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Determinants in the Adoption of Climate Change Adaptation Strategies: Evidence from Wheat Farmers in Bundelkhand Region, India

Surandra Singh Jatav and Sanatan Nayak

ABSTRACT

By using systematically collected field survey data of 200 farmers and binary logistic regression, results of this study reveals that wheat farmers of Bundelkhand, Uttar Pradesh, India are well-aware of changing climate and adjusting their farm practices to enhance climate resilience capacity. Farmers use their indigenous knowledge coupled with extension services provided by the government to diversify their occupation and cropping pattern as adaptation strategies. The Binary logistic regression results show that information on climate, access to institutional credit and having crop insurance motivate farmers to improved irrigation facilities. Further, farmers perceive that increase in temperature, decline in rainfall and water tables jointly change cropping pattern from the high water-intensive crop (wheat) to low water-intensive crop (chickpea) as a climate adaptation strategy. The study suggests developing a common platform for government services for the region. Community participation and regular training programmes in the sample villages are benefiting farmers to channelize their indigenous knowledge and optimize local resources, which leads to sustainable farming.

Keywords: *Farmers Perception; Climate Adaptation; Rainfed Agriculture; Bundelkhand Region*

INTRODUCTION

Climate change poses a serious socio-ecological challenge for marginal wheat farmers in India in recent decades (Singh, 2020a). The agricultural sector in general and marginal farmers in particular are believed to be adversely affected by changing in climate (Singh and Sanatan, 2014). Rapid land degradation, frequent and extreme droughts are significant manifestations of climate change leading to productivity losses in rainfed regions like Bundelkhand in Uttar Pradesh (Singh 2020b). Appropriate weather conditions are still important to improve agricultural productivity, despite major technical developments (Singh and Sanatan, 2018; Singh, 2019). The main influences deciding crop yields include temperature and rainfall. Because of the changing climate conditions

Department of Economics, Babasaheb Bhimrao Ambedkar University, Lucknow, India.

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with different intensities in the world, wheat farming is under serious pressure (Sanghi and Mendelsohn, 2008). However, shifting climate patterns have a severe impact on crop farming in developed and low income countries, leading to a sharp drop in crop yields (Singh and Sanatan, 2021). Climate change affects rural subsistence in developed countries and increases the insecurity of agricultural populations. While farmers have used the recommended amounts of input and crop management strategy, variation in seasonal temperatures and stress have adversely affected the crop yield and, in particular, the yield of wheat (Singh and Sanatan, 2021). Efforts to tackle the negative effects of climate change, especially on small farmers and agriculture in general, are therefore essential. Most modelling and observational studies have shown that climate change affects more likely to rainfed farmers (Singh 2020a, b & c).

Farmers have always faced multiple risks, for example, in India, major concerns for farmers included variability in climate and lack of access to modern technology and correct & updated timely weather information (Singh and Sanatan, 2020). Regional surveys have shown that Bundelkhand is highly vulnerable to climate change (Singh 2020a, b & c; GoI 2008). Bundelkhand region is highly susceptible to drought, is one of the least developed socio-economic region of India. Increasing demand for natural resources and harsh and deteriorating biophysical conditions such as low soil productivity and more regular extreme events such as temperature variation and intensify droughts have increased the degree of climate vulnerability in the region. For example, in the Bundelkhand region, crop productivity is 1.4 times lower than in other area of Central India (Singh, 2020a).

Consequently, adaptation to climate change has been a core and well-known feature of regional climate and science policies over the last twenty years (IPCC 2014; Panda 2016). Most updated research has believed that adaptation to reduce the adverse impacts of climate change is the most successful approach (Singh, 2020 a & b; Singh and Sanatan, 2021; Jatav et al., 2022). By adjusting environmental and socioeconomic conditions, farmers will maintain food, employment and livelihood stability. Adaptation is also used to reduce complications posed by such risks or potential risks, such as climate change or adverse weather conditions (IPCC 2001). Given the frequent geographical impacts of climate change, it is critical that broad-based climate change adaptation programs supporting smallholder farmers take local needs into account and incorporate learning from recent autonomous and projected adaptation efforts.

