



Assessing Climate Change Adaptation Strategies among Livestock Rearers in Bundelkhand Region, India

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HIGHLIGHTS

- Scientific livestock adaptations showed very low adoption in the region.
- Education, herd size and livelihood diversification emerged as key adaptation enablers.
- Socioeconomic capacity and social engagement play a more influential role in shaping how livestock rearers in Bundelkhand respond to climatic risks through adaptation strategies.

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ABSTRACT

The study was conducted in the year 2024-25, assessing both the degree of implementation of adaptation measures and the factors that influence these strategies among livestock rearers in the Banda district of Uttar Pradesh and Chhatarpur district of Madhya Pradesh. A total of 320 livestock rearers were chosen as respondents using a multi-stage sampling method. Eighteen adaptation strategies were identified using a Climate Change Adaptation Index (CCAI), and subsequently analysed through factor analysis and ordinal logistic regression to ascertain the determinants of adaptation behaviour. Findings revealed that maintaining fodder banks (mean score: 1.825), seasonal livelihood diversification (1.6906), and vector control measures (1.4625), were the most frequently adopted strategies. Conversely, preventive healthcare, low-cost housing improvements, and feeding adjustments reflected lower levels of adoption. Factor analysis identified three components, accounting for 72.22 per cent of the total variation. Ordinal logistic regression showed that herd size, community participation and education levels were favourably correlated with enhanced adaptation, but family size showed negative significance. A majority of respondents (66.87%) exhibited a moderate level of adaptability. The results highlighted the disparate adaptive capacities among livestock rearers and the need for targeted extension interventions in the Bundelkhand region.

INTRODUCTION

Climate change has become one of the most significant global challenges of the 21st century, profoundly affecting agriculture and livestock production systems. According to the IPCC Sixth Assessment Report AR6, 2023, warming trends in South Asia are progressing more rapidly than the world average, with the occurrence of heatwaves, droughts, and irregular rainfall patterns.

These climatic stressors impact smallholder livestock producers, who depend significantly on climate-sensitive natural resources for feed, water, and pasture. Livestock is a vital element of mixed farming systems in India, offering nourishment, financial security, draught power, and cultural significance; thus, any disturbance in animal productivity and health poses a direct threat to rural livelihoods (IPCC, 2023). India remains one of the most climate-vulnerable countries because rural livelihoods depend heavily on

climate-sensitive natural resources, and farmers' adaptation decisions are strongly shaped by rainfall variability, temperature stress, and access to institutional support (Jatav & Singh, 2023). The cattle sector in India, while making a substantial contribution to agricultural GDP, is very susceptible to climate variations due to its reliance on rain-fed feed resources and inadequate adaptive infrastructure. Several studies have reported that rising temperatures, diminishing water resources, and increased disease prevalence are adversely affecting livestock productivity throughout the country's agro-climatic region. According to (Maiti et al., 2014) it was found that dairy producers in coastal Odisha and West Bengal increasingly depended on short-term coping methods.

The Bundelkhand region experiences extreme temperatures, unpredictable rainfall, and chronic water scarcity, making dairy farming in the region highly vulnerable to climate variability (Mishra et al., 2025). Irregular rainfall pattern, water shortages, deteriorated pastures, and repeated drought cycles have intensified livelihood insecurity among the livestock-dependent communities. Similar findings have been documented by (Pathak et al., 2024), who reported that livestock rearers face considerable exposure to drought, erratic rainfall and groundwater depletion. The region's significant dependence on indigenous knowledge, restricted access to veterinary services, and inadequate extension systems further hinder livestock rearers from implementing sustainable climate-resilient methods (Tripathi et al., 2023). Prior evaluations have highlighted that although livestock rearers in drought-stricken areas employ various practical and economical coping strategies, more substantial and investment-intensive approaches are inadequately utilized owing to financial limitations and insufficient institutional support (Shanthya & Meena, 2024; Singh et al., 2012).

