



Determinants of Farmers' Adaptation Strategies Towards Climate-resilient Agriculture in Haryana, India

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Abstract

Climate change poses a significant challenge to agriculture, particularly in regions where farming is the primary livelihood. Haryana, a key agrarian state in northern India, is highly vulnerable to climate-induced risks such as temperature fluctuations, erratic rainfall, and resource depletion. This study examines farmers' adaptation mechanisms and the factors influencing their adoption of climate-resilient strategies in Hisar and Sonipat districts. Primary data were collected from 120 farmers through a structured interview schedule using a multi-stage random sampling technique. Descriptive statistics and a probit regression model were employed to analyse adaptation mechanisms and the determinants influencing their adoption. The findings reveal that the most frequently adopted adaptation measures include increased irrigation (65.8%), enhanced fertilizer application (63.3%), and adjustments in crop sowing time (60.8%). Other strategies, such as crop insurance (58.3%), soil and water conservation techniques (38.3%), and intercropping (36.7%), were also observed. Probit regression analysis identified key determinants influencing adaptation decisions. Age exhibited a negative impact, suggesting that older farmers are less likely to adopt adaptation strategies. Conversely, landholding size, education level, income level, and access to climate change information positively influenced adaptation decisions. However, family type and occupation type did not significantly impact adaptation choices. The study highlights the need for targeted policies to enhance climate adaptation, particularly through improved access to climate-related information, education, and financial resources. Strengthening extension services and promoting sustainable adaptation mechanisms can improve farmers' resilience and ensure agricultural sustainability in Haryana.

Keywords: Adaptation strategies, Climate resilience, Probit model

Introduction

Climate change poses a profound and escalating threat to agricultural systems worldwide, challenging the stability of rural livelihoods and the resilience of food production. In India, agriculture remains a cornerstone of the economy and, occupying approximately 43% of the country's geographical area and contributing 18.3% to gross domestic product (GDP) in 2022–23. Yet, the sector now confronts rising temperatures, shifts in monsoon patterns, increasing frequency of extreme weather events and resource depletion all of which undermine crop productivity and soil health (IPCC, 2007; Fussler, 2007).

Smallholder farmers form the backbone of India's agricultural landscape, and they are

especially vulnerable to climate variability. Reliant largely on rainfed systems, these producers face multiple stressors: heat stress diminishes photosynthetic efficiency and grain filling; erratic rainfall and drought impose water deficits; pest and disease outbreaks intensify under warmer, more humid conditions; and declining soil fertility exacerbates yield losses over time (Rawat *et al.*, 2013). Despite efforts to curb global emissions, the atmospheric concentrations of long-lived greenhouse gases (LLGHGs) continued their upward trend. As per the IPCC (2021), the globally averaged dry-air mole fraction for reached 410 ppm in 2019, with and also quantified at 1866 ppb and 332 ppb, respectively, firmly establishing a continued increase in radiative forcing (Masson *et al.*, 2021). Beyond direct yield reductions, climate change disrupts the availability of critical

resources integral to rural livelihoods. Fuelwood scarcity limits energy access, fodder shortages compromise livestock health, and groundwater depletion exacerbates water insecurity for irrigation and domestic use (Gene, 2012). In fragile regions such as the Himalayan foothills, projections indicate that agricultural output could decline substantially by 2050, heightening risks of food insecurity and out-migration (Dahal, 2008).

Adaptation has emerged as a vital strategy for sustaining agricultural productivity and buffering rural communities against these mounting risks. Farmers worldwide employ a diverse array of climate-resilient practices to maintain yields and stabilize incomes (Schipper, 2007; Vignola *et al.*, 2015). Common measures include adjusting sowing dates to synchronize with shifting rainfall regimes; diversifying crop portfolios to spread risk; intensifying irrigation schedules to alleviate drought stress; adopting short-duration, drought or pest-resistant crop varieties; increasing fertilizer and organic amendments to bolster soil fertility; and subscribing to crop insurance schemes such as the Pradhan Mantri Fasal Bima Yojana to mitigate financial losses. KVK plays a pivotal role in the agricultural landscape of India (Gautam *et al.*, 2024). The effectiveness and adoption rate of these strategies, however, depend on farmers' socio-economic attributes, access to information, institutional support and resource endowments (Nhemachena and Hassan, 2007; Kumar and Sidana, 2018).

