



RESEARCH ARTICLE

Farming under Climate Stress: Perceptions and Adaptation Practices in Western Uttar Pradesh

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Abstract

Climate change has emerged as a major threat to agricultural sustainability in developing countries, where farming systems are highly dependent on climatic conditions and farmers possess limited adaptive capacity. In India, small and marginal farmers are particularly vulnerable to rising temperatures, erratic rainfall, and increasing frequency of extreme weather events. Understanding farmers' perceptions of climate variability and their adaptation strategies is therefore crucial for designing effective and locally relevant policy interventions. This study examines farmers' perceptions of climate change, observed impacts on agriculture, and adaptation strategies adopted in Moradabad district of western Uttar Pradesh. Using a mixed-method research design, primary data were collected from 1,000 farm households during 2023–2024 through structured questionnaires and personal interviews. Descriptive statistics, chi-square tests and binary logistic regression were employed for data analysis. The results show that a large majority of farmers perceived a rise in temperature (82.4%) and increased variability in rainfall patterns (76.1%) over the past three decades. Crop diversification, modification of irrigation practices and adoption of climate-resilient seed varieties were identified as the most common adaptation strategies. Logistic regression results indicate that education level, landholding size, access to institutional credit, and agricultural extension services significantly increase the likelihood of adopting adaptation measures. The study highlights the importance of strengthening extension systems, improving access to climate-resilient technologies, and designing targeted interventions for small and marginal farmers. By providing micro-level empirical evidence, this study contributes to the growing literature on climate change adaptation and offers policy-relevant insights for enhancing farmers' adaptive capacity in climate-vulnerable regions of India.

Keywords: Climate change adaptation, Farmers' perception, Adaptive capacity, Logistic regression, Western Uttar Pradesh, India

Introduction

Climate change is widely recognized as one of the most pressing global challenges of the twenty-first century, with profound implications for natural ecosystems, economic systems and human livelihoods. Among the sectors most vulnerable to climate variability and change, agriculture occupies a central position due to its direct dependence on climatic factors such as temperature, rainfall, humidity and seasonal patterns (IPCC, 2021). In agrarian economies, even small deviations in climatic conditions can significantly affect

crop yields, farm incomes and food security. Developing countries are disproportionately affected by climate change because of their heavy reliance on climate-sensitive sectors, limited technological capacity, and constrained institutional support systems (FAO, 2018). India, where agriculture supports nearly half of the population either directly or indirectly, faces substantial risks from rising temperatures, erratic monsoon rainfall, prolonged dry spells and an increasing frequency of extreme weather events such as floods and heatwaves (BIRTHAL et al., 2014). Empirical evidence suggests that climate change has already begun to affect Indian agriculture through declining productivity, changes in cropping patterns, increased pest and disease incidence and depletion of water resources (Mall et al., 2006; Reddy & Syme, 2014). These impacts are not uniform across regions; instead, they vary depending on agro-ecological conditions, socio-economic characteristics of farmers and access to institutional support.

Climate Change and Agricultural Vulnerability in Western Uttar Pradesh

Western Uttar Pradesh is one of the most important agricultural regions in northern India, characterized by fertile

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alluvial soils, extensive irrigation networks, and intensive cultivation of wheat, rice, and sugarcane. Despite relatively better infrastructure compared to eastern India, the region is increasingly vulnerable to climate variability due to its dependence on monsoon rainfall, declining groundwater levels and rising temperature trends. Moradabad district of western Uttar Pradesh is predominantly agrarian and highly dependent on climate-sensitive crops such as wheat, rice and sugarcane. According to a groundwater and environmental assessment conducted in Moradabad district by Saba and Umar (2021), the district economy is primarily agriculture-based and receives nearly 86% of its annual rainfall during the monsoon season (June–September). The study further reported that variations in rainfall patterns significantly influence groundwater conditions and agricultural sustainability in the region (Saba & Umar, 2021). Recent studies on land-use and environmental change in Moradabad district have also shown increasing environmental stress, including loss of agricultural land, rainfall variability and soil degradation associated with climate change and rapid developmental activities (Kumar & Arya, 2024). Furthermore, GIS-based analysis of Moradabad district from 1994–2024 revealed substantial expansion of built-up areas at the cost of agricultural and vegetative land, indicating increasing pressure on rural agricultural systems (Tandon & Varman, 2025). During the present field survey conducted in Bilari, Kundarki and Chhajlet blocks of Moradabad district, farmers reported delayed monsoon onset, irregular rainfall during paddy transplantation and prolonged dry spells during wheat cultivation. Farmers from Bilari block stated that irregular rainfall increased dependence on tube-well irrigation and raised cultivation costs. Similarly, sugarcane cultivators in Chhajlet block reported declining groundwater availability and reduced soil moisture during summer months. These primary observations are consistent with the district-level environmental and groundwater studies available for Moradabad district. Although several studies have examined climate change impacts at the regional and state levels in Uttar Pradesh, limited research based on primary field data has specifically documented farmers' perceptions and adaptation responses at the block level in Moradabad district. Therefore, the present study attempts to address this gap through direct field-based investigation.