Recent studies show that livestock rearers' adaptation behaviour is shaped by climate exposure, along with socioeconomic and institutional conditions, and that limited technical knowledge can restrict adoption (Pankaj, 2013; Sejian et al., 2015). The growing focus on short-term coping strategies and reactive measures such as heightened watering frequency, altered feeding schedules, and vector control shows the dominance of immediate relief operations over systemic resilience-building initiatives. The IPCC AR6 emphasizes that livestock systems in tropical areas must focus on mitigating heat stress, developing robust feed systems, and enhancing water-use efficiency to maintain productivity and minimize climate-related losses. This study was conducted in Banda (UP) and Chhatarpur (MP), aims to comprehensively assess the adaptation strategies employed by livestock rearers in Bundelkhand and identify the factors influencing their adaptive behaviour.

METHODOLOGY

The study was conducted in the Bundelkhand region of India, focusing specifically on the Banda district in Uttar Pradesh and Chhatarpur district in Madhya Pradesh. These two districts were selected purposively on the basis of highest population of milch animals in the region (Livestock Census, 2019) and because a large share of rural households depend directly on livestock for their livelihoods. The study adopted a descriptive and diagnostic approach to document the adaptation strategies currently practised by livestock rearers and to examine the factors influencing their

adoption. A multi-stage sampling method was used to obtain a representative sample from the two districts. In the first stage, two blocks were randomly selected from each district, comprising a total of four blocks. In the second stage, four villages were randomly chosen from each selected block, resulting in sixteen villages. In the third stage, twenty livestock rearers were randomly selected from each village based on two criteria: (i) at least fifteen years of experience in livestock rearing and (ii) ownership of a minimum of four milch animals. This procedure produced a final sample size of 320 respondents. Data were collected using a Climate Change Adaptation Index (CCAI) developed specifically for this study. The index was designed after conducting a pilot survey with 40 livestock rearers from non-sampled villages in the study area. Based on the pilot and expert inputs, eighteen adaptation strategies covering heat stress management, feed and water security, breed selection, housing modifications, milk handling, and animal healthcare were identified. These strategies were further grouped into components through exploratory factor analysis. Respondents indicated their level of adoption for each strategy using three ordered categories: "never adopted (0)," "adopted but discontinued (1)," and "adoption continued (2)." This coding made the dataset suitable for ordinal logistic regression. The explanatory variables included demographic, socioeconomic, and institutional factors such as age, family size, total annual income, herd size, level of education (four categories), farmer-to-farmer extension, social participation, gender, assistance from external agencies, experience of extreme climatic events, and a composite community participation score. Data analysis was carried out using SPSS and Microsoft Excel. Descriptive statistics were used to determine adoption, non-adoption, and discontinuation patterns for each strategy, while mean CCAI scores were employed to rank the strategies according to their relative importance.

RESULTS

Adaptation strategies

The significant variance in Table 1 shows the extent to which livestock rearers implement various methods. The most highly regarded adaptation practices were the maintenance of fodder banks (WMS = 1.8250), followed by seasonal livelihood diversification (1.6906) and vector control and mastitis prevention (1.4625). These approaches were predominantly favoured due to their cost-effectiveness, ease of implementation, and provision of immediate advantages during drought or heat events. In contrast, the methods with the lowest rankings comprised preventative healthcare (0.7781), feeding cattle during cooler hours (0.8063), and structural housing enhancements (0.8281), suggesting that livestock rearers paid significantly less attention to long-term or investment-intensive measures. A significant result is that coping-oriented techniques prevail over planned adaptation measures.

The summary of the factor analysis, in Table 2 presents the latent dimensions underlying the 18 adaptation strategies. The KMO value of 0.721 and a highly significant Bartlett's Test ($\chi^2 = 2304.987$; $p < 0.001$) confirmed the suitability of the dataset for principal component analysis. Three components with eigenvalues greater than one were extracted, together explaining 72.22% of the total variance. The rotated component matrix (Varimax) revealed clear

