***0.77***	***0.79***	***0.81***
McFadden R^2		***O.222***	***0.234***	***0.321***	***0.289***	***0.278***	***0.312***	***0.231***	***0.211***	***0.292***	***0.311***	***0.321***

(***P < 0.01; **p < 0.05; *p < 0.1) Source: Author's Own Calculation.

Table 6
Logistic Regression Model of Households Characteristics- Adaptation-Rabi- Temperature(White colour row)/Rainfall(Grey colour row)..

Variable Name		Crop Variety	Change Land	Increase Irrigation	Soil conservation	Water Conservation	Buy Insurance	Migrate Urban Area	Farm to non-Farm	Lease Land	Horticulture	Vegetables
Age	TEMP.	-0.001 (0.927)	-0.012 (0.283)	.0033 (0.035)**	-0.050 (0.011)**	-0.323 (0.017)**	-0.0262 (0.022)**	-0.0819 (0.000)***	-0.003 (0.018)**	-0.0258 (0.244)	-0.0314 (0.032)**	-0.003 (0.009)**
	PREC.	0.016 (0.179)	-0.014 (0.229)	0.0265 (0.034)**	-0.050 (0.012)**	-0.338 (0.033)**	-0.026 (0.021)**	-0.081 (0.000)***	-0.003 (0.019)**	-0.025 (0.258)	-0.031 (0.031)**	-0.002 (0.003)**
Gender	TEMP.	0.685 (0.008)**	0.528 (0.031)**	0.991 (0.005)**	0.607 (0.021)**	0.394 (0.040)**	0.579 (0.029)**	0.890 (0.009)**	0.572 (0.041)**	3.162 (0.058)*	0.677 (0.011)**	0.268 (0.091)*
	PREC.	0.332 (0.021)**	0.570 (0.041)**	0.641 (0.052)*	0.747 (0.013)**	0.346 (0.059)*	0.776 (0.023)*8	0.890 (0.009)**	0.454 (0.028)**	3.225 (0.055)*	0.677 (0.011)**	0.288 (0.052)*
Marital Status	TEMP.	1.096 (0.113)	-0.087 (0.887)	-1.034 (0.265)	0.880 (0.397)	2.381 (0.038)**	-1.393 (0.135)	1.614 (0.135)	0.194 (0.829)	-1.426 (0.129)	7.791 (0.000)***	0.343 (0.659)
	PREC.	1.764 (0.042)	0.812 (0.288)	-1.157 (0.214)	1.156 (0.295)	2.479 (0.030)**	-1.435 (0.125)	1.614 (0.135)	0.235 (0.795)	-1.518 (0.106)	7.791 (0.000)***	0.314 (0.686)
Education	TEMP.	0.135 (0.000)***	0.056 (0.059)*	0.260 (0.000)***	0.211 (0.001)**	0.452 (0.000)***	0.294 (0.000)***	0.025 (0.060)*	0.004 (0.917)	0.085 (0.248)	0.115 (0.059)*	0.111 (0.007)**
	PREC.	0.115 (0.001)**	0.105 (0.002)	0.255 (0.000)***	0.217 (0.000)***	0.467 (0.000)***	0.304 (0.000)***	0.025 (0.060)*	0.001 (0.969)	0.080 (0.283)	0.115 (0.059)*	0.113 (0.009)**
HH Size	TEMP.	0.029 (0.726)	0.183 (0.027)**	0.304 (0.008)**	0.484 (0.001)**	0.412 (0.009)**	0.024 (0.034)**	0.957 (0.000)***	0.092 (0.451)	0.339 (0.043)**	1.109 (0.005)***	0.117 (0.033)**