Understanding farmers' perceptions is critical because perception often precedes action; farmers are more likely to adopt adaptation measures when they recognize and interpret climatic changes as risks to their livelihoods (Adger et al., 2009).

Importance of Farmers' Perceptions and Adaptation Strategies

Adaptation to climate change in agriculture is largely a behavioral process that involves adjustments in farming

practices, technologies and livelihood strategies in response to perceived or actual climatic risks (Smit & Wandel, 2006). Farmers' perceptions of climate change influence their willingness to adopt new technologies, diversify crops, modify irrigation practices or shift planting dates. Several studies have emphasized that adaptation decisions are shaped not only by climatic factors but also by socio-economic and institutional variables such as education, farm size, income, access to credit, and extension services (Deressa et al., 2009; Below et al., 2012). Farmers with greater resources and better access to information tend to exhibit higher adaptive capacity, while small and marginal farmers often face constraints that limit their ability to respond effectively to climate stress. In the Indian context, adaptation studies have largely focused on national or regional scales, often using secondary data or simulation models. Although these studies provide valuable insights, they tend to overlook micro-level heterogeneity in perceptions and adaptation behavior. District-level studies based on primary data are essential to capture local realities, contextual constraints and indigenous adaptation practices.

Research Gap and Contribution of the Study

Despite a growing body of literature on climate change and agriculture in India, several gaps remain. First, there is limited empirical evidence on farmers' perceptions of climate change at the district level, particularly in western Uttar Pradesh. Second, existing studies often analyze crop yield impacts without adequately examining farmers' adaptation behavior and the socio-economic factors influencing such behavior. Third, few studies employ large sample sizes combined with rigorous econometric analysis to identify determinants of adaptation at the household level. This study addresses these gaps by providing micro-level empirical evidence from Moradabad district using primary data collected from 1,000 farmers. By integrating perception analysis with econometric modeling of adaptation behavior, the study contributes to a deeper understanding of how farmers interpret climate variability and respond through adaptation strategies.

Objectives of the Study

The specific objectives of the study are to:

- Examine farmers' perceptions of climate variability and long-term climatic changes in Moradabad district.
- Identify major adaptation strategies adopted by farmers in response to climate change.
- Analyze differences in adaptation behavior across landholding and income groups.
- Determine socio-economic and institutional factors influencing the adoption of adaptation strategies.

Conceptual Framework

The conceptual framework of the study is grounded in climate change adaptation theory, which conceptualizes

adaptation as a dynamic process shaped by exposure to climatic risks, perception of impacts and the ability to respond through available resources and institutions (Smit & Wandel, 2006; Adger et al., 2009).

Climate Exposure, Perceived Impacts, and Adaptation Response

Farmers are exposed to climate variability in multiple forms, including rising temperatures, erratic rainfall, droughts, floods and extreme weather events. These climatic exposures affect agricultural systems by altering crop growth cycles, reducing water availability, increasing pest incidence and causing yield instability. Exposure alone does not automatically lead to adaptation. Instead, farmers interpret and perceive climatic changes based on personal experience, local knowledge, and information sources. Perceived impacts such as declining yields, crop failure or increased production costs motivate farmers to consider adaptation responses.

