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Determinants of Climate Change Adaptation Strategies in Bundelkhand Region, India

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ABSTRACT

The study attempted examining climate change adaptation strategies in the most backward regions of India, i.e., the Bundelkhand region. Data were collected from 200 farmers during April and May of 2017, and a binary logistic regression model was used to analyze the data. The farmers were most likely to improve irrigation facilities if they have access to institutional credit, information about the weather, and have taken crop insurance. Also, farmers perceived that an increase in temperature, a decline in rainfall, and a decline in water tables motivate and influence farmers to change their cropping pattern from wheat (a water-intensive crop) to chickpea (a less water-intensive crop) to cope with the changing climate. Hence, the present study recommends that since water table is declining continuously and creating water crisis even in the rainy season for agriculture and domestic consumption, community participation in the conservation of water-bodies is vital. Further, the adoption of crop varieties that require less water, are drought tolerant and mature early will help increase farm productivity and reduce cultivation costs. Lastly, an advance regional weather forecasting system capable of providing farmers with accurate information that will enable them to change cropping patterns and adjust farming practices are required.

INTRODUCTION

For marginal wheat growers in India, climate change has become a major socio-ecological concern in recent decades (Singh, 2020a). Climate change is thought to have negative effects on agriculture overall and on marginal farmers in particular (Singh and Sanatan, 2014; Singh, 2020c). Appropriate weather conditions are still important to improve agricultural productivity, despite major technical developments (Singh & Sanatan, 2018; Singh, 2019). Because of the changing climate conditions at different intensities around the world, wheat farming is under serious pressure (Sanghi & Mendelsohn, 2008). Further, 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 & Sanatan, 2021). Climate change affects rural subsistence in developing countries (Ravindera and Singh, 2020) and increases the insecurity of rural populations (Dupdal et al., 2021; Letha et al., 2021). Productivity losses in rainfed areas, such as Bundelkhand, are mostly attributable to the rapid rate of land degradation and the increased frequency and severity of droughts that are a result of climate change (Singh, 2020b). While farmers have used the recommended amounts of input and crop management strategies, variation in seasonal temperatures and stress have adversely affected crop yields (Singh, 2020a), in particular the yield of wheat (Singh & Sanatan, 2021). Efforts to tackle the negative effects of climate change, especially on small farmers and agriculture in general, are therefore essential (Singh, 2020b). Most modelling and observational studies have shown that climate change is more likely to affect rain-fed farmers (Sanghi & Mendelsohn, 2008; Singh, 2021).

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The Bundelkhand region is historically more vulnerable to climate change. The region had experienced drought once every 16 years during the 18th and 19th centuries, whereas it increased to three times during 1968–1992, and now it is a recurrent annual phenomenon (GoI, 2017). The average annual rainfall of the region continued to be below average during 2004–2022 (GoI, 2022). The severity of the low rainfall was such that 40 per cent of the net sown area remained fallow, which resulted in 30 per cent less food grain production (NRAA, 2018). Apart from drought, variations in temperature are also a cause of household vulnerability (Singh, 2020b). The average temperature has been increased by 0.28°C during 1969–2017 compared with 1960–90 (Singh, 2020b). A rise in temperature leads to high evapotranspiration, causing a loss of soil moisture and reductions in groundwater recharge and surface water. In light of the above, the present study made an attempt to identify the key determinants that influence and motivate farmers to adopt a rational, cost-effective, and climate-smart adaptation strategy in Jhansi and Jalaun districts of the Bundelkhand region.

METHODOLOGY

The present study was carried out in the Bundelkhand region of India. In the region, wheat is the main food grain crop. The field survey was carried out in the months of April and May of 2017, at the end of Rabi harvesting season. Further, a multi-stage sampling technique was opted for in the sample selection. In first step, two districts (one developed, Jhansi, and one developing, Jalaun) were chosen from a total of 13 in the Bundelkhand region based on various hydrological, climatic, soil, and agricultural parameters. There are five sub-divisions (i.e., tehsils) in each of the selected districts, and at second stage, all five tehsils from each district were chosen. In third stage, one development block from each tehsil was chosen purposefully. In fourth stage, one village from each selected block was chosen randomly. Finally, 20 farm households from each village were selected randomly. Thus, a total of 2 districts, 10 tehsils, 10 development blocks, 10 villages, and 200 farm households were selected for the study.

The Binary Logistic Regression (BLR) model was adopted for identifying the key determinants of climate change adaptation in the sample farmers (Singh, 2020a; 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:

$$Logit\ (P) = \log\left(\frac{P}{1-P}\right) \quad \text{... (1)}$$

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

$$P_r\left(y = \frac{1}{x_i}\right) = \frac{exp^{x'b}}{1+e^{x'b}}; = \log\left(\frac{P}{1-P}\right) = \text{Logit}\ (P_i) = \beta_0 + \beta_i \quad \text{... (3)}$$

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;

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

The dependent variable (adaptation strategy) is binary, with values as 1 for farmers using at least one of the identified climate adaptation strategies and 0 for farmers using none of the strategies mentioned. This was done so that adapted farmers might be distinguished from non-adapted ones. 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.

