International Journal of Applied Review
www.multiappliedjournal.com
E-ISSN: 3107-8443
Received: 13-09-2026, Accepted: 13-10-2026, Published: 28-10-2026
Volume 2, Issue 4, 2026, Page No. 16-24

Climate change, agricultural vulnerability and rural livelihood adaptation in Bilaspur District, Chhattisgarh

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DOI: https://doi.org/10.66856/ijar.2026.2.4.2110

Abstract
This study examines climate variability, agricultural vulnerability and rural livelihood adaptation in Bilaspur District, Chhattisgarh, within a predominantly rainfed rice-growing setting. The source manuscript reports a mixed-methods study integrating a household survey of 420 farming households in 42 villages across six selected blocks, 24 focus-group discussions, 45 key-informant interviews and a 1990–2022 climate series. Mann–Kendall and Sen-slope analyses characterized climate trends; Livelihood Vulnerability Index (LVI) and LVI–IPCC frameworks assessed vulnerability; and binary logistic regression examined adaptation correlates.
Annual mean temperature reportedly increased by 0.032°C year−1 ($p < 0.001$), while annual rainfall showed no statistically significant trend despite increasing monsoon variability. Drought-year rice yields were 18.4% lower than normal-year yields. The composite LVI was 0.452, with stronger vulnerability among marginal, rainfed and female-headed households. Of the respondents, 73.1% adopted at least one adaptation measure: crop diversification (48.6%), changed planting dates (42.1%) and water-efficient practices (38.3%) were prominent. Education, farm size, irrigation, extension access, credit access and climate information were positively associated with adoption. The study highlights the need for targeted irrigation, climate services, institutional access and livelihood diversification. This shortened article retains the source manuscript's reported results; the underlying data have not been independently reanalysed.

Keywords: Climate change, livelihood vulnerability, rice agriculture, adaptation, LVI–IPCC, smallholder farmers, Chhattisgarh

Introduction
Climate change threatens agricultural productivity and rural wellbeing through heat stress, fluctuations in monsoon timing, extreme precipitation and prolonged dry spells. Smallholder production systems are particularly exposed because access to irrigation, savings and risk-reducing technologies is uneven (Morton, 2007; IPCC, 2022) [39]. In India, this vulnerability intersects with poverty, market access, land fragmentation and reliance on seasonal rainfall (Birthal *et al*., 2014; Auffhammer *et al*., 2012) [4, 7].
Bilaspur occupies an important rice-producing landscape in central India. The original study situates the district within a region characterized by high dependence on kharif rainfall and restricted irrigation access (Government of Chhattisgarh, 2020) [19]. The dominant concern is not only whether total rainfall changes, but whether moisture arrives at critical phenological stages. Delayed onset, intra-seasonal dry spells, rainfall extremes and high temperature around flowering can reduce crop yields and farm income (Peng *et al*., 2004; Goswami *et al*., 2006) [18, 44].

Research problem and objectives
Macro-scale climate assessments do not necessarily explain differences between households facing comparable weather hazards. The manuscript therefore integrates historical climate trends, self-reported livelihood outcomes and institutional influences on adaptation. It addresses five objectives: to characterize 1990–2022 temperature and rainfall trends; assess vulnerability using LVI indicators; describe on-farm and livelihood adaptations; model their socioeconomic and institutional correlates; and identify policy opportunities for climate-resilient rural development.
The emphasis on livelihood outcomes is necessary because similar rainfall anomalies can produce markedly different consequences. Farm households with reliable irrigation, savings, access to advice or a second income source may respond to the same dry spell differently from households wholly reliant on rainfed rice. Moreover, climate adaptation is a process, not a single decision: initial experimentation, continued use, and adjustments after a failed season can each depend on different resources. The present analysis therefore treats climate hazard exposure, pre-existing economic sensitivity and farmers' coping options as related but analytically distinct elements of rural resilience.

Literature Review and Conceptual Framework
Studies of Indian agriculture associate temperature extremes, monsoon anomalies and drought with unstable production; responses vary by crop, district and resource endowment (Auffhammer *et al*., 2012; Guhathakurta *et al*., 2020) [4, 20]. Adaptation comprises changes in crop varieties and planting dates, water management, diversification, insurance, savings and off-farm employment (Smit & Skinner, 2002; Aryal *et al*., 2020) [3, 55]. Adoption may be constrained by credit, information, access to extension services and household assets (Below *et al*., 2012; Deressa *et al*., 2009) [5, 11].
Vulnerability is interpreted as the interaction of exposure to climate hazards, sensitivity of production and livelihoods, and adaptive capacity (IPCC, 2014). The Sustainable Livelihoods Framework locates household responses within

access to human, natural, social, financial and physical capital (DFID, 1999). The LVI approach operationalizes this understanding using composite household indicators (Hahn *et al*., 2009) [22]. Important concerns are differential vulnerability across gender and social categories and whether institutional interventions reach the most exposed households (O'Brien *et al*., 2004; Arora-Jonsson, 2011) [2, 40].

