



Factors Affecting Adoption of Climate-smart Agriculture Practices: Evidence from Uttar Pradesh, India

Surendra Singh Jatav

Assistant Professor, Department of Economics, Babasaheb Bhimrao Ambedkar University, Lucknow, Uttar Pradesh, India

Email id: surendra.singh735@gmail.com

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ABSTRACT

The study examined the determinants of climate-smart agriculture (CSA) practices in Uttar Pradesh. The systematically collected data of 480 sampled farmers from two regions of Uttar Pradesh, namely Central and Bundelkhand, was analysed using the binary logistic regression model. A field survey was conducted in August and September 2022. Farmers belonging to the Lucknow district were having relatively higher adoption rates of CSA practices. Entrepreneurial orientation (EO), consisting of risk-taking, innovativeness, and pro-activeness, was a significant factor influencing farmers' adoption of CSA techniques. The findings show that male farmers are more inclined to use irrigation, certified seed, crop rotation, and soil testing. Education is linked to the acceptance of certified seed and soil testing, which necessitates financial commitment from farmers. Farmers, who have improved their irrigation facilities their income increased by 11.50 per cent, while those who had tested soil before plantation, the income increased by 54.76 per cent. Therefore, research indicates that entrepreneurship training and education courses for farmers should be customised to aspects of entrepreneurial orientation, such as risk-taking, innovativeness, and proactiveness.

INTRODUCTION

Unusual weather patterns impact agricultural productivity in India (Singh, 2020a). Droughts and floods are caused by abnormal weather patterns, which greatly impact the agricultural sector due to its sensitivity to weather conditions (Chand & Biradar, 2017). Floods, cyclones, and hurricanes have diminishing detrimental effects based on their restricted occurrence areas (Jatav & Singh, 2023). Drought is severe and long-lasting when it happens. Drought is considered a significant threat to agriculture among all weather-related crises (Singh & Alka, 2019). Specific regions in the nation are designated as susceptible to various natural disasters (Jena et al., 2023). Drought is a prolonged natural calamity that is more intricate and difficult to foresee accurately compared to other disasters (Singh et al., 2019). Both farmers and the government find it challenging to be adequately equipped to deal with it (Singh, 2020). Its effects are both prolonged and severe.

Approximately 77 per cent of India's total land area is susceptible to drought, making more prone to land degradation (Chand & Biradar, 2017) and frequent droughts. As far as Bundelkhand region is concerned, meteorological data show that the region almost every year has experienced drought (IMD, 2023). Further, agricultural drought is a complex issue with significant repercussions on the farming community in the Bundelkhand region (Jatav, 2024).

Considering the current high level of vulnerability (Singh & Nayak, 2014; Jatav, 2020; Singh, 2020a), implementing climate-smart agriculture (CSA) technology is a powerful strategy that can increase productivity, strengthen resilience to climate-related challenges, and decrease greenhouse gas emissions (Shitu et al., 2018; Kangogo et al., 2023; Nain et al., 2024). This approach also helps to secure food and income for farmers (Jatav & Mubeena, 2023). Implementing CSA techniques provides a double benefit for

both commercial and public parties and plays a crucial role in reducing poverty in rural regions (Jena et al., 2023). Many studies emphasise the triple benefits of adopting CSA, which include improvements in output, reduction of risks, and increased revenue, seen in both developing and wealthy countries (Mungai et al., 2016; Makate et al., 2017; Lan et al., 2018). Overall, CSA practices are both environmentally sustainable and friendly, fostering improved yields and income. Farmers have incorporated CSA techniques, such as enhanced crop varieties, laser land levelling and zero tillage, leading to increased farm production and lowered production costs within India's rice-wheat system in the Indo-Gangetic Plain region (Khatri-Chhetri et al., 2016). In Bihar, farmers have adopted conversation agriculture (CA) alongside improved livestock management, resulting in enhanced food security for both large and medium-scale farmers (Lopez-Ridaura et al., 2018).