	PREC.	0.038 (0.657)	0.058 (0.505)	0.298 (0.008)**	0.317 (0.037)**	0.433 (0.007)**	0.111 (0.024)*	0.957 (0.000)***	0.104 (0.400)	0.351 (0.037)**	1.109 (0.005)***	0.114 (0.042)**
Dependency Ratio	TEMP.	0.149 (0.244)	0.192 (0.120)	0.302 (0.071)*	0.611 (0.004)**	0.0806 (0.702)	0.129 (0.463)	0.550 (0.004)**	-0.055 (0.763)	0.567 (0.027)**	0.248 (0.000)**	0.283 (0.064)**
	PREC.	-0.063 (0.630)	0.084 (0.528)	0.281 (0.087)*	0.357 (0.110)	0.001 (0.994)	0.176 (0.321)	0.550 (0.004)**	.056 (0.761)	0.592 (0.003)**	0.248 (0.000)**	0.266 (0.044)**
Family Type	TEMP.	0.515 (0.027)	0.335 (0.126)	-0.587 (0.071)*	1.099 (0.010)**	0.297 (0.450)	-0.510 (0.076)*	0.103 (0.000)***	0.017 (0.958)	-0.707 (0.009)***	1.402 (0.001)***	0.208 (0.001)***
	PREC.	0.170 (0.464)	0.119 (0.611)	-0.799 (0.013)**	1.066 (0.012)**	0.232 (0.556)	-0.588 (0.045)**	0.103 (0.000)***	0.144 (0.664)	-0.778 (0.019)**	1.402 (0.001)***	0.235 (0.003)***
Secondary Occupation	TEMP.	0.355 (0.155)	0.233 (0.354)	-0.609 (0.116)	0.185 (0.001)***	0.648 (0.048)**	0.388 (0.225)	0.152 (0.658)	0.471 (0.135)	0.167 (0.702)	0.670 (0.079)*	0.525 (0.048)**
	PREC.	0.010 (0.967)	-0.115 (0.648)	-0.577 (0.132)	1.153 (0.003)***	0.640 (0.051)*	0.252 (0.437)	0.152 (0.658)	0.527 (0.098)*	0.318 (0.437)	0.670 (0.079)*	0.536 (0.040)**
Livestock	TEMP.	0.272 (0.004)***	0.194 (0.030)**	0.483 (0.000) ***	0.439 (0.000)***	0.338 (0.007)***	0.154 (0.202)	0.161 (0.205)	0.221 (0.033)**	0.092 (0.456)	0.569 (0.000)***	0.446 (0.000)***
	PREC.	0.338 (0.000)***	0.124 (0.149)	0.447 (0.001)***	0.422 (0.001)***	0.347 (0.006)***	0.169 (0.164)	0.161 (0.205)	0.228 (0.029)**	0.098 (0.429)	0.569 (0.000)***	0.448 (0.040)*
Land Size	TEMP.	0.210 (0.188)	0.020 (0.912)	-0.221 (0.224)	0.163 (0.322)	0.027 (0.877)	0.225 (0.458)	0.084 (0.737)	0.277 (0.107)	0.582 (0.006)***	0.607 (0.012)**	0.532 (0.024)**
	PREC.	0.141 (0.310)	0.188 (0.200)	-0.219 (0.217)	0.193 (0.334)	0.068 (0.699)	0.338 (0.314)	0.084 (0.737)	0.279 (0.103)	0.595 (0.005)***	0.607 (0.012)**	0.490 (0.037)**