Haryana, a leading food-grain producer in northern India—epitomizes the challenges and opportunities of adaptation in a region characterized by intensive irrigation and multiple cropping cycles in a year. The state spans two major agro-climatic zones: (1) the eastern semi-arid plains, which feature high irrigation density but face increasing monsoon variability, and (2) the western dry plains, where scant rainfall, rising temperatures and saline soils constrain productivity. The study aims to examine the adaptation mechanisms adopted by farmers to address climate change and to identify the factors influencing the adoption of climate-resilient strategies in Haryana, India.

Material and Methods

Study area selection

The study was conducted in the state of Haryana, India. To represent regional diversity in agro-climatic conditions, two districts Hisar and Sonipat were purposively selected. Hisar lies in the western dry plains zone with relatively low rainfall and high temperature fluctuations, while Sonipat falls in the more humid eastern semi-arid plains zone with relatively better water availability. These contrasting zones allowed for comparative assessment of climate change impacts on crop productivity across different agro-ecological contexts.

Sampling design

A multi-stage random sampling technique was employed to ensure representative data collection. First, one block was randomly selected from each of the two districts. Then, two villages from each selected block were chosen at random, resulting in a total of four villages. From each village, 30 farmers were selected using a simple random sampling method, giving a total sample size of 120 respondents. Primary data were collected using a structured and pre-tested interview schedule administered through face-to-face interviews.

Data analysis

To determine the ranking of adaptation mechanisms adopted by farmers, frequency and percentage analyses were employed. Simple comparisons were made based on percentage distribution, and the adaptation mechanisms were ranked in descending order according to the percentage obtained.

Probit regression model

To examine the determinants influencing the adoption of climate-resilient strategies among farming, a binary probit regression model was employed. This model is suitable when the dependent variable is dichotomous, i.e., takes a value of either 0 or 1. In this study, households with adoption index $\leq 50\%$ were regarded as non-adopters, and households with index $> 50\%$ were

regarded as adopters. The probit regression model was estimated using SPSS software by IBM.

The probit model estimates the probability that a household adopts climate-resilient strategies as a function of several explanatory variables. The general form of the probit model is as follows:

$$P(Y = 1 | X) = \Phi(X\beta)$$

Where:

Y is the binary dependent variable

X is a vector of explanatory variables (Age, Education level, Family type, Occupation type, Landholding size, Income level, Information about climate change)

β is a vector of coefficients to be estimated

Φ denotes the cumulative distribution function of the standard normal distribution

Results and Discussion

Adaptation mechanism of farmers to address climate changes

The result highlights various adaptation measures implemented by farmers in response to changing climate conditions in Table 1. The findings revealed that a significant percentage of farmers have adopted specific strategies to mitigate the challenges posed by climate change. Firstly, survey data indicate that 65.8% of farmers have increased their irrigation practices. This suggests that farmers are actively modifying the frequency or quantity of irrigation to adapt the shifting climatic conditions. Such adjustments help maintain

adequate water availability for crop growth, which is particularly relevant in Haryana's high irrigation density cropping systems. Abiotic stresses are the major type of stresses that plants suffer (Raza *et al.*, 2019). Secondly, 63.3% of farmers reported increased fertilizer application. This demonstrates that farmers were utilizing fertilizers to enhance crop productivity and compensate for any nutrient deficiencies caused by climate changes, thus maintaining healthy and productive crops. Kumar and Sidana (2018) observed that climate change led to changes in the timing of fertilizer application. Additionally, 60.8% of farmers have modified their crop sowing time. This adaptation measure reflects the farmers' efforts to align the timing of planting with shifts in temperature or rainfall patterns. By doing so, they aimed to optimize crop growth and maximize yields. Cropping and sowing seasons delay/early start can have also significant impact on crop production as well as the adaptation strategies of the farmers to offset negative effect of climate change (Salman *et al.*, 2018).