Table 1. Ranking of adaptation strategies

S.No. Statements	WMS	RANK
1. Extra bathing of cattle and buffaloes	1.4000	4
2. Search for alternate sources of income (out migration)	0.9063	11
3. Grow drought or heat resilient green fodders	0.9031	12
4. Add extra concentrate during heat/drought periods (beyond normal ration)	0.8938	13
5. Seasonal livelihood diversification (short-term wage/migration, fodder trading, value addition like ghee/khoya)	1.6906	2
6. Strengthen vector control (ticks/flies) and mastitis prevention (shade at milking, teat dipping, insect repellent smoke, Animal hygiene)	1.4625	3
7. Adopt low-cost housing improvements (floor drainage, non-slip)	0.8281	16
8. Provide mineral mixture or feed additives, electrolytes/buffers during heat stress (e.g, ORS, Sodium bicarbonate, salt and urea molasses block)	1.1750	5
9. Improve milk handling in heat (shift milking to cooler hours; shade at collection; insulated cans)	1.1281	7
10. Prefer local breeds suited to heat or water stress as per local advisories	1.1500	6
11. Maintain fodder banks (silage/hay) for drought periods	1.8250	1
12. Instant actions on local weather/heat-cold wave alerts (IMD SMS alerts/KVK/KCC)	1.0500	9
13. Adjust herd structure seasonally (destocking of chronic low producers before peak drought)	0.9500	10
14. Seek paravet /veterinary/cooperative advice specifically on heat and drought operations for cattle and buffaloes	1.0750	8
15. Shift feeding to cooler hours (early morning/late evening); split feeding	0.8063	17
16. Increase watering frequency; ensure clean, shaded drinking water	0.8344	15
17. Reduce midday exposure, reschedule grazing/animal movements away from 11:00 AM–04:00 PM	0.8844	14
18. Preventive Health care (timely vaccination, deworming)	0.7781	18

Table 2. Factor analysis summary for adaptation strategies

KMO and Bartlett's Test			
Test		Value	
KMO Measure of Sampling Adequacy		0.721	
Bartlett's Test of Sphericity (χ^2)		2304.987	
df		55	
Sig.		< 0.001	
Total Variance Explained			
Component	Eigenvalue	% of Variance	Cumulative %
1	4.397	39.97%	39.97%
2	2.006	18.23%	58.20%
3	1.542	14.02%	72.22%
Rotated Component Matrix (Varimax)			
Adaptation Strategy	Comp 1	Comp 2	Comp 3
Increase watering frequency	0.939	—	—
Reduce midday exposure	0.936	—	—
Extra concentrate feeding	0.919	—	—
Grow drought resistant fodder	0.846	—	—
Shift feeding to cooler hours	0.597	—	—
Seasonal livelihood diversification	—	0.872	—
Maintain fodder banks	—	0.808	—
Prefer local breeds	—	0.754	—
Alternate income (migration)	—	—	0.841
Weather alert-based actions	—	—	0.747
Low-cost housing improvements	—	—	0.629

and interpretable groupings of adaptation practices. Component 1 represented immediate heat-stress and feeding-water management actions such as increased watering, reduced midday exposure, feeding adjustments, and use of concentrate supplements. Component 2 captured resource-buffering and livelihood security measures, including maintaining fodder banks, preferring heat-tolerant breeds, and engaging in seasonal livelihood diversification. Component 3 included structural and advisory-based strategies such

as housing improvements, weather-alert responses, and migration-based income alternatives.

The scree plot, Figure 1 illustrates the eigenvalues corresponding to each component derived from Principal Component Analysis (PCA). An evident inflexion point (“elbow”) emerges after the third component, signifying that only the initial three components possess eigenvalues exceeding 1 and significantly contribute to variance explanation. Components 1, 2, and 3 exhibit

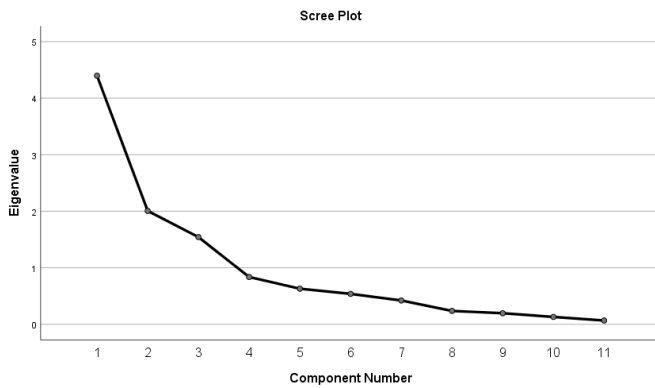


Figure 1. Scree plot for adaptation strategies

significant decreases in eigenvalue magnitude, justifying their preservation, whereas the subsequent components display a

generally horizontal trajectory, signifying little explanatory capacity. This visual pattern confirms the factor-analytic findings presented in Table 2, substantiating the extraction of three significant adaption factors from the dataset.