Marginal (0 > 1 ha.)	TEMP.	0.680 (0.350)	0.482 (0.543)	-1.053 (0.241)	1.332 (0.183)	2.812 (0.003)**	1.264 (0.315)	-0.313 (0.792)	-0.589 (0.482)	-1.090 (0.376)	-1.791 (0.120)	-1.912 (0.061)*
	PREC.	-0.107 (0.870)	0.380 (0.580)	-0.388 (0.653)	1.160 (0.304)	3.205 (0.001)***	1.837 (0.178)	-0.313 (0.792)	-0.392 (0.641)	-0.595 (0.436)	-1.791 (0.120)	-1.691 (0.095)*
Small (1-2 ha)	TEMP.	.0741 (0.245)	.0581 (0.943)	0.064 (0.937)	2.046 (0.016)**	2.140 (0.009) ***	1.337 (0.209)	0.040 (0.968)	-0.288 (0.686)	-2.123 (0.025)**	-1.648 (0.088)*	-1.849 (0.031)**
	PREC.	0.137 (0.812)	0.324 (0.588)	0.406 (0.605)	2.346 (0.012)**	2.538 (0.002)***	1.596 (0.164)	0.040 (0.968)	-0.299 (0.674)	-2.133 (0.026)**	-1.648 (0.088)*	-1.709 (0.048)**
Medium (2-4 ha)	TEMP.	0.239 (0.639)	0.229 (0.668)	-1.114 (0.100)	1.440 (0.032)**	1.315 (0.035)**	0.266 (0.741)	0.183 (0.822)	0.139 (0.798)	1.699 (0.017)**	1.193 (0.093)*	1.558 (0.019)**
	PREC.	0.0817 (0.860)	0.322 (0.498)	-0.780 (0.231)	1.655 (0.023)**	1.667 (0.009)***	0.401 (0.640)	0.183 (0.822)	0.152 (0.779)	1.657 (0.021)**	1.193 (0.093)*	1.442 (0.029)**
Large (≤ 4 ha)	TEMP.	1.124 (0.000)***	0.685 (0.004)***	-1.863 (0.000)***	1.440 (0.002)***	1.097 (0.000)***	1.390 (0.000)***	1.202 (0.000)***	1.897 (0.000)***	1.783 (0.000)***	1.177 (0.000)***	0.706 (0.002)***
	PREC.	0.891 (0.000)***	0.966 (0.000)***	0.761 (0.015)***	1.156 (0.000)***	0.994 (0.000)***	1.417 (0.000)***	1.202 (0.000)***	1.933 (0.000)***	1.816 (0.000)***	1.177 (0.000)***	0.690 (0.000)***
Land Right	TEMP.	0.359 (0.110)	-0.051 (0.807)	-0.635 (0.035)**	0.959 (0.107)	0.756 (0.141)	0.899 (0.001)***	-0.030 (0.916)	1.620 (0.004)***	1.168 (0.279)	0.683 (0.265)	0.967 (0.000)***
	PREC.	-0.148 (0.527)	-0.021 (0.929)	-0.249 (0.386)	0.723 (0.201)	0.746 (0.148)	0.839 (0.002)***	-0.030 (0.916)	1.544 (0.006)***	1.147 (0.289)	0.683 (0.265)	1.047 (0.000)***
Soil Characteristics	TEMP.	1.260 (0.023)**	1.202 (0.003)***	1.446 (0.001)***	13.268 (0.988)	13.010 (0.991)	2.032 (0.061)*	1.169 (0.020)**	0.477 (0.663)	12.360 (0.994)	13.819 (0.992)	1.874 (0.073)*
	PREC.	1.678 (0.025)**	1.132 (0.003)***	1.435 (0.001)***	12.780 (0.984)	13.722 (0.955)	2.067 (0.057)*	1.169 (0.020)**	0.385 (0.726)	12.293 (0.994)	13.819 (0.992)	1.975 (0.059)*