Furthermore, 58.3% of the farmers reported availing crop insurance schemes, such as the Pradhan Mantri Fasal Bima Yojana. This reflects their awareness of climate-induced risks like droughts and pest infestations. The adoption of crop insurance serves as a risk management strategy, enabling them to safeguard their agricultural livelihoods against potential losses. Moreover, 38.3% of farmers adopted soil and water conservation technologies as an adaptation strategy. These practices, such as improved irrigation scheduling and rainwater management,

Table 1. Adaptation mechanism of farmers to address climate changes (Multiple Responses, n = 120)

Statements	Frequency	Percentage	Rank
Crop insurance	70	58.33	IV
Increased seed rate used	29	24.17	VIII
Adopt soil and water conservation technology	46	38.33	V
Fertiliser application has been increased	76	63.33	II
Practicing inter/mixed cropping	44	36.67	VI
Adopt drought/pest resistant varieties	27	22.50	IX
Adopt short duration crop varieties	36	30.00	VII
Adjustment in crop sowing time	73	60.83	III
Number of irrigation given has increased	79	65.83	I
Reduced cultivated area	14	11.67	X

play a crucial role in minimizing runoff, preventing nutrient loss, and reducing the risk of secondary salinization. By enhancing water-use efficiency and maintaining soil structure, these measures directly contribute to better water quality and long-term soil health, thereby strengthening the resilience of agriculture in salinity-prone regions. Additionally, 36.7% of farmers practice intercropping or mixed cropping. By growing different crops together, farmers can optimize land utilization and minimize the impact of climate variations on their overall crop production. Salman *et al.* (2018) reported in Pakistan that diversification of crops is the major strategy used by farmers in adaptation to climate change. Furthermore, 30.0% of farmers have adopted short-duration crop varieties. This means that farmers were selecting and cultivating crop varieties with shorter growth cycles, enabling them to complete the growth and harvesting process within a limited period. This adaptation measure allows farmers to adapt to changing climatic conditions by adjusting their crop cycles. Mahato (2014) recommended developing short-duration crop varieties that can mature before the peak heat phase set in.

Moreover, 24.2% of farmers have increased the seed rate per unit area. This suggests that farmers were compensating for lower germination rates or ensuring better plant establishment under changing climatic conditions by increasing the number of seeds sown. Furthermore, 22.5% of farmers have adopted drought- or pest-resistant crop varieties. This indicates that farmers were selecting specific varieties bred or selected for their ability to withstand drought or resist pests. By

doing so, they aimed to minimize crop losses and maintain yields despite adverse climate conditions. Choudhary *et al.* (2025) noted that farmers perceived changes in rainfall patterns as the major climate concern, which supports their adoption of drought- and pest-resistant crop varieties. The findings align with Mahato (2014), who emphasized participatory and formal plant breeding as essential approaches for developing climate-resilient crop varieties capable of tolerating higher temperatures, drought, and salinity, thereby supporting farmers' adaptive capacity. By implementing these measures, farmers aimed affect to enhance resilience, maintain productivity, and mitigate risks associated with climate change in agricultural systems.

Factors influencing adaptation of climate resilient strategies

The study examined various factors that influence the adaptation of climate resilient strategies. The results revealed several statistically significant factors in Table 2. Firstly, age was found to have a significant impact (coefficient = -1.161, $p = 0.013$), indicating that younger farmers are more likely to adopt climate-resilient strategies compared to older farmers. This relationship was statistically significant at 5% level with a p-value of 0.013. Iheke and Agodike (2016) also reported that the adoption of climate change mitigation strategies tends to decline with increasing age of farmers, indicating that younger farmers are generally more proactive in adopting adaptive measures. Secondly, education level showed a positive coefficient (0.877), suggesting that as education

Table 2. Factors that influencing adaptation of climate resilient strategies (n = 120)

Sl. No.	Parameter	Coefficient	Standard Error	p-Value
	Intercept	-6.622	1.7286	0.0003
1.	Age	-1.161**	0.4657	0.013
2.	Education level	0.877**	0.3594	0.015
3.	Family type	0.487	0.4496	0.279
4.	Occupation type	-0.448	0.3869	0.247
5.	Land holding size	0.446**	0.2202	0.043
6.	Income level	1.413***	0.5271	0.007
7.	Information of climate change	2.904***	0.9537	0.002

*, ** and *** denote significance at 10, 5 and 1% levels, respectively.

level increases, the probability of being an adopter also increases. The p-value of 0.015 indicated that education level was statistically significant at 5% level. Kumar and Sidana (2018) also supported the present findings that education has a positive impact on adaptation. Iheke and Agodike (2016) also reported that higher education levels increase the likelihood of adopting climate-resilient strategies, which is consistent with the findings of the present study. Similarly, Deressa *et al.* (2009) and Maddison (2007) found a significant relationship between the education level of the household head and adaptation to climate change. Abid *et al.* (2015) further observed that as the education level of the household head increases, the likelihood of adopting climate change adaptation measures also rises.