In view of the above, this paper aims at identifying the determinants which influence and motivate farmers to adopt a rational climate-smart adaptation strategy. The paper has addressed the following key questions: (i) what are the major climate adaptation strategies adopted by the farmers, (ii) how a farmer decides to choose a rational adaptation strategy, and (iii) what are the socioeconomic and biophysical determinants that influence and motivate farmers to adopt a rational adaptation strategy.

METHODOLOGY

The present study was conducted in Bundelkhand region of Uttar Pradesh, India. Region lies between the Yamuna River and Northern scarp of the Vindhyan plains of Uttar Pradesh state. Wheat is the most important food crop in Bundelkhand region. Its economic activities are related to production, processing, distribution, and consumption, which is widely considered a key for economic development, food security, and poverty reduction.

An extensive field survey was conducted to extract information on farmers' perception of climate change and the key determinants (i.e., land size, age, gender, education, access to institutional credit and crop insurance). Field survey was conducted in April- May 2017 during harvesting time of Rabi season. Multistage sampling technique was opted for the sample selection. In first step, two districts, viz., Jhansi and Jalaun out of seven districts were randomly chosen. In second step, one development Block from each district was chosen purposely. In third step, 2 villages from each development Block were chosen purposely. In fourth step, probability proportional size (PPS) approach was adopted for the selection of households. Thus, 2 districts, 2 development Blocks, 4 villages and 200 samples were selected for the study.

Binary Logistic Regression (BLR) model was adopted for identifying the key determinants of climate change adaptation in the sample farmers (Singh, 20202a; Jatav et al., 2021). BLR model was separately used for Jhansi and Jalaun districts to capture regional heterogeneity in the region. The logistic distribution function for the decision on adopting adaptation measures to climate change can be specified as:

$$Logit\ (P) = \log\left(\frac{P}{1-P}\right) \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Let $P_i = P_r\left(\frac{Y=1}{X=x_i}\right)$, then the model can be written as...............(2)

$$P_r\left(y = \frac{1}{x_i}\right) = \frac{exp^{x'b}}{1+e^{x'b}}; = \log\left(\frac{P}{1-P}\right) =$$

$$\text{Logit}(P_i) = \beta_0 + \beta_i X_i \text{..........(3)}$$

Where; P_i is a probability of deciding to adopt adaptation strategies (dependent variable), X_i's are independent variables, β_0 is the intercept and β_i is the regression coefficient of respective variables.

We can write the model in terms of odds as;

$$\frac{P_i}{(1-P_i)} = \exp\ (\beta_0 + \beta_1 X_i \ldots\ldots\ldots\ldots. (4)$$

The dependent variable (adaptation strategy) is binary, with values as 1 for farmers using at least one of the identified climate adaptation strategies (Table 1) and 0 for farmers using none of the strategies mentioned. This was done to differentiate farmers between who adapted and farmers who did not adapted. One of the farmer's adaptation techniques, including crop pattern change, improved irrigation facilities, and the use of early matured seed varieties, have identified to climate change. The hypothesized independent variables affecting the development of adaptation strategies by farmers include the cumulative impact of different factors such as geographical, socio-economic characteristics and extended resources for farmers. Based on previous research on adaptation strategies (Singh, 2020a & b; IPCC, 2014; Panda, 2016), the present study finds the following explanatory variables and analyzed their effect on farmers adopting climate change adjustment strategies (Table 1).

Table 1. Description of the Dependent and Explanatory Variables

Dependent Variables	**Description**
Cropping pattern change	Categorical (Yes= 1, No= 0)
Improved irrigation facilities	Categorical (Yes= 1, No= 0)
Use of early matured varieties	Categorical (Yes= 1, No= 0)
Explanatory Variables	
Education	Categorical (Below secondary = 0, above =1)
Farmer perceived rainfall was declined	Categorical (Yes = 1, No = 0)
Farmer perceived temperature was increased	Categorical (Yes = 1, No = 0)
Land size	Continuous (in acre)
Farmer has access to institutional credit	Categorical (Yes = 1, No = 0)
Farmer has access to climate information regularly	Categorical (Yes = 1, No = 0)
Farmer has insured their crop through weather-based crop insurance	Categorical (Yes = 1, No = 0)
Participation in Training Programme	Categorical (Yes = 1, No = 0)