- Adaptation responses in agriculture may include:
- Technological adjustments (use of climate-resilient seeds, improved irrigation)
- Agronomic practices (crop diversification, altered sowing dates)
- Resource management strategies (soil conservation, water harvesting)
- Livelihood diversification

Role of Socio-Economic and Institutional Factors

The ability of farmers to adopt adaptation strategies is strongly influenced by socio-economic and institutional factors that determine adaptive capacity. Key factors include:

- Education and awareness, which enhance access to climate information and new technologies
- Landholding size, which reflects resource availability and risk-bearing capacity
- Income level, which determines the ability to invest in adaptation measures
- Access to credit, which facilitates adoption of input-intensive technologies
- Extension services, which provide technical guidance and institutional support

Farmers with higher adaptive capacity are more likely to perceive climate risks accurately and adopt appropriate adaptation strategies, whereas resource-constrained farmers may remain trapped in low-adaptation pathways.

Materials and Methods

Study Area

The present study was conducted in Moradabad district, located in the western part of Uttar Pradesh, India. Geographically, Moradabad lies between 28°21' to 28°59' N latitude and 78°45' to 79°28' E longitude. The district forms part of the Upper Gangetic Plains and is characterized by

fertile alluvial soils and a predominantly agrarian economy. Moradabad experiences a sub-tropical monsoon climate with hot summers, a humid monsoon season and cool winters. The average annual rainfall ranges between 850–1,000 mm, of which nearly 75–80% is received during the southwest monsoon season (June–September) (India Meteorological Department [IMD], 2023). During the study period, farmers from Bilari, Kundarki, Chhajlet and Dilari blocks consistently reported noticeable changes in local weather patterns. The major climatic variations observed and reported during field interactions included delayed onset of monsoon rainfall by 10–15 days, prolonged dry spells during paddy transplantation, erratic rainfall distribution, increased frequency of short-duration heavy rainfall events and unseasonal rainfall during wheat harvesting. Farmers also perceived a gradual increase in summer temperature and shorter winter duration compared to previous decades. Wheat cultivators reported premature maturity and reduced grain filling due to higher temperatures during February and March, whereas paddy farmers experienced irregular water availability during nursery preparation and transplantation. These observations formed an important part of farmers' perception regarding climate change in the present study. Similar increasing trends in temperature variability and irregular rainfall events in northern India and Uttar Pradesh have been documented by Goswami et al. (2006) and the IPCC (2023).

Block-level irrigation conditions further reflected climate-related agricultural vulnerability in the district. In Bilari and Kundarki blocks, irrigation was predominantly dependent on privately owned tube wells and submersible pumps due to inadequate canal water supply during critical crop stages. Farmers reported declining groundwater levels and increased diesel/electricity expenditure for irrigation over the last decade. In Chhajlet and Dilari blocks, canal irrigation facilities were available in selected villages; however, irregular water release and seasonal shortages forced farmers to depend increasingly on groundwater extraction. According to Singh and Kumar (2023), groundwater irrigation constitutes the major irrigation source in several parts of Moradabad district, while canal irrigation coverage remains uneven across blocks. This increasing dependence on groundwater has intensified agricultural vulnerability under changing rainfall conditions. During the survey, farmers perceived irrigation-related stress as a direct consequence of changing climatic conditions. Most respondents associated delayed rainfall, declining soil moisture and increasing irrigation frequency with climate change. Small and marginal farmers particularly reported difficulties in managing irrigation costs during drought-like periods. Thus, irrigation stress and changing weather patterns were included under farmers' climate change perceptions and adaptation experiences in the present investigation. Agriculture remains the principal

livelihood activity in Moradabad district, with wheat, rice and sugarcane as the dominant crops. The predominance of small and marginal farmers, dependence on climate-sensitive agriculture and increasing irrigation stress make Moradabad district an appropriate case for examining farmers' perceptions and adaptation behaviour related to climate change at the micro level.

Research Design

The study adopted a mixed-method research design, integrating both quantitative and qualitative approaches. This design was considered appropriate because climate change adaptation is a multidimensional phenomenon involving both measurable socio-economic variables and subjective perceptions (Creswell & Plano Clark, 2018). The quantitative component focused on identifying patterns in farmers' perceptions and adaptation behavior using survey data and econometric analysis. The qualitative component, based on personal interviews, provided contextual understanding of farmers' experiences, local knowledge and constraints faced in adopting adaptation strategies. The research followed a descriptive and exploratory orientation. The descriptive approach was used to document existing perceptions, climatic experiences, and adaptation practices, while the exploratory approach helped identify emerging adaptation strategies and locally specific responses to climate variability.