Determinants of adaptation behaviour

The determinants of adaptation behaviour and the underlying structure of adaptation strategies were examined using ordinal logistic regression. The consolidated regression results in Table 3 show the socioeconomic and demographic factors shaping climate adaptation among livestock rearers. The overall model was statistically significant ($\chi^2 = 105.291, p < 0.001$), indicating that the selected predictors meaningfully improved the model compared to the intercept-only specification. Both Pearson and Deviance goodness-of-fit tests were non-significant, confirming that the model fits the data well, and the proportional odds assumption was

Table 3. Coefficient estimates for determinants of adaptation

Explanatory Variables	Estimate (β)	Exp (β) Point Estimate	Sig. (p)
Location			
Community Participation Total	0.478	0.6200222	0.007**
Herd Size	0.460	1.58407398	0.000**
Age	0.015	1.01511306	0.304
Income Total	5.003E-7	1.0000005	0.644
Family Size	-0.346	0.70751249	0.000**
[Education=.00]	-1.205	0.299692	0.020*
[Education=1.00]	-2.513	0.0810248	0.000**
[Education=2.00]	-1.347	0.26001915	0.001**
[Education=3.00]	0 ^a	-	.
[Farmer to farmer extension =.00]	0.068	-	0.888
[Farmer to farmer extension =1.00]	0 ^a	1.07036531	.
[Social Participation=.00]	-0.518	-	0.175
[Social Participation=1.00]	0 ^a	0.59571078	.
[Gender=1.00]	0.872	-	0.145
[Gender=2.00]	0 ^a	2.39168945	.
[Assistance from external agency=.00]	-0.313	-	0.479
[Assistance from external agency =1.00]	0 ^a	0.73124991	.
[Extreme climatic events experienced=.00]	-0.053	-	0.914
[Extreme climatic events experienced =1.00]	0 ^a	0.94838001	.

**Indicates significant at 1 % level of significance, in a two-tailed test

*Indicates significant at 5 % level of significance, in a two-tailed test

Model fit statistics		
-2 Log Likelihood (Intercept only)		527.766
-2 Log Likelihood (Final model)		422.475
Chi-square		105.291
df		13
p-value		< 0.001
Goodness-of-Fit		
	Pearson	Deviance
Chi-square	711.828	417.741
df	607	607
Sig.	0.846	1.000
Test of Parallel Lines (Proportional Odds Assumption)		
Statistic	Value	
-2 Log Likelihood (Null model)	422.475	
-2 Log Likelihood (General model)	400.210	
Chi-square	22.265	
df	13	
Sig.	0.251 (NS → assumption holds)	

satisfied ($p > 0.05$), supporting the use of the ordinal logit framework. Among the significant predictors, herd size had a strong positive effect, suggesting that households managing larger herds are more inclined to adopt multiple adaptation strategies, likely due to a higher stake in protecting productive assets. Community participation also showed a positive and significant influence on adaptation, meaning individuals who are more actively involved in local groups or collective activities tend to adopt a wider set of climate-related strategies, possibly because such networks facilitate knowledge exchange, collective learning, and better access to information. Family size, on the other hand, had a negative association with adaptation, indicating that households with more dependents may face constraints in reallocating labour or resources toward new practices. Education further displayed a clear gradient; lower schooling levels were strongly linked with reduced adaptation when compared to the most educated category (0a), which is the baseline category, as shown in the table, indicating higher adaptation in highly educated categories. Other variables such as age, income, gender, extension contact, and exposure to extreme climate events were not statistically significant in predicting adaptation levels. Taken together, the findings suggest that socioeconomic capacity and social engagement, rather than basic demographic attributes, play a more influential role in shaping how livestock rearers in Bundelkhand respond to climatic risks through adaptation strategies.