Additionally, implementing soil-enhancing practices such as regular soil bunds has decreased crop failure risk (Singh et al., 2019). Farmers in India have adopted diverse CSA, resulting in increased production, reduced costs, and improved food security in various region that help to meet SDGs like reducing poverty and improving food security (Khatri-Chhetri et al., 2016). In Bundelkhand region, Choudhary et al., (2022) highlighted the positive impact of soil and water conservation initiatives on farm productivity and income. With these evidence, the present study aims to evaluate the impact of CSA practices adoption on farmers' income in the Bundelkhand and Central region by using systematically collected field survey data.

METHODOLOGY

The present study was conducted in two regions of the most populous state in India, namely the Bundelkhand region and the Central Region of Uttar Pradesh (UP). Field survey data was collected using a multistage random sampling process. A field survey was done in August and September 2022. Initially, Uttar Pradesh was chosen. Then, two specific locations were intentionally picked to analyse the factors determining the adoption of climate-smart agricultural practices: an underdeveloped region, Bundelkhand, and a developed one, Central Uttar Pradesh. Two districts from each region were chosen in the third phase. Selected districts include Jhansi and Lalitpur from the Bundelkhand area, and Lucknow and Barabanki from the Central region. Two Development Blocks were chosen from each district in the fourth phase. Two villages were chosen from each Development Block in the fifth phase. 30 samples were ultimately chosen from each village. The 2 regions, 4 districts, 8 Development Blocks, 16 villages, and 480 samples were chosen to study the factors influencing CSA practices.

Further, the Binary Logistic regression (BLR) model was adopted for identifying the key influencing determinants of CSA practices in the surveyed farmers. The logistic distribution function for the decision on adoption of CSA practices can be specified as:

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

$$\text{Let } P_i = P_r\left(\frac{Y=1}{x=x_i}\right), \text{ then model can be written as} \quad \dots (2)$$

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

Where; P_i is a probability of adoption of CSA (dummy variable; 1 if farmer adopted CSA and otherwise = 0), $X_i'S$ are independent variables, β_0 is the intercept and β_i is the regression coefficient of CSA.

Based on the collected data, farmers are faced with a range of CSA practices to choose from in their attempts to adapt climate change. Farmers may adopt a single practice or a combination of practice depending on the climate change effects on their farms and the available resources.

RESULTS

Categorisation of CSA practices

The present study created a categorization of CSA activities which connects CSA practices with the primary resource needed (Table 1). The first group consists of procedures that need extra unskilled work. Typically, farmers in this group are responsible for simple responsibilities like opening and closing furrows when irrigating. The second group includes techniques that need farmers' knowledge and abilities. Effective agricultural methods include understanding which crops to cycle with wheat and how to adjust the production schedule. The last group consists of procedures that primarily need financial resources. Farmers are required to cover the costs of certain procedures, such as certified seed and soil-testing services. Farmers adopt various CSA strategies to increase farm income. For instance, improving irrigation has insured regular water supply for water- intensive crops like, whet. This strategy does not require additional skills to adopt. Digging ponds, minor check dams and rainwater harvesting are not only help in food security but also motivate farmers to grow cash crops. Further, changing cultivation calendar along with crop rotation and inter-cropping help farmers to deal with changing climate. Furthermore, soil testing and use of certified seeds are require skills and finance to increase crop productivity and farm income.

Table 1. Typology of CSA practices adopted by Sample Farmers

CSA Practice	CSA Category		
	Unskilled Labour	Skilled Labour	Finance
Improved Irrigation	√		
Change in Cultivation Calendar		√	
Certified Seed			√
Crop Rotation		√	
Soil Testing			√
Inter-cropping	√		

Source: Field Survey, 2022

CSA adopted by surveyed farmers

Table 2 demonstrates the adoption rate of CSA practices. The results show that among the sample districts, farmers in Lucknow district have adopted CSA practices more than those in others. For example, more than 80 per cent of sample farmers in Lucknow district have improved their irrigation facilities to grow wheat crop, while only 41.25 per cent of farmers in Lalitpur district did the same. Nearly half of the farmers in Lucknow district have changed their cropping calendar to deal with climate change, while