FINDINGS AND DISCUSSION

Socio-economic Characteristics of the Surveyed Households

In comparison with those at national level, the socio- economic characteristics of the households represent the region's backwardness. The literacy rate in Jalaun and Jhansi is slightly less than the national average, i.e., 50.24 percent & 49.76 percent (Table 2). In addition, the household's average annual income is also modest and varies. The averages of land in both districts are also smaller than in the country (0.26 and 0.35 hectares) (1.18 ha). Almost 15 percent of the people belong to the planned divisions of castes and planned tribes in India.

In addition, 35 percent of Jalaun's households and 20 percent of Jhansi's households do not have electricity connection. Almost 50 percent & 40 percent of the population of the samples have no sanitary and drinking facilities within the household. Almost 30 percent of the population lives in extreme poverty. In totality, the findings demonstrate that most

Table 2. Socio-economic Characteristics of Surveyed Farm Households

Sl.No.	Household Socioeconomic Characteristics	Jalaun	Jhansi	India
1	Female (%)	44.74	44.18	48.00
2	Literate population (%)	50.24	49.76	74.01
3	Mean Income (US $)	334	374	2198
4	Mean land size (Acre)	0.26	0.35	1.18
5	Mean age of the head of household (Years)	31.36	30.04	29.00
6	Share of Scheduled caste population (%)	13.82	7.81	16.60
7	Share of Scheduled tribe population (%)	2.80	5.10	8.60
8	Share of Hindu Religion (%)	84.21	84.37	79.80
9	Marital Status (%)	52.39	53.32	45.60
10	Households having electricity connection (%)	65.00	80.00	89.70
11	Households having sanitation facility (%)	57.00	51.00	51.77
12	Households using improved drinking water facility (%)	61.00	60.00	99.14
13	Households below poverty line (%)	29.00	26.00	23.60

Source: Field Survey Data, 2017 & Census, 2011. Note: One US$= 69.49 Indian Rupees (INR).

Farmers' Perception on Climate Change

Figure 1 depicts that farmers are well aware of the changing climatic conditions. About 70 percent in Jalaun and 64 percent in Jhansi, farmers perceived that rainfall distribution had declined over the last five years. Likewise, <90 percent of farmers in both districts perceived that the summer season had become relatively hotter in recent years compared with last decade. Further, about 88 percent of farmers in Jalaun and 98 percent of farmers in Jhansi perceived that the frequency of heat-waves had been increased, which was a major factor for mortality in the summer season. < 90 percent of farmers perceived that the water table in the sample villages had been drastically declined due to less rainfall and higher water consumption. Therefore, farmers are digging more and deeper tube-wells to meet water demand for agriculture and domestic purposes. In totality, increase in temperature and decline in rainfall putting stress on the marginalized farming community.

The present study's findings are in the same direction of Hansen et al (2004) and Bryan et al (2009). These studies have pointed out that farmers' perception of climate change depends on their recent and past experiences. Our results are also in the line with Indian Meteorological Department temperature record for the Bundelkhand region, which suggests a significant increase in annual temperature by about 0.01^{0}C per year during 1951 to 2017. In the case of rainfall, the actual annual rainfall trend during 1951-2017 showed a decline of 1.41 millimetre per year. The summer and winter rainfall also show sharp decline annually of about -0.59 millimetre and about -0.06 millimetre respectively.