Research on adaptation also draws attention to the difference between short-term coping and sustained capacity building. Selling productive assets, reducing food consumption or increasing costly borrowing may enable a household to survive an immediate shock while undermining future adaptation capacity. In contrast, crop diversification, timely seasonal advice and financially sustainable irrigation can potentially reduce longer-term risk, provided their costs and trade-offs are understood (Agrawal, 2010; Eriksen *et al*., 2021) [1, 15]. Water and soil management require attention to collective institutions because upstream abstraction and groundwater use generate external effects beyond a single farm.

Risk is also multidimensional. A drought may lower rice production but improve prices for some growers, while heavy rainfall can damage harvested crops, roads, storage facilities and market access. The livelihood approach therefore considers agricultural outcomes together with food purchases, household debt, labour supply and access to services rather than relying on output statistics alone. This helps explain why a moderate district-level index can conceal high vulnerability within particular villages and household categories.

Study Area and Agricultural Profile

The source manuscript describes the Bilaspur study region in northern Chhattisgarh, where monsoonal agriculture, especially rice production, remains central to rural livelihoods. For its reference geography, the manuscript reports an annual rainfall mean of 1,287 mm, with approximately 85–90% arriving during the monsoon. The agricultural profile gives a net sown area of 456,320 ha, irrigation over approximately 37% of this area and cropping intensity of 128%. Rice occupies the largest kharif area, while wheat, gram, pulses and vegetables contribute to seasonal diversification. These spatial figures should be interpreted against the administrative boundary and reference year used in the original study, which were not independently checked in this abridgement.

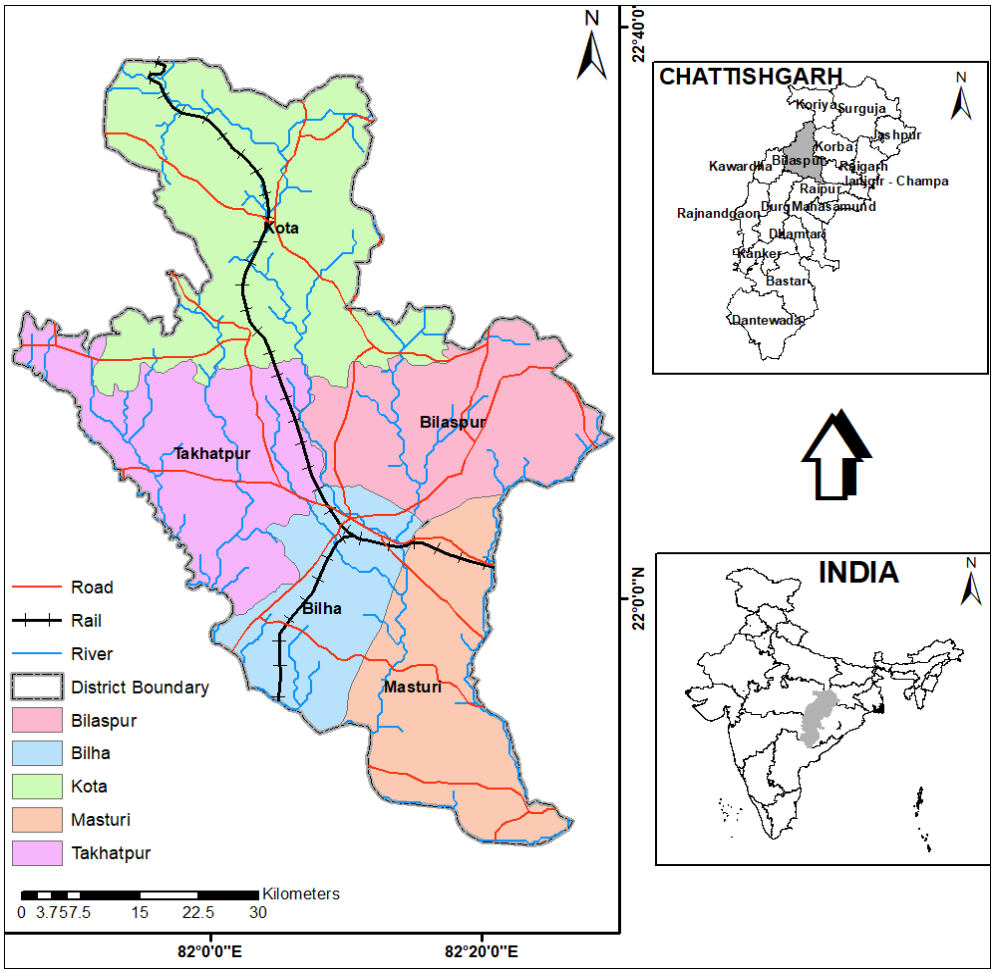


Fig 1: Study-area map reproduced from the supplied manuscript (historical administrative depiction; boundary date not independently verified).