Farm Distance	TEMP.	-0.205 (0.044)**	0.194 (0.066)*	-0.423 (0.002)**	-0.287 (0.027)**	-0.009 (0.947)	-0.009 (0.945)	-0.037 (0.808)	0.037 (0.756)	0.104 (0.478)	0.126 (0.351)	-0.711 (0.000)***
	PREC.	-0.151 (0.125)	0.006 (0.947)	-0.398 (0.003)**	-0.580 (0.000)***	-0.009 (0.947)	-0.014 (0.918)	-0.037 (0.808)	0.022 (0.855)	0.097 (0.509)	0.126 (0.351)	-0.722 (0.000)***
Farm Mechanization	TEMP.	0.702 (0.020)**	0.235 (0.427)	0.189 (0.001)***	0.498 (0.024)**	1.724 (0.000)***	0.516 (0.174)	0.320 (0.403)	0.271 (0.446)	0.595 (0.212)	1.772 (0.000)***	1.149 (0.000)***
	PREC.	-0.703 (0.018)**	-0.262 (0.368)	0.184 (0.002)***	0.477 (0.047)**	1.496 (0.000)***	0.562 (0.144)	0.320 (0.403)	0.281 (0.432)	0.503 (0.297)	1.772 (0.000)***	1.14 (0.000)***
Animal Labor	TEMP.	-0.642 (0.050)*	-0.814 (0.004)***	-1.416 (0.000)***	-0.450 (0.686)	-0.075 (0.945)	-17.409 (0.988)	-1.490 (0.000)***	-0.586 (0.471)	1.783 (0.992)	-14.927 (0.992)	-1.304 (0.007)***
	PREC.	-0.304 (0.373)	-0.238 (0.501)	-1.041 (0.002)***	0.444 (0.614)	-0.049 (0.964)	-17.531 (0.988)	-1.498 (0.000)***	-.478 (0.558)	-13.192 (0.992)	-14.927 (0.992)	-1.154 (0.012)**
Family Labor	TEMP.	0.689 (0.001)***	0.148 (0.480)	0.851 (0.009)***	0.469 (0.159)	1.036 (0.001)***	0.883 (0.001)***	0.623 (0.033)**	0.372 (0.191)	1.585 (0.002)***	1.147 (0.002)***	.488 (0.032)**
	PREC.	1.015 (0.000)***	1.071 (0.000)***	0.719 (0.024)**	0.658 (0.053)*	1.235 (0.000)***	0.934 (0.000)***	-1.498 (0.000)***	0.436 (0.130)	1.545 (0.002)***	1.147 (0.002)***	0.461 (0.043)**
Prob. LR stat		***0.001****	***0.000****	***0.001****	***0.000****	***0.000****	***0.001***	***0.000***	***0.001****	***0.001***	***0.001***	***0.000****
S.D. Dependent Variable		***0.579***	***0.519***	***0.551***	***0.501***	***0.500***	***0.488***	***0.416***	***0.481***	***0.566***	***0.421***	***0.490***
R^2 Count		***0.72***	***0.72***	***0.84***	***0.80***	***0.78***	***0.81***	***0.72***	***0.72***	***0.75***	***0.81***	***0.82***
McFadden R^2		***0.228***	***0.229***	***0.320***	***0.294***	***0.272***	***0.316***	***0.229***	***0.216***	***0.281***	***0.312***	***0.324***

(***P < 0.01; **p < 0.05; *p < 0.1) Source: Author's Own Calculation.