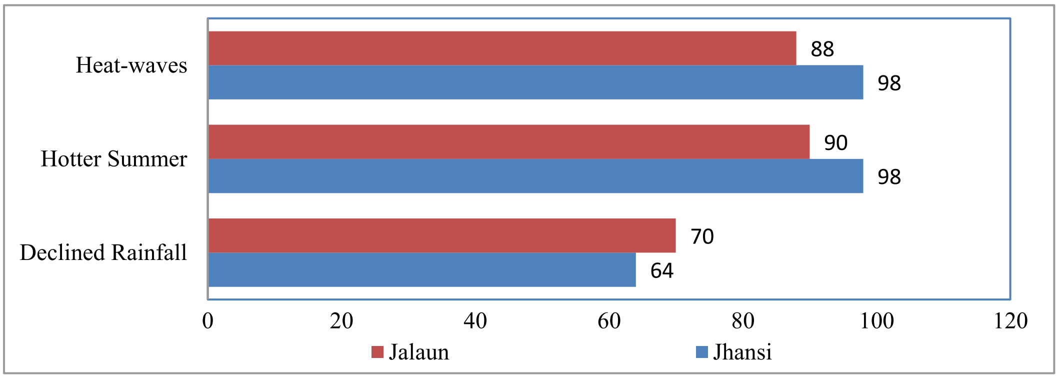

Figure. 1. Farmers perception on Climate Change

Adaptation Strategies adopted by Surveyed Farmers

Figure 2 reflects that farmers have adopted differential adaptation strategies on cropping pattern change from water intensive crop (wheat) to low water intensive crop (chickpea) in Rabi season. In this connection, statistics reveals that about 82 percent of farmers in Jhansi and about 72 percent of farmers in Jalaun have changed their cropping pattern. Further, by utilising natural resource management techniques and expert advice provided by local agriculture officers, about 62 percent of farmers in Jhansi and 52 percent of farmers in Jalaun have improved their irrigation facilities to get regular and assured water whenever required for irrigation. As Bundelkhand is a dry region, farmers have used sprinklers for efficient use of water. Moreover, about 72 percent of farmers in Jhansi and 52 percent of farmers in Jalaun have used Early Maturing Seed Varieties (EMSV) to cope with changing climate. EMSV are very useful to have climate resilience practices. They have required less water, time and inputs compared with traditional seed varieties. Surveyed farmers are growing EMSV such as UP 2382, which get ready in 109 days for harvesting. Per hectare production (5545 kg/ha) is also relatively higher as they are specially designed for dry regions, like Bundelkhand region.

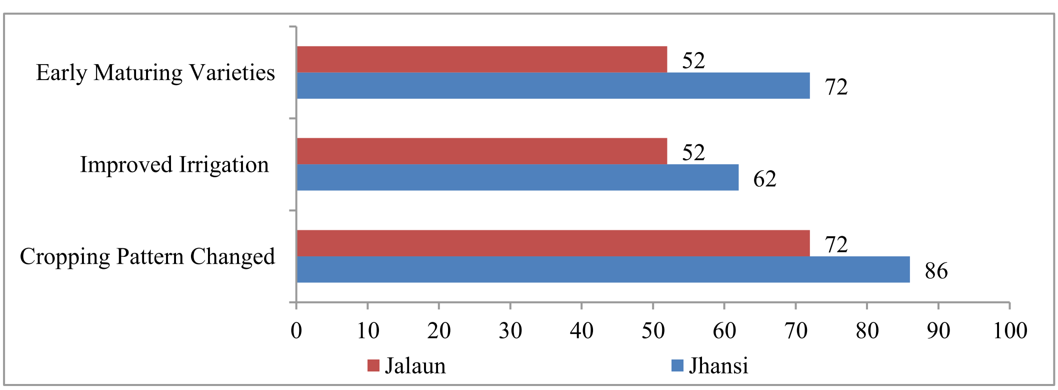

Figure. 2 Adaptation Strategies of Farmers

Determinants of Climate Adaptation Strategies

The Binary Logistic Regression (BLR) model results help in identifying the determinants of climate adaptation strategies namely cropping pattern change, improved irrigation and early maturing varieties (Table 3). The study has used BLR model at district-level to capture regional dimensions of climate change adaptation. Results depict that decrease in rainfall motivated farmers to change their cropping pattern, while restricted to use early maturing varieties and improve irrigation in Jhansi district and on the other hand, rainfall has positively associated with identify adaptation strategies in Jalaun district (Table 3). Whereas, temperature, education, land size, participation in agricultural training programmes, access of agricultural credit, information of climate, and crop insurance are positively associated with the identifying adaptation strategies in both the districts.