The manuscript uses a geographical description and administrative statistics that should be checked against the relevant district boundary year in any subsequent spatial analysis. This is important for long climate series and for administrative data collected before and after district reorganization. From a planning perspective, the main biophysical characteristics are the strong monsoon concentration of rainfall, persistent dependence on rice,

limited irrigation and uneven farm sizes. These conditions make the sequence of rainfall events within the kharif season particularly consequential for household livelihoods. The reported seasonal crop areas include 312,450 ha under rice, 24,680 ha under pulses and 18,920 ha under oilseeds in kharif; wheat, gram, vegetables and lentils contribute to rabi cultivation. Marginal and small holdings together dominate the reported agricultural structure. In such settings, diversification may improve resilience but is constrained by input liquidity, access to seed and guaranteed markets. These figures are retained from the author-supplied article; the abridgement has not reconciled them against district statistical handbooks.

Materials and Methods

1. Research design and sample

The study reports a convergent mixed-methods design. Climate observations for 1990–2022 were assembled from IMD gridded products, district stations and secondary agricultural statistics. A multistage sample selected six blocks—Bilaspur, Masturi, Kota, Takhatpur, Lormi and Mungeli—stratified by irrigation coverage, then 42 villages (seven per block) and 420 farming households (ten per village). The survey took place from October 2021 to March 2022. The original manuscript reports 24 focus-group discussions and 45 semi-structured key-informant interviews with extension staff, agricultural researchers, farmers and village representatives. Note that the historical listing of selected blocks may not align with the present administrative district boundary.

Eligibility required agriculture as the principal livelihood for at least five years. The 12-part structured questionnaire covered demographic background, holdings, assets, agriculture, climatic perceptions, observed impacts, adaptation, extension, finance, social networks, food security, and income. The questionnaire was reviewed by experts and pilot-tested with 25 farmers; interviews were undertaken with trained enumerators using digital forms, with re-interviews for a reported 10% quality check. Qualitative responses were thematically coded and triangulated with quantitative findings (Braun & Clarke, 2006) [8].

2. Climate and vulnerability measurements

Non-parametric Mann–Kendall tests examined time trends, and Sen's slope quantified change per year; rainfall variability was expressed by CV = 100(σ/μ) (Kendall, 1975) [30]. Measures included annual and seasonal rainfall, temperature, heat-wave days, heavy-rainfall occurrences, dry-spell frequency and monsoon timing. Correlations were calculated between climatic indicators and rice yield. These statistical relationships are associations, rather than controlled causal estimates.

The LVI combines seven domains: sociodemographic profile, livelihood strategies, social networks, health, food security, water resources, and natural disasters/climate variability. Each subcomponent was standardized, aggregated to a domain and averaged by indicator weights. In the LVI–IPCC formulation, the domains were regrouped as exposure (E), sensitivity (S) and adaptive capacity (AC), with reported index (E − AC) × S. Higher composite values indicate comparatively greater vulnerability within the applied operationalization (Hahn *et al.*, 2009) [22].

3. Adaptation modelling and safeguards

Adaptation adoption (yes/no) was modelled using a binary logistic specification, $\log[p/(1-p)] = \beta_0 + \Sigma\beta_i X_i$. Explanatory factors included education, household composition, farm and irrigated area, livestock, nonfarm earnings, extension contact, credit, distance to market, climate information and farmer-group membership. Model fit was assessed using likelihood-ratio and Hosmer–Lemeshow tests, Nagelkerke pseudo-R^2 and classification accuracy. The manuscript reports informed consent, confidentiality, institutional ethics approval and the right to withdraw.

The study's design has several useful features: the weather series extends beyond the survey period; the household instrument covers both physical exposure and institutional capacity; and focus groups and interviews provide contextual explanations for numerical patterns. At the same time, climatic exposure and household outcomes are observed at different temporal scales, a limitation for direct attribution. In particular, farmers' accounts of long-term yield decline may reflect remembered extreme years, changing input prices, land quality, or management practices alongside weather conditions. Accordingly, descriptive trends, cross-sectional associations and causal interpretations should remain clearly distinguished.