Farm-size can be considered as a wealth indicator (Deressa et al., 2009), and therefore, larger farm-size may help ease liquidity constraint. On the contrary, to the previous studies (Nhemachena and Hassan, 2008; Bryan et al., 2009; Gbetibouo 2009), this study has found a positive relationship between farm-sizes and adaptation strategies, particularly between on-farm adaptation and financial diversification strategies which increase farm productivity. In the study area, most of the farmers belong to marginal (0 > 1 ha) and small (1–2 ha) farm-size groups. Migration to urban areas for other opportunities has a positive relation with marginal and small land size-groups. The remittance from the urban areas helped farmers to adopt modern agricultural technology in the fields and for the consumption of their large family sizes. The farmers with large land-size also found to have positive and significant relation with most of the adaptation strategies in both seasons. It is more likely that large farm holding farmers are more prepared and capable of adopting adaptation strategies like crop-diversification, irrigation management, and soil and water conservation approaches. Although large farm-sizes can give lower yields due to proportionately lesser use of other required inputs other than land at an initial stage, in the long-run economies of scale lowers the substantial fixed transaction costs of innovation. Large family-size owning small farms may often experience conflicts in households for ownership rights, which may affect individual decision making. Although this study does not find any strong relation between adaptation strategies and land rights, well-defined property rights can promote farm-level adaptation. The ownership of land increases the likelihood of adaptation of capital intensive strategies such as conservation technologies. The study also found the more likelihood of changing land from farm to non-farm because of the right to decide on the farm. The soil characteristics are found to have a significant relationship in the case of changing land for cultivation, soil conservation, and planting vegetables in both seasons. Reversely, land rotation and soil conservation strategies helping them to increase the fertility of the land and high productivity of the land motivate them to implement agricultural practices. This study has not found a strong relationship between adaptation strategies and farm distance but found farm distance negatively related to some on-farm strategies such as crop varieties, land rotation and soil conservation practices. The land near the house eases the implementation of these strategies. The farm distance is also negatively significant in planting vegetables in both seasons. The farmers plant vegetables in the home stated area because it is easy to provide frequent planting requirements of vegetables. Farm mechanization often promotes undertaking on-farm adaptation strategies that are technology-intensive. The ownership of the farm machines helps farmers in the smooth implementation of conservation practices. On the contrary to this, animal labour is found to have a negative relationship with all adaptation strategies. The family labour (two or more than two family labour) is found to have a significant positive relationship with labour-intensive adaptation strategies such as soil conservation, water conservation, horticulture, and vegetables in both seasons. The large family-size is associated with a higher labour endowment, which enables a household to accomplish various agricultural activities. The adoption of agricultural technologies requires financial wellbeing (Knowler and Bradshaw, 2007).

4. Conclusion

The study aimed to evaluate how farmers' perception of climate change affects their adaptation decisions based on a micro-level assessment of farm households through analysis of survey data collected from seven districts of Bihar state in northern India. Identifying the differences in farmers' farming activities across farming seasons, the study distinguishes between seasonal adaptation. The study results provide useful insight on the importance of farmers' perceptions of climate change determined by their past experiences on changes in climate variables and extreme events, and socio-economic characteristics of farm households like age, education, gender, household size, and land size. Enabling arrangements of these factors together encourage the commencement and implementation of adaptation decisions by farmers in the study region. Farmer's perception of climate change was analysed based on their long-term observations of climate variables like temperature and precipitation levels and the number of hot and cold days. The findings of the study very well validate the fact that farmers' perception of changes in temperature and precipitation levels and their personal experiences with previous climate extremes like floods and drought are the key catalysts of their adaptation actions. Further, the study results identify that strong mental recognition of the farmers enhances their understanding of the nuances of climate change. As far as choices of adaptation strategies are concerned, the study results find that most of the farmers adopt strategies related to altering farm practices, strategies enabling income diversification and those related to institutional support. Among all the analysed adaptation strategies, the study finds that migrating farm-households are better placed in adopting multiple adaptation strategies and are more capable of adopting adaptation strategies that are knowledge, capital and resource-intensive. Since the majority of farmers are marginalized and smallholders in the study region and India, income guarantee can be an effective measure to offer farmers a sense of security by helping them meet a part of their consumption and expenditure needs. In this direction, this study recommends complementing farm-level adaptation options with the provision of non-climate sensitive local livelihood opportunities for income guarantee. The study also identifies the importance of socio-economic characteristics of farm households in farmers' adaptation. Therefore, policies need to encourage and strengthen social networks through group-based adaptation approaches. Policy entry points should focus on maintaining robust linkages between climate risk reduction and capacity building through community participation and institutional development. The farming activities in the study area is a primary occupation but considerably a very complex system due to the resource availability and climatic condition. The outcome of this study provides the systematic framework to assess the farmer's perception of climate change and the factor determine the adaptation decision. This frame can be used to study the farmer's behaviour at the different local, regional and global level to minimise the impact of climate change.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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