The calculated odds ratio shows that there is 2.54 times higher probability to change their cropping pattern in favour of low water-intensive crops (i.e., chickpea) from high water-intensive crops (i.e., wheat), if farmers perceived that rainfall will decline in Jhansi district. On the other hand, there is 3.24, 2.64 & 1.58 times higher probability to change cropping pattern, use of early maturing varieties and will improve irrigation respectively, if farmers perceive that rainfall will decline in Jalaun district. Further, there is 3 times higher probability to adopt recommended adaptation strategies (early maturing seed variety), if farmers perceive that temperature will be increased in the near future in Jhansi district and on the other hand, there is less likelihood to adopt recommended strategies in Jalaun district compared with Jhansi district. Education is a vital indicator in the climate change adaptation strategy. It is expected that educated farmers are more likely to adopt recommended strategies. Results from table 3 revealed that there is 2.51 & 3.64 times higher probability to change cropping pattern and use of early maturing variety, if farmers having education-level above from secondary level in Jhansi district and on the other hand, there is 1.62, 2.64 & 3.24 times higher probability to change cropping pattern, use of early maturing varieties and improved irrigation, if farmers having education-level above from secondary-level in Jalaun district. The odds ratios of land size depicts that there is 3.24, 2.64 & 4.32 times higher probability to adopt recommended adaptation strategies, if farmers having higher land size in Jhansi district and on the other hand, odd ratio shows that relatively less likelihoods to implement adaptation strategies in Jalaun district compare to Jhansi district.

The extension services depict that farmers who participated in the agriculture development programme are relatively more likely to adopt recommended adaptation strategies in Jhansi compared to Jalaun. There is 4.26, 2.34 & 3.24 times higher probability to adopt recommended strategies in Jhansi, while the corresponding figures are only 2.45 & 3.54 for Jalaun.

Further, odd ratio of access to institutional credit reveals that farmers those are availing credit from institutional sources are more likely (3.24 times higher) improved their irrigation system in Jhansi, while corresponding figures for Jalaun is relatively higher than that of Jhansi. Likewise, odd ratio of information on climate depicts that farmers having information of changing climate, there is 1.59 & 2.64 times higher probability to use early maturing varieties and improved irrigation in Jhansi and on the other hand, there is 3.64, 3.59 & 1.64 times higher probability for adaptation strategies in Jalaun. Lastly, the odd ratio of crop insurance shows that there is 4.95, 3.59 & 2.44 times higher probability for identifying adaptation strategies in Jhansi, while there is 4.24, 3.29 & 3.82 times higher probability to adopt in Jalaun. In totality, the likelihood analysis (odd ratio) reveals that farmers belonging to the Jalaun are having higher likelihood for identifying adaptation strategies compared to Jhansi.

The results are in the same line of Maddision's (2006). These studies suggested that educated farmers have more knowledge and information about climate change and agronomic practices that they can use of. More specifically households with larger farm size and family head having higher educational attainment are more likely to adopt identified adaptation strategies.

While institutional credit and weather-based crop insurance protect them from the adverse impacts of calamities. Microfinance can reduce vulnerability through ex-ante risk reduction via livelihood diversification, ex-post risk mitigation via savings and insurance, and finally risk coping via credit. In the absence of insurance, farmers have to rely on coping mechanisms such as withdrawing savings, accessing loans selling assets, or reducing expenditure (Felton et al., 2015). Risk-averse farmers that can't use these ex-post coping mechanisms have been found to sacrifice total income for income stability. Further, Pierro and Desai (2008) found the weather-based insurance using physical triggers as proxy mechanisms have been more successful than traditional crop insurance in reducing transaction costs, pay-out times, disputes, and asymmetric information problem.

Table 3. Determinants of Adaptation Strategies

Sl.No.	Independent Variables	Jhansi			Jalaun		
		Cropping pattern change	Early maturing varieties	Improved irrigation	Cropping pattern change	Early maturing varieties	Improved irrigation
1	Rainfall	0.482* (2.54)	-0.265* (0.84)	-0.632* (0.64)	0.621* (3.24)	0.325* (2.64)	0.531* (1.58)
2	Temperature	0.125* (3.28)	0.632* (2.54)	0.745* (3.25)	0.138* (2.88)	0.262* (1.54)	0.145* (1.25)
3	Education	0.045* (2.51)	0.038** (3.64)	0.149** (0.91)	0.049** (1.62)	0.472** (2.64)	0.324** (3.24)