The coefficient for family type was positive (0.487), indicating that certain family types were associated with a higher probability of being an adopter. However, the p-value of 0.279 suggested that family type may not be statistically significant in influencing the probability of being an adopter. Similarly, the coefficient for occupation type was negative (-0.448), implying that certain occupation types were associated with a lower probability of being an adopter. However, the p-value of 0.247 indicated that occupation type may not be statistically significant.

Land holding size showed a positive coefficient (0.446), suggesting that larger land holdings were associated with a higher probability of being an adopter. The p-value of 0.043 indicated that land holding size was statistically significant at 5% level. Income level had a positive coefficient (1.413), indicating that higher income levels were associated with a higher probability of being an adopter. The p-value of 0.007 indicated that income level was statistically significant at 1% level. Iheke and Agodike (2016) indicated that adoption of climate change adaptation measures increases with enhanced access to credit and higher income, supporting the findings of the present study. Kumar and Sidana (2018) observed that off-farm income of households had a positive and significant impact on almost all adaptation technologies. Kim *et al.* (2012) found out household income positively and

significantly influences the adoption of adaptation to climate change while Gebitobo (2009) explained about wealthier farmers were more interested to adapt by changing planting practices, using irrigation, and altering the amount of land farmed (Uddin *et al.*, 2014). Further, Nhemachena and Hassan (2007) indicated that per capita income has a positively influence on farmers' decisions to take-up adaptation measures. Findings of the studies of Croppenstedt *et al.* (2003) and Deressa *et al.* (2009) also support our findings of a positive relationship between household size and adoption of agricultural technology or adaptation to climate change.

Lastly, the coefficient for information of climate change was positive (2.904), suggesting that having more information about climate change was associated with a higher probability of being an adopter. The p-value of 0.002 indicated that information of climate change was statistically significant at 1% level. Kumar and Sidana (2018) indicated that farmers with information on climate variability tended to have a positive influence on adaptation technologies. Tucker *et al.* (2010) also report that local knowledge plays a critical role in formulating perceptions of farmers about climate change in Central America and Mexico. Farmer awareness of changes in climate attributes was important in the adaptation decision making process (Maddison 2007).

In addition to the overall adaptation strategies (Table 2), Table 3 presents the factors specifically influencing the adoption of soil and water conservation technologies. The analysis indicates that income level and information on climate change were the only statistically significant factors, with positive coefficients, suggesting that wealthier and better-informed farmers are more likely to adopt these practices. Other factors such as age, education, family type, occupation type, and landholding size were not statistically significant for this particular strategy. In summary, based on the findings, age, education level, land holding size, income level, and information of climate change were identified as statistically significant factors influencing the adoption of climate resilient strategies. However, family type

Table 3. Factors influencing adaptation of soil and water conservation technology (n = 120)

Sl. No.	Parameter	Coefficient	Standard error	p-Value
	(Intercept)	-3.017	0.8731	0.001
1.	Age	0.264	0.2230	0.236
2.	Education level	0.297	0.1989	0.136
3.	Family type	-0.022	0.2910	0.940
4.	Occupation type	-0.183	0.2434	0.452
5.	Land holding size	-0.218	0.1489	0.143
6.	Income level	0.711***	0.2650	0.007
7.	Information of climate change	1.042**	0.4501	0.021

*, ** and *** denote significance at 10, 5 and 1% levels, respectively.

and occupation type may not have a statistically significant impact in this analysis.

Conclusion

The study concludes that farmers in Haryana are responding to climate variability through a range of adaptation strategies, with increased irrigation, higher fertilizer use, and adjustment in sowing time being the most commonly adopted measures. The adoption of crop insurance also reflects growing awareness of climate-related risks. The probit model analysis identified key factors influencing the adoption of climate-resilient strategies. Age had a negative effect, indicating that younger farmers are more likely to adapt. In contrast, education level, landholding size, income level, and access to climate change information positively and significantly influenced adaptation behaviour. These findings indicate that socio-economic characteristics and access to information are critical in shaping farmers' adaptive responses. Strengthening these areas can enhance the effectiveness of climate adaptation at the farm level, particularly in diverse agro-climatic contexts like those found in Haryana.

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