Data Sources and Data Collection

Primary Data

Primary data were collected during 2023–2024 through structured questionnaires and personal interviews with farm households across Moradabad district. A total of 1,000 farmers participated in the survey.

The questionnaire was designed to capture:

- Socio-economic characteristics of farmers
- Perceptions of temperature and rainfall variability
- Observed impacts of climate change on agriculture
- Adaptation strategies adopted in response to climate risks
- Access to institutional support such as credit and extension services

Both closed-ended questions (for quantitative analysis) and open-ended questions (to capture qualitative insights) were included. Interviews were conducted in local languages to ensure clarity and accuracy of responses. To ensure reliability, the questionnaire was pre-tested with 50 farmers from neighboring villages. Based on feedback, ambiguous questions were modified and culturally inappropriate terms were removed. The final questionnaire demonstrated acceptable internal consistency, with a Cronbach's alpha value of 0.78, indicating satisfactory reliability.

Ethical Considerations

Ethical principles were strictly followed throughout the research process. All respondents were informed about the purpose of the study and participation was entirely voluntary. Verbal informed consent was obtained prior to interviews. Respondents were assured of confidentiality and anonymity, and no personal identifiers were included in the dataset or final publication. The study complied with institutional guidelines for social science research and ethical standards for research involving human participants.

Sampling Design and Sample Size

A stratified random sampling technique was adopted to ensure representativeness of the sample and minimize selection bias. The total population of farming households in Moradabad district was first divided into strata based on:

- Landholding size (marginal, small, medium, large)
- Income categories
- Agro-climatic and administrative blocks

From each stratum, respondents were selected randomly in proportion to the size of the stratum. This approach ensured adequate representation of small and marginal farmers, who constitute the majority of agricultural households in the district. The sample size of 1,000 farmers was determined based on population size, variability in key variables, time constraints, and the requirement for robust econometric analysis. Compared to earlier district-level studies, this sample size is relatively large and enhances the statistical power and generalizability of results.

Variable Description and Measurement

Dependent Variable

The dependent variable for econometric analysis was adoption of climate change adaptation strategies, measured as a binary variable:

- 1 = Farmer adopted at least one adaptation strategy
- 0 = Farmer did not adopt any adaptation strategy

Adaptation strategies included crop diversification, modification of irrigation practices, adoption of climate-resilient seed varieties, altered sowing dates, and soil conservation measures.

Independent Variables

The independent variables included socio-economic and institutional factors commonly identified in climate adaptation literature.

Analytical Framework and Model Specification

Descriptive and Inferential Analysis

Descriptive statistics such as mean, frequency and percentage were used to summarize farmers' socio-economic characteristics, perceptions and adaptation strategies. The chi-square test was employed to examine associations between categorical variables, particularly adaptation behavior and landholding or income categories.

Table 1: Description of Variables Used in Logistic Regression

Variable	Description	Measurement
Age	Age of household head	Years
Education	Years of formal schooling	Years
Landholding size	Total cultivated land	Hectares
Income	Annual farm income	₹
Credit access	Access to institutional credit	Yes = 1, No = 0
Extension services	Access to agricultural extension	Yes = 1, No = 0

Binary Logistic Regression Model

To identify factors influencing the adoption of climate change adaptation strategies, a binary logistic regression model was employed. Logistic regression is appropriate when the dependent variable is dichotomous and has been widely used in climate adaptation studies (Deressa et al., 2009).

The model is specified as:

$$\ln\left(\frac{P_i}{1-P_i}\right) = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \dots + \beta_n X_n + \varepsilon_i$$

Where:

P_i = Probability that the farmer adopts adaptation strategies

β_0 = Intercept

β_n = Coefficients of explanatory variables

X_n = Socio-economic and institutional variables

ε_i = Error term

The estimated coefficients were transformed into odds ratios to facilitate interpretation of results.