Results

1. Temperature and rainfall trends, 1990–2022

According to the source analysis, all reported temperature parameters increased significantly, with minimum temperature warming faster than maximum temperature. Annual mean temperature rose by approximately 1.05°C over the 33-year study interval. The average number of days reaching at least 45°C rose from 6.2 per year in 1990–1999 to 11.8 in 2013–2022. Rates are presented in Table 1.

Table 1: Temperature trends in the supplied manuscript (1990–2022)

Temperature variable	Mean (°C)	Trend (°C yr−1)	Kendall τ	p value
Annual mean	25.8	+0.032	0.418	<0.001
Annual maximum	34.2	+0.028	0.352	0.002
Annual minimum	17.4	+0.041	0.465	<0.001
Summer maximum	42.6	+0.035	0.386	0.001
Monsoon mean	27.3	+0.038	0.421	<0.001

Annual and monsoon rainfall declined slightly in the fitted series, but their trends were not statistically significant. In contrast, monsoon variability increased: its reported moving CV rose from 14.2% to 24.6% between the first and last periods considered. Dry spells of at least seven days increased from 1.4 to 2.8 occurrences per year. This distinction between changes in rainfall totals and changes in seasonal distribution is central to the study's agricultural interpretation.

Table 2: Rainfall trends and variability (1990–2022)

Rainfall category	Mean (mm)	CV (%)	Trend (mm yr−1)	p value
Annual	1,287.4	19.2	−2.14	0.184
Monsoon	1,142.6	21.4	−1.98	0.224
Post-monsoon	68.3	45.7	+0.32	0.462
Winter	24.2	62.8	−0.08	0.734
Pre-monsoon	52.3	51.3	−0.18	0.643

The manuscript reports a mean monsoon onset near 14 June (standard deviation approximately 11 days), mean cessation around 28 September and an average monsoon duration of 106 days. Its estimated onset delay of 0.42 days annually was not statistically significant ($p = 0.132$); it should therefore be described as a suggestive direction rather than a confirmed change. The reported frequency of drought years increased across some decades, but decadal classification is sensitive to both the rainfall reference period and the chosen drought threshold. Stronger inferences would benefit from an explicitly documented local long-period average, sensitivity tests and separate identification of agricultural drought and meteorological drought.

2. Crop-yield exposure to climate variability

Rice-yield associations were strongest for July–August rainfall ($r = 0.584$, $p < 0.001$), followed by total monsoon rainfall ($r = 0.512$, $p = 0.002$). Greater rainfall variability ($r = −0.438$), longer dry spells ($r = −0.467$) and higher September temperature ($r = −0.392$) were negatively correlated with production. These coefficients describe observed relationships in the reported dataset and do not isolate effects of other production changes, including technology, fertilizer or seed variety.

Table 3: Selected relationships between climate conditions and rice yield

Climate predictor	Pearson r	p value
Monsoon total rainfall	0.512	0.002
July–August rainfall	0.584	<0.001
Rainfall distribution (CV)	−0.438	0.010
September flowering-stage temperature	−0.392	0.024
Dry-spell duration	−0.467	0.006
Heavy-rainfall days	−0.213	0.234

Mean rice yield was reported as 2,340 kg ha−1. Drought-year yields were 18.4% lower, and years with excess rain 12.7% lower, than normal-year yields. Variability in rice yields increased between the earliest and latest decades of the climate series. Together, these results suggest vulnerability to both moisture deficits and rainfall concentration, though the comparison design precludes a strong causal attribution.

3. Household profile and reported livelihood effects

Surveyed household heads averaged 48.3 years of age and 5.2 years of formal schooling. Mean landholding was 1.84 ha and mean agricultural income share 68.4%. In the sample, 41.2% had irrigation access, 31.9% formal credit, 38.6% extension contact and 22.4% crop insurance. Farmers frequently perceived a warming climate (94.8%), irregular rainfall (87.6%), heat waves (82.3%) and delayed or uncertain monsoon timing (73.1%). Perception frequencies represent respondents' views rather than independent climate observations.

Table 4: Key household indicators and farmer-reported impacts (n = 420)

Measure	Reported value
Mean landholding / irrigated area	1.84 ha / 0.68 ha
Annual gross household income (mean)	₹127,340
Households reporting lower crop yields	78.3%
Households reporting water scarcity	71.4%
Households reporting delayed sowing	68.9%
Households reporting food shortage	58.6%
Households reporting lower dietary diversity	64.2%
Food-secure months (mean)	8.4 months
Average annual income reduction (reported)	₹23,480

Households reported higher input costs, growing debt burdens