Sl.No.	Independent Variables	Jhansi			Jalaun		
		Cropping pattern change	Early maturing varieties	Improved irrigation	Cropping pattern change	Early maturing varieties	Improved irrigation
4	Land Size	0.238* (3.24)	0.652* (2.64)	0.742* (4.32)	0.634* (2.83)	0.454** (1.89)	0.648* (3.92)
5	Training Programme	0.421* (4.26)	0.024* (2.34)	0.064* (3.24)	0.421* (2.45)	0.025* (3.54)	0.064* (0.64)
6	Agricultural Credit	0.246** (0.54)	0.045* (0.45)	0.215** (5.64)	0.846** (2.95)	0.248* (5.64)	0.616* (3.36)
7	Information of Climate	0.002 *** (0.95)	0.064** (1.59)	0.841* (2.64)	0.692** (3.64)	0.068** (3.59)	0.241* (1.64)
8	Crop Insurance	0.652 *** (4.95)	0.682** (3.59)	0.021* (2.44)	0.462** (4.24)	0.026** (3.29)	0.266* (3.82)
	Constant	-1.616* (0.19)	-0.087* (0.91)	-0.294- (0.74)	-0.420* (0.65)	-0.348 ** (0.70)	0.694- (0.24)
	LR chi^2	28.54	26.43	33.21	15.35	3.32	13.62
	Prob > chi^2	0.0019	0.0031	0.0054	0.0029	0.0062	0.000
	Pseudo R^2	0.8948	0.9521	0.9528	0.9226	0.9381	0.8582
	Log likelihood	-85.842	-76.635	-102.049	-166.246	-168.326	-87.698
	No. Obs.	100	100	100	100	100	100

Source: Estimated from field survey data, 2017. Note *, **, and *** indicate 1, 5, 10 percent level of significance respectively. Values in parentheses are odd ratios. Because of our analysis was carried out at district level, hence, 100 observations are mentioned in the last row of Table 3

CONCLUSION

Climate change is adversely affecting to farmers across the world. It also increases the degree of vulnerability as majority of the farmers are marginal and have limited resources capacity to cope. Further, fragmentation of land size, over-utilization of natural resources in the declining stage of common property resources are adding an additional layer of susceptibility in the higher vulnerable system. In order to understand the farmers' perception and determination of climate change adaptation, the present study was undertaken on most climate-sensitive agro-climatic region of Uttar Pradesh, India i.e., Bundelkhand region. The results of this study reveal that farmers are well-aware of changing climatic condition. Hence, farmers are adjusting their farm practices and diversifying their occupation to neutralise the adverse effect of climate change. Farmers have changed their cropping pattern, adopted to practice improved irrigation, and grow early maturing varieties as climate adaptation strategies. The Binary logistic regression results confirm that educated farmers having information on changing climate are wisely adjusting their farm practices. Further, the availability of extension services like access to crop insurance and institutional credit also positively influencing farmers' copping behaviour.

As far as policy implications from this study are concerned, the study suggests that the development of a common platform for government services is a prerequisite in the region. Asymmetric information on climate change is also the main barrier which restricts farmers from better utilization of indigenous knowledge. Hence, community participation and regular training programs in the sample villages are surely benefiting farmers to channelize their indigenous knowledge and optimize local resources which leads to sustainable farming.

The results of this study, however, needs to be interpreted with caution because of certain limitations. First, this study uses small sample size, i.e. 200 respondents from selected two districts of Bundelkhand region, excluded 11 districts. Therefore, it would be difficult to generalize the findings in the context of the drought-prone regions of India. Adaptations are varying region-to-region and village-to-village; therefore, it may be possible to miss other relevant farm-level effective adaptation measures, which would otherwise have been adopted by farmers. Second, this study has taken only 10 determinants of climate change adaptation, excluding other determinants. Therefore, results of this study are only valid, if these variables are included into estimation, otherwise results would be biased. Finally, Indian farming society has complex and divided into castes, classes, religions systems which varies from region-to-region and even household-to-households. Hence, it generates scope for future research on farmers 'perception of climate change, determinants of climate change adaptation.

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