Table 2. Climate Smart Agriculture Practices adopted by Sample Farmers

CSA Practices	Central Region		Bundelkhand Region	
	Lucknow	Barabanki	Jhansi	Lalitpur
Improved Irrigation	80.50	60.75	45.25	41.25
Changes in Cultivation Calendar	45.25	38.50	35.50	25.75
Used Certified Seed	90.50	70.50	65.75	40.75
Rotated Crops	75.25	61.25	42.25	43.25
Tested Soil	45.25	38.50	30.25	27.25
Adopted Inter-cropping (Wheat+Mustard)	75.25	70.50	60.25	56.75

only 25.75 per cent of farmers have changed their cropping pattern. More than 90 per cent of farmers in Lucknow district have used certified seeds, followed by 70.50 per cent in Barabanki district, 65.75 per cent in Jhansi district, and only 43.25 per cent in Lalitpur district. The rotation of crops is also a vital CSA strategy to increase farm income and cope with the changing climate. Table 2 shows that about 75.25 per cent of farmers in Lucknow district (the highest) have rotated crops, while only 43.25 per cent of farmers in Lalitpur district have rotated crops. Soil testing is also important for higher income and yield. The study reports that

more than 45 per cent of farmers in Lucknow district have tested their field's soil before planting seeds, while only 27.25 per cent of farmers in Lalitpur district have tested soil. Lastly, intercropping (wheat and mustard) in the Rabi season is highly recommended CSA practice in both regions. The results show that more than 75 per cent of farmers in Lucknow district have adopted intercropping, while only 56.75 per cent of farmers in Lalitpur district have adopted intercropping CSA to deal with changing climate change and increase their farm income.

Determinants of CSA practices

Table 3 illustrates the factors influencing CSA practices in the research area. Farmers have adopted CSA based on their skills and the availability of funds. The binary logistic regression results show that male farmers are more likely to adopt both skilled and unskilled CSA practices than female farmers. The calculated odd ratios show that if the head of household (the farmer) is male, there is a 2.25, 2.24, and 2.25 times higher probability of adopting intercropping, using certified seed, and adjusting the cropping calendar to increase farm productivity and income. Likewise, an experienced farmer is more likely to adopt identified CSA practices, which is reflected in terms of his or her age. The calculated odd ratios show that there is a 4.58, 4.25, 3.65, and 2.29 times higher

Table 3. Determinates of CSA practices

Variables/CSA	Irrigation	Change in cultivation calendar	Certified seed	Crop rotation	Soil Testing	Inter-cropping
Gender (Male = 1; Female = 0)	0.458* (1.25)	0.141* (2.25)	0.371* (2.24)	0.198** (1.75)	0.237** (1.25)	-0.421** (2.45)
Age (Years)	0.240* (3.24)	0.010** (1.29)	0.003** (1.58)	0.038* (2.45)	-0.021* (0.25)	-0.008* (0.45)
Household Size (Number)	-0.043* (0.79)	-0.024* (0.95)	-0.002* (0.75)	0.005* (0.60)	-0.009* (0.75)	0.021* (0.92)
Education (Years of formal education)	0.014* (1.65)	0.026* (2.65)	0.036** (1.68)	0.008* (1.85)	0.041** (1.90)	0.014* (1.62)
Years of Experience	0.009* (2.29)	0.006* (4.58)	0.008* (3.65)	0.004** (4.25)	0.012** (1.25)	-0.015** (1.85)
Land Size (owned = 1; otherwise = 0)	0.454* (1.99)	0.051** (2.15)	0.229* (3.25)	0.230** (2.49)	0.241* (3.21)	0.263** (2.78)
Access climate Information Yes = 1; No = 0)	-0.038* (2.21)	0.487** (4.35)	0.373*** (6.32)	0.194* (2.24)	0.435*** (2.24)	-0.053** (1.28)
Credit Received credit = 1; otherwise = 0)	0.117* (2.45)	0.195* (4.25)	0.303** (3.24)	-0.008* (4.21)	0.357*** (2.34)	-0.099* (1.29)
Entrepreneurial orientation -1 (Strongly agree to take Risk = 1; Strongly disagree to take Risk = 0)	0.092** (3.42)	0.215*** (2.65)	0.103*** (1.54)	0.111*** (2.48)	0.112** (3.75)	0.007* (4.25)
Entrepreneurial orientation -2 (Strongly agree to adopt Innovativeness idea = 1; Strongly disagree to adopt Innovativeness idea = 0)	-0.055** (3.25)	0.025** (1.74)	0.070** (2.37)	0.029* (3.19)	-0.066* (1.25)	-0.018* (0.28)
Entrepreneurial orientation -3 (StrongPro-activeness = 1; non-pro-activeness = 0)	0.076** (4.95)	0.048* (3.48)	0.063** (3.45)	0.280** (4.25)	-0.179* (2.48)	-0.486* (2.26)
Constant	-0.543* (0.159)	0.452* (0.627)	0.862*** (0.486)	0.650* (0.851)	0.900* (0.206)	-0.842* (0.416)
LR Chi ²	25.55	27.25	35.45	22.35	29.35	35.24
Prob> Chi ²	0.0030	0.0016	0.0019	0.0086	0.0001	0.0021
Log Likelihood	-69.993	-84.521	-116.432	-124.239	-132.374	-85.241
Number of observation	480	480	480	480	480	480