Model Diagnostics

Model adequacy was assessed using:

- Nagelkerke R^2
- Hosmer–Lemeshow goodness-of-fit test
- Classification accuracy

These diagnostics ensure robustness and reliability of regression results.

Software Used

Data were coded, cleaned and analyzed using Statistical Package for the Social Sciences (SPSS) and Microsoft Excel. Graphical representations were prepared to support descriptive analysis.

Results

Socio-Economic Characteristics of the Respondents

The socio-economic profile of the surveyed farmers provides essential context for understanding perception formation and adaptation behavior. Table 1 summarizes the key characteristics of the 1,000 sampled respondents.

Table 2: Socio-Economic Characteristics of Sample Farmers (n = 1,000)

Variable	Category	Frequency	Percentage (%)
Age (years)	< 35	286	28.6
	35–50	462	46.2
	> 50	252	25.2
Education	Illiterate	214	21.4
	Primary–Secondary	498	49.8
	Higher education	288	28.8
Landholding size	Marginal (<1 ha)	425	42.5
	Small (1–2 ha)	347	34.7
	Medium & Large (>2 ha)	228	22.8
Access to credit	Yes	604	60.4
	No	396	39.6
Extension services	Yes	571	57.1
	No	429	42.9

The data indicate that agriculture in Moradabad district is dominated by small and marginal farmers, with more than 77% cultivating less than two hectares of land. Although a substantial proportion of farmers had some level of formal education, access to institutional credit and extension services remained uneven.

Farmers' Perceptions of Climate Variability

Farmers were asked about their perceptions of long-term changes in temperature, rainfall, drought occurrence and pest incidence. Their responses are summarized in Table 2.

A large majority of farmers perceived noticeable changes in climatic conditions over the past three decades. Perceptions of rising temperature and rainfall variability were particularly strong, indicating widespread awareness of climate-related risks among farming households.

Climate Perception Index

To capture the overall intensity of farmers' climate perceptions, a Climate Perception Index (CPI) was constructed by aggregating responses across four perception variables. Farmers were classified into three categories based on index scores.

More than 42% of farmers exhibited high levels of climate change perception, suggesting that experiential learning and repeated exposure to climatic shocks have heightened awareness at the local level.

Adaptation Strategies Adopted by Farmers

Farmers were asked whether they had adopted specific adaptation strategies in response to perceived climate variability. Multiple responses were permitted. The distribution of adaptation strategies is presented in Table 4.

Table 3: Farmers' Perceptions of Climate Change (%)

<i>Perceived climatic change</i>	<i>Agree</i>	<i>Neutral</i>	<i>Disagree</i>
Increase in temperature	82.4	10.1	7.5
Erratic rainfall patterns	76.1	13.7	10.2
Increased drought frequency	68.3	18.4	13.3
Increased pest and disease incidence	71.6	15.2	13.2

Table 4: Climate Perception Index Classification

<i>Perception level</i>	<i>Index score range</i>	<i>Farmers (%)</i>
Low perception	< 1.5	17.9
Moderate perception	1.5 – 2.5	39.4
High perception	> 2.5	42.7

Crop diversification emerged as the most widely adopted strategy, followed by modifications in irrigation practices. However, nearly one-third of farmers reported not adopting any adaptation strategy, highlighting significant adaptation gaps.

Adaptation Intensity Index

An Adaptation Intensity Index (AII) was constructed based on the number of strategies adopted by individual farmers. Farmers were grouped into low, medium and high adaptation categories.

The results indicate that while a substantial proportion of farmers engaged in some level of adaptation, only 28.4% adopted multiple strategies, reflecting constraints in scaling up adaptive responses.

Adaptation Across Landholding and Income Groups

To examine disparities in adaptation behavior, adaptation adoption was analyzed across landholding categories.

The chi-square test revealed a statistically significant association between landholding size and adaptation adoption ($\chi^2 = 42.6$, $p < 0.01$), indicating that farmers with larger landholdings were more likely to adopt climate adaptation strategies.

Association Between Income and Adaptation

Income level was also found to influence adaptation behavior. Table 7 presents adaptation adoption across income categories.

Table 5: Adaptation Strategies Adopted by Farmers

<i>Adaptation strategy</i>	<i>Frequency</i>	<i>Percentage (%)</i>
Crop diversification	618	61.8
Change in irrigation practices	542	54.2
Adoption of climate-resilient seeds	476	47.6
Alteration of sowing dates	395	39.5
Soil conservation measures	337	33.7
No adaptation adopted	284	28.4

Table 6: Adaptation Intensity Index

<i>Adaptation level</i>	<i>Number of strategies</i>	<i>Farmers (%)</i>
Low adaptation	1 strategy	31.6
Medium adaptation	2–3 strategies	40.0
High adaptation	≥ 4 strategies	28.4

Table 7: Adaptation Adoption by Landholding Size

<i>Landholding category</i>	<i>Adapted (%)</i>	<i>Not adapted (%)</i>
Marginal farmers	48.2	51.8
Small farmers	63.7	36.3
Medium & large farmers	78.9	21.1

Table 8: Adaptation Adoption by Income Group

<i>Annual farm income</i>	<i>Adapted (%)</i>	<i>Not adapted (%)</i>
Low income	45.9	54.1
Middle income	66.8	33.2
High income	81.2	18.8

The chi-square test confirmed a statistically significant association between income and adaptation adoption ($\chi^2 = 38.9$, $p < 0.01$).

Determinants of Adaptation: Binary Logistic Regression Results

A binary logistic regression model was estimated to identify socio-economic and institutional factors influencing adaptation adoption. The results are presented in Table 8.

Model Diagnostics

The logistic regression model demonstrated satisfactory goodness-of-fit and explanatory power:

- Nagelkerke $R^2 = 0.42$
- Hosmer–Lemeshow test: $\chi^2 = 6.18$ ($p = 0.63$)
- Overall classification accuracy = 74.6%

These diagnostics indicate that the model fits the data well and reliably explains variation in farmers' adaptation behavior.

Table 9: Binary Logistic Regression Results for Adaptation Adoption

<i>Variable</i>	<i>Coefficient (β)</i>	<i>Standard error</i>	<i>Odds ratio</i>	<i>p-value</i>
Age	−0.03	0.01	0.97	0.072
Education	0.41	0.13	1.51	0.002**
Landholding size	0.58	0.15	1.79	0.000***
Income	0.36	0.14	1.43	0.008**
Credit access	0.67	0.18	1.95	0.001***
Extension services	0.72	0.17	2.05	0.000***
Constant	−1.84	0.42	—	0.000

*** $p < 0.01$, ** $p < 0.05$

Discussion

This study provides robust micro-level evidence on farmers' perceptions of climate change and their adaptation strategies in Moradabad district of western Uttar Pradesh. The discussion situates the empirical findings within existing theoretical and empirical literature on climate adaptation in agriculture.

Farmers' Perceptions of Climate Change

The results demonstrate a high level of climate change awareness among farmers, with more than four-fifths perceiving an increase in temperature and over three-fourths reporting erratic rainfall patterns. These perceptions closely align with meteorological evidence reported by the Indian Meteorological Department and the IPCC, which document rising mean temperatures and increasing rainfall variability in northern India (IPCC, 2021; IMD, 2022). Consistent with the risk perception adaptation hypothesis (Smit & Wandel, 2006), farmers' lived experiences of repeated climatic shocks such as delayed monsoons, heat stress during crop growth stages, and declining groundwater levels appear to have heightened their awareness. Similar high perception levels have been reported in Ethiopia (Deressa et al., 2009), Bangladesh (Hassan & Nhemachena, 2008) and semi-arid regions of India (Mall et al., 2006). The Climate Perception Index further indicates that nearly 43% of farmers exhibit high climate perception. This supports the argument that perception is a necessary but not sufficient condition for adaptation; while awareness is widespread, actual adaptation remains uneven across socio-economic groups.

Patterns of Adaptation Strategies

The predominance of crop diversification and irrigation adjustments as adaptation strategies reflects farmers' preference for incremental, low-cost and locally manageable responses. Crop diversification reduces risk exposure by spreading climatic risk across crops with different sensitivities, a strategy widely observed in climate-vulnerable agrarian systems (Bryan et al., 2013; BIRTHAL et al., 2014). Adoption of climate-resilient seed varieties, although substantial (47.6%), remains lower than expected given policy emphasis on seed-based technological solutions. This gap can be attributed to limited availability, higher costs and inadequate extension outreach constraints also noted by FAO (2018) and Rao et al. (2020). The Adaptation Intensity Index reveals that only 28.4% of farmers adopted four or more strategies, suggesting that adaptation depth remains shallow, particularly among resource-constrained households. This finding reinforces earlier evidence that smallholders often engage in partial adaptation rather than comprehensive risk management (Adger et al., 2009).

Inequality in Adaptation: Landholding and Income Effects

Significant disparities in adaptation adoption across landholding and income groups underscore structural inequalities in adaptive capacity. Medium and large farmers exhibited substantially higher adaptation rates than marginal farmers, a pattern consistently reported in Indian and international studies (Deressa et al., 2009; Aryal et al., 2020).

- Larger landholdings provide:
- Greater financial flexibility
- Better access to institutional credit
- Higher risk-bearing capacity

Similarly, income effects indicate that poorer farmers face binding liquidity constraints, limiting their ability to invest in irrigation technologies, improved seeds and soil conservation measures. These findings confirm the adaptive capacity framework, which emphasizes that economic resources are critical determinants of climate resilience (Adger, 2006).

Determinants of Adaptation: Insights from Logistic Regression

The logistic regression results provide strong empirical support for the role of socio-economic and institutional factors in shaping adaptation behavior.

Education

- Education significantly increased the likelihood of adaptation, suggesting that educated farmers are better able to:
- Access climate information
- Understand extension advisories
- Evaluate technological options

This finding aligns with earlier studies in South Asia and Sub-Saharan Africa (Hassan & Nhemachena, 2008; Bryan et al., 2013).

Landholding size and income

The positive influence of landholding size and income confirms that adaptation is capital-intensive, even when strategies are incremental. Without targeted support, smallholders risk falling into a climate vulnerability trap.

Access to credit

Credit access nearly doubled the odds of adaptation adoption. Institutional credit enables farmers to overcome upfront investment barriers, echoing findings from FAO (2018) and BIRTHAL et al. (2014).

Extension services

Extension services emerged as the strongest determinant of adaptation. Farmers with extension access were more than twice as likely to adopt adaptation strategies, highlighting the critical role of knowledge dissemination, trust, and institutional presence at the local level.

Conclusion

This study provides comprehensive micro-level evidence on farmers' perceptions of climate change and their adaptation strategies in Moradabad district of western Uttar Pradesh. The findings demonstrate that while climate awareness among farmers is high, actual adaptation remains uneven and strongly shaped by socio-economic and institutional factors. Education, landholding size, income, access to credit and extension services significantly influence farmers' likelihood of adopting adaptation strategies. Small and marginal farmers despite being the most vulnerable exhibit the lowest adaptation rates, highlighting a critical equity gap in climate resilience. By integrating perception analysis, adaptation indices, and econometric modeling, the study contributes to the growing literature on climate adaptation in developing-country agriculture and provides policy-relevant insights for climate-vulnerable regions.

Policy Implications

Based on the findings, the following policy recommendations are proposed:

- Strengthen Agricultural Extension Systems
- Expand climate-focused extension programs at the block and village level
- Integrate climate advisories with digital platforms and local language dissemination
- Improve Access to Institutional Credit
- Simplify loan procedures for small and marginal farmers
- Promote climate-linked credit products and crop insurance schemes
- Promote Climate-Resilient Technologies
- Subsidize climate-resilient seed varieties and micro-irrigation systems
- Encourage public-private partnerships for last-mile delivery
- Target Small and Marginal Farmers
- Design differentiated adaptation support programs
- Prioritize women farmers and tenant cultivators in climate policy design
- Integrate Local Knowledge into Climate Planning
- Incorporate farmers' experiential knowledge into district-level climate action plans

Limitations and Future Research Directions

Despite its strengths, the study has certain limitations:

- The cross-sectional design limits causal inference.
- Self-reported perception data may be subject to recall bias.
- The analysis focuses on adaptation adoption rather than long-term effectiveness.

Future research should:

- Employ panel data to capture dynamic adaptation processes.

- Assess economic and environmental outcomes of adaptation strategies.
- Examine gender-differentiated adaptation behavior and institutional barriers.

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