DISCUSSION

The adaptive behaviour of livestock rearers in Bundelkhand shows a strong reliance on practical, low-cost, and experience-based responses to climate stress, a pattern widely observed across climate-affected regions of India. Similar to the present findings, Pathak et al. (2024) reported that livestock rearers in Bundelkhand preferred easily adoptable, low-investment measures. Comparable behaviour was also documented by Sejian et al. (2015), who noted that livestock rearers generally prioritise immediate heat-stress relief, shade, wallowing, modified grazing schedules, and more water, while long-term structural solutions receive less emphasis. Similar short-term preferences were also observed in semi-arid regions, where adjustments in feeding time and water provision were common, despite sometimes reducing productivity (Mishra et al., 2025). As noted by Das (2017), rising temperature-humidity levels provoke quick adjustments cooling, shading, feeding changes, rather than scientific housing improvements or preventive healthcare. The limited adoption of high-investment measures such as water harvesting, livestock insurance, improved ventilation, and preventive veterinary care reflects financial and technical constraints similar to those noted by (Choudhary, 2020). Chronic issues like weak extension services and persistent fodder scarcity, as highlighted by (Singh et al., 2012 & Das, 2017), also contribute to the reliance on fodder storage, crop residue use, and feeding modifications as key adaptation strategies. Evidence from the Indo-Gangetic Plain also shows that livestock rearers value low-cost climate-smart measures but lack confidence in expensive innovations due to financial risk (Shitu & Nain, 2024). The medium adaptation level among most respondents indicates a partially developed adaptation profile, moderate awareness and practice, but limited depth, similar to the fragmented climate-resilient packages reported in Tamil Nadu by

Shanthya and Meena (2024). Socioeconomic factors strongly influence adaptation behaviour. Larger herd ownership had a positive association with adaptation, consistent with the IPCC report, which argues that households with more livestock have greater incentive to protect their assets. In contrast, the negative effect of large family size supports the “financial dilution effect” described by Pankaj (2013), where higher dependency ratios reduce capacity for climate-related investments. Education emerged as a key enabler, supporting (Sejian et al., 2015), who found that educated livestock rearers interpret weather advisories better and adopt improved feeding and health strategies. Similar patterns were observed among tribal dairy farm women in Jammu & Kashmir, where limited education and low empowerment checked the adoption of improved livestock practices (Singh et al., 2017). These studies collectively demonstrate that limited resources, low awareness, and weak access to services suppress long-term adaptation in Bundelkhand as well. Community participation also showed a positive association with adaptation. This aligns with Olawuyi et al. (2021), who found that involvement in social-capital networks significantly increases the likelihood of adopting a wider set of climate-adaptive practices. Likewise, (Chen & Tang, 2025) showed that social networks, trust, and participation all promote multiple adaptation behaviours. These findings suggest that community-based learning and shared support systems enable livestock rearers in Bundelkhand to expand their adaptation behaviour. Factor analysis in this study grouped adaptation strategies into three clusters: (i) heat-stress management, (ii) feed and water security, and (iii) structural or advisory interventions. This aligns with the typology proposed by Prasad et al. (2015), which distinguishes short-term physiological coping, resource buffering, and long-term systemic strategies. The dominance of the first two clusters shows that adaptation in Bundelkhand remains mostly reactive. Along with the regression results, this indicates that adaptation is shaped by financial limits, feasibility, indigenous knowledge, and access to veterinary and advisory services. Enhancing climate-adaptive extension, ensuring fodder and water security, and improving credit access are essential for moving livestock rearers from short-term coping to sustainable, climate-resilient practices.

CONCLUSION

Livestock rearers in the drought-prone Bundelkhand region rely mainly on short-term, experience-based practices to manage rising climate stress. Measures such as fodder storage, seasonal livelihood adjustments, vector control, frequent watering, and altered grazing routines are widely used, while long-term strategies that require higher investment, improved housing, preventive healthcare, water harvesting, or advanced feeding remain limited due to financial and structural constraints. The analysis shows that adaptation is strongly shaped by socioeconomic conditions. Households with larger herd size, better education, and stronger community participation adopt more measures, whereas resource-poor families face greater hurdles. Factor analysis confirms that adaptation is multidimensional, involving heat-stress management, resource buffering, and structural improvements, though the first two dominate. Overall, the study indicates that adaptation in the

Bundelkhand region is still largely reactive, underscoring the need for stronger institutional support through veterinary services, climate-smart extension, drought-resilient fodder options, and accessible credit.

DECLARATIONS

Ethics approval and informed consent: Informed consent was sought from the respondents regarding the study during the course of the data collection.

Conflict of interest: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

The authors declare that during the preparation of this work, they thoroughly reviewed, revised, and edited the content as needed. The authors take full responsibility for the final content of this publication.

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