Note: *, **, and *** indicate 1, 5, 10 percent level of significance, respectively. Values in parentheses are odd ratios

probability of changing cropping patterns, rotating crops, using certified seed, and improving their irrigation systems if farmers have a basic understanding of the topography of the area than unexperienced and seasonal farmers. The large household size shows a higher dependency ratio and restricts farmers from adopting recommended CSA practices. Further, education and experience are positively associated with the adoption of CSA practices. The higher the education level, the higher the probability of CSA adoption. The calculated odd ratios show that there is a 2.65, 1.90, 1.85, and 1.68 times higher probability to adjust their cropping pattern, test soil, rotate cropping patterns, use certified seeds to deal with climate change, and insure regular income from agriculture. Similarly, land ownership has increased the probability of adoption of identified CSA practices more than that of farmers who don't have ownership of the land. The calculated odd ratios show that there is a 3.25, 3.21, 2.78, and 2.15 times higher probability of using certified seed, testing their soil before plugging, intercropping, and changing their cropping pattern than that of others.

Access to climate information and credit also motivates farmers to adopt identified CSA practices. The logistic regression results show that, except for irrigation and intercropping, all CSA practices are positively associated with access to climate information. The calculated odd ratios show that there is a 6.32, 4.35, 2.24, and 2.21 times higher probability that farmers use certified seeds, change their cropping calendar, rotate crops, and test soil before plugging if they have prior information about climate than farmers who don't have climate information access. Likewise, credit is vital to deal with climate change and rural distress, as farming is becoming more costly day by day. Credit at a minimal rate helps farmers to adopt CSA practices, especially those that require funds, like the use of certified seeds and soil testing. The calculated odd ratios show that there is a 4.25, 4.21, 3.24, 2.45, and 2.34 times higher probability to change their cropping pattern, rotate crops, use certified seeds, test soil, and improve irrigation to deal with changing climate change and increase farm income.

Farmers' entrepreneurship orientation skills to adopt identified CSA are categorised into three categories, i.e., taking risk, innovativeness, and pro-activeness. All three skills are positively associated with the identified CSA practices. A risk-taking farmer is more inclined to adopt CSA than a farmer who is not willing to take a risk. For example, the use of a new variety of seed is a risk, as it requires skills to choose the best variety from among the available varieties. Similarly, innovative ideas like biological pest control, digging ponds to harvest rainwater, and wisely selected crops give assured returns on their investment. Moreover, Indian farmers are facing dual problems, i.e., crop failure and market failure. Pro-active farmers make decisions about when and how to sell their farm produce, which gives them assured returns.

Change in income after the adoption of CSA practices

Table 4 demonstrates changes in the income of sample farmers after the adoption of CSA practices. The adopted CSA is a win-win situation. Farmers who have improved their irrigation facilities their income has increased by 11.50 per cent, while those who have tested soil before plantation's income has increased by 54.76 per cent. Further, changes in cultivation calendars to deal with

Table 4. Change in Income after the adoption of CSA Practices

CSA Practices	Pre- CSA Per Capita Income	Post- CSA Per Capita Income	Change Income (%)
Irrigation	354	400	11.50
Changes in cultivation calendar	216	362	40.33
Certified seed	158	224	29.46
Crop Rotation	95	157	39.49
Soil Testing	76	168	54.76
Inter-cropping	345	460	25.00

Note: One US\$ = 82.90 Indian Rupees (INR)

changing climates are highly recommended CSA practices, and as Table 4 depicts, after adjustment of sowing dates, farmer's income has increased by 40.33 per cent.