RESULTS AND DISCUSSION

Farmers' perception of climate change

Table 1 depicts that farmers are well aware of the changing climatic conditions. About 70 per cent in Jalaun and 64 per cent in Jhansi perceived that rainfall distribution had declined over the last five years. Likewise, more than 90 per cent of farmers in both districts perceived that the summer season had become relatively hotter in recent years compared with the last decade. Further, about 88 per cent of farmers in Jalaun and 98 per cent of farmers in Jhansi perceived that the frequency of heat-waves had increased, which was a major factor for mortality in the summer season. More than 90 per cent of farmers perceived that the water table in the sample villages had 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 total, increase in temperature and decline in rainfall have put stress on the marginalised farming community.

Table 1. Farmers' perception on Climate Change

Perception attributes	Jhansi	Jalaun
Farmers perceived that frequencies of heat-waves has been increased	98	88
Farmers perceptive that summer-days become hotter	98	90
Farmers perceived that rainfall has been declined	64	70
Farmers perceived that water table has been declined	95	90

Source: Field Survey Data, 2017. *Note:* values are in per cent

Adaptation strategies adopted by surveyed farmers

Table 2 shows that farmers used different climate adaptation strategies to cope with changing climate and increase farm income, i.e., cropping pattern change, use of early maturing varieties and improving irrigation system. In this connection, statistics reveal that about 82 per cent of farmers in Jhansi and about 72 per cent of farmers in Jalaun have changed their cropping patterns from wheat (water intensive crop) to chickpea (less water intensive crop). Further, by utilising natural resource management techniques and expert advice provided by local agriculture officers, about 62 per cent of farmers in Jhansi and 52 per cent of farmers in Jalaun have improved their irrigation facilities to get regular and assured water whenever irrigation is required. As Bundelkhand is a dry region, farmers have used sprinklers to make efficient use of water. Moreover, about 72 per cent of farmers in Jhansi and 52 per cent of farmers in Jalaun have used early maturing seed varieties (EMSV) to cope with the changing climate. EMSV are extremely useful for implementing climate resilience practices. They have required less water, time and inputs compared with traditional seed varieties. Farmers in the study are growing EMSVs like UP 2382, which are ready for harvest in 109 days. Per hectare production (5545 kg/ha) is also relatively higher as they are specially designed for dry regions, like the Bundelkhand region.

Table 2. Adaptation Strategies of Farmers in surveyed Districts

Adaptation strategies	Jhansi	Jalaun
Farmers have used early maturing varieties	72	52
Farmers have improved irrigation system	62	52
Farmers have changed their cropping pattern	86	72

Source: Field survey data, 2017. *Note:* values are in per cent

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 the BLR model at the district level to capture regional dimensions of climate change adaptation. The results show that a decrease in rainfall motivated farmers in Jhansi district to change their cropping pattern while being restricted to use early maturing varieties and improve irrigation, whereas rainfall has been positively associated with climate adaptation strategies in Jalaun district (Table 3). Temperature, education, land size, participation in agricultural training programmes, access to agricultural credit, information about the climate, and crop insurance are positively associated with cropping pattern change, improved irrigation, and early maturing varieties adaptation strategies in both districts.

The calculated odds ratio shows that there is a 2.54 times higher probability that farmers will change their cropping pattern in favour of low water-intensive crops (i.e., chickpea) from high water-intensive crops (i.e., wheat), if they perceive that rainfall will decline in Jhansi district. On the other hand, there is a 3.24, 2.64 and 1.58 times higher probability of changing cropping pattern, using early maturing varieties, and improving irrigation, respectively, if farmers perceive that rainfall will decline in Jalaun district. Further, there is a 3 times higher probability to adopt recommended adaptation strategies (early maturing seed varieties) if farmers perceive that temperatures will increase in the near future in Jhansi district; on the other hand, there is a lower likelihood to adopt recommended strategies in Jalaun district compared with Jhansi district. Education is a critical indicator in the adaptation strategy for climate change. It is anticipated that educated farmers will be more likely to implement the recommended strategies. Results from Table 3 revealed that there is 2.51 and 3.64 times higher probability to change cropping pattern and use of early maturing varieties, farmers who attained higher education (above secondary level) are more likely to adapt to climate change 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, respectively, if farmers having education level above from secondary-level in Jalaun district. The odds ratios of land size depict that there is a 3.24, 2.64 and 4.32 times higher probability to adopt cropping pattern change, early maturing varieties, and improved irrigation adaptation strategies. Recommended adaptation strategies, if farmers have a larger land size in Jhansi district and on the other hand, the odd ratio shows that there are relatively fewer likelihoods to implement adaptation strategies in Jalaun district compared to Jhansi district.

Table 3 shows that farmers who participated in the agriculture development programme were relatively more likely to adopt cropping pattern change, early maturing varieties, and improved irrigation adaptation strategies in Jhansi compared to Jalaun. There is a 4.26, 2.34 and 3.24 times higher probability of adopting recommended strategies in Jhansi, while the corresponding figures are only 2.45 and 3.54 for Jalaun. Further, the odd ratio of access to institutional credit reveals that farmers who are availing credit from institutional sources are more likely (3.24 times higher) to have improved their irrigation system in Jhansi, while corresponding figures for Jalaun are relatively higher than those of Jhansi. Likewise, the odd ratio of information on climate shows that farmers who have information about changing climates have a 1.59 and 2.64 times higher probability of using early maturing varieties and improved irrigation in Jhansi, while on the other hand, they have a 3.64, 3.59, and 1.64 times higher probability of adopting adaptation strategies in Jalaun. Lastly, the odd ratio of crop insurance shows that there is a 4.95, 3.59, and 2.44 times higher probability of identifying adaptation strategies in Jhansi, while there is a 4.24, 3.29, and 3.82 times higher probability of adopting them in Jalaun. In totality, the likelihood analysis (odd ratio) reveals that farmers belonging to Jalaun have a higher likelihood of identifying adaptation strategies compared to those in Jhansi.

Farmers everywhere are feeling the adverse effects of the changing climate. Since most farmers already operate on the margins, their already precarious financial situations become much more precarious. Additionally, the greater susceptible system is being further compromised by the fragmentation of land size and the overuse of natural resources during the depletion stage of common property resources. This research focused on the most climate-sensitive agro-climatic area of Uttar Pradesh, India, i.e., the Bundelkhand region, to get insight into farmers' perspectives and resolve on climate change adaptation. This research shows that farmers are aware of the effects of climate change and are responding to the negative effects of climate change by making changes to their farming operations and diversifying their income streams. Farmers have adapted by shifting their cropping patterns, using new methods of irrigation, and planting early maturing cultivars in order to combat the effects of climate change. The findings of a binary logistic regression study show that well-informed farmers who are adapting to a changing environment are doing so in a sensible manner. Having access to extension services like crop insurance and institutional loans also has a favourable effect on farmers' copping behaviour.

Table 3. Determinants of Climate adaptation strategies

Independent Variables	Jhansi			Jalaun		
	Cropping pattern change	Early maturing varieties	Improved irrigation	Cropping pattern change	Early maturing varieties	Improved irrigation
Farmer perceived rainfall declined	0.482*	-0.265*	-0.632*	0.621*	0.325*	0.531*
(Yes = 1, No = 0)	(2.54)	(0.84)	(0.64)	(3.24)	(2.64)	(1.58)
Farmer perceived temperature increased	0.125*	0.632*	0.745*	0.138*	0.262*	0.145*
(Yes = 1, No = 0)	(3.28)	(2.54)	(3.25)	(2.88)	(1.54)	(1.25)
Education (Below secondary = 0, above = 1)	0.045*	0.038**	0.149**	0.049**	0.472**	0.324**
	(2.51)	(3.64)	(0.91)	(1.62)	(2.64)	(3.24)
Land Size (in acre)	0.238*	0.652*	0.742*	0.634*	0.454**	0.648*
	(3.24)	(2.64)	(4.32)	(2.83)	(1.89)	(3.92)
Training Programme (Yes = 1, No = 0)	0.421*	0.024*	0.064*	0.421*	0.025*	0.064*
	(4.26)	(2.34)	(3.24)	(2.45)	(3.54)	(0.64)
Agricultural Credit (Yes = 1, No = 0)	0.246**	0.045*	0.215**	0.846**	0.248*	0.616*
	(0.54)	(0.45)	(5.64)	(2.95)	(5.64)	(3.36)
Information of Climate (Yes = 1, No = 0)	0.002***	0.064**	0.841*	0.692**	0.068**	0.241*
	(0.95)	(1.59)	(2.64)	(3.64)	(3.59)	(1.64)
Crop Insurance (Yes = 1, No = 0)	0.652***	0.682**	0.021*	0.462**	0.026**	0.266*
	(4.95)	(3.59)	(2.44)	(4.24)	(3.29)	(3.82)
Constant	-1.616*	-0.087*	-0.294	-0.420*	-0.348**	-0.694
	(0.19)	(0.91)	(0.74)	(0.65)	(0.70)	(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. observation	100	100	100	100	100	100

Source: Estimated from field survey data, 2017. *Note:* *, **, and *** indicate 1, 5, 10 per cent 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

The study suggests, since water table is declining continuously and creating water crisis even in the rainy season for agriculture and domestic consumption, community participation in the conservation of water-bodies is vital. The adoption of crop varieties that require less water, are drought tolerant and mature early will help increase farm productivity and reduce cultivation costs. Advance regional weather forecasting system capable of providing farmers with accurate information that will enable them to change cropping patterns and adjust farming practices are required. Community participation and regular training programs in the sample villages are surely benefiting farmers to channelize their indigenous knowledge and optimize local resources which lead to sustainable farming.

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