DISCUSSION

Entrepreneurship orientation (EO), consisting of risk-taking, innovativeness, and pro-activeness, is a significant factor influencing farmers' adoption of CSA techniques. The findings show that risk-taking is a significant factor in the adoption of CSA. Similar determinants were reported by Gupta et al., (2013) & Gupta et al., (2023) in different context. The finding indicates that risk-taking influences the choice to adopt all methods except intercropping in a favourable manner. Irrigation is mostly used in the sample villages to cultivate high-value wheat crop. Cultivating wheat and mustard together in irrigated fields is a novel method that focuses on two key factors: maximising productivity and reducing costs. This might clarify the correlation between risk-taking behaviour and the evolving cultivation schedule. Farmers who are ready to take risks are more likely to modify the crop cycle. Utilising certified seed and doing soil testing are two methods that need extra funding. Certified seed accounts for the majority of expenses in wheat production. Investing in certified wheat seeds and soil testing carries a greater risk due to severe climate change. The farmer could not recoup the investment expenses, especially when purchasing seeds on credit, which increases the risk. Our data indicate that farmers who are inclined to take risks are more inclined to employ certified seed and soil testing techniques. Additionally, crop rotation necessitates understanding which crop should alternate with wheat. Crop rotation is linked to increased yields, enhanced soil fertility, and decreased pest and disease occurrence. Crop rotation is limited by small land sizes, which is a common feature among smallholder farmers, in addition to knowledge requirements. Crop rotation dictates that wheat may be cultivated on a plot of land once every three seasons, so a farmer can only allocate one-third of their area to wheat cultivation. This may clarify the correlation between risk-taking and the choice to use crop rotation.

Furthermore, the study's findings validate a favourable correlation between inventive capabilities and the use of CSA techniques. The present study discovered a direct correlation between farmers' innovativeness and their utilisation of certified seed. One potential factor might be the affordability and accessibility of certified seeds. The research findings revealed that

farmers who are proactive tend to utilise irrigation, adjust the production schedule, and use certified seeds. However, they are less likely to employ intercropping in wheat cultivation. Farmer pro-activeness has a detrimental impact on the choice to intercrop wheat with other crops. Possible explanations include ensuring a diverse range of crops for family food security and spreading risk in case one crop fails due to inadequate rainfall. Intercropping may be advantageous, but it may not be compatible with other agricultural strategies. Proactive wheat farmers who prioritise market-oriented production choices tend not to engage in intercropping, as shown by the findings. Proactive farmers demonstrate a market orientation via their employment of certified seed and irrigation practices, which are positively related to their level of pro-activeness. The knowledge of such practices also plays role in furthering such technologies (Ghanghas et al., 2015). The findings of this study show that daring farmers are ready to sacrifice immediate gains in agricultural productivity that come from using proper crop rotation. As Boyabath et al., (2019) showed that while crop rotation planning is advantageous in the long term, short-term income losses are unavoidable. An effective rotation planning strategy that considers market dynamics and crop selection may help limit losses, according to their argument. Further, proactive farmers are more inclined to take the initiative in responding to requirements and seizing possibilities. They are likely to be the first to water wheat fields, adjust their cropping schedule, and use certified seeds. Our findings support Hansen's (2015) conclusion that proactive action is essential for farmers to customise technology to their own farm requirements.

CONCLUSION

The study's results suggest that farmers have used various CSA strategies to enhance both output and profitability. Implementing CSA techniques results in a mutually beneficial scenario in terms of revenue. Entrepreneurial orientation (EO) improves the possibility of adopting all practices, but innovativeness decreases the likelihood of using certified seed. Being proactive has a good impact on the adoption of irrigation, altering the growing schedule, and using certified seeds. Therefore, research indicates that entrepreneurship training and education courses for farmers should be customised to impact the aspects of entrepreneurial orientation, such as risk-taking, innovativeness, and pro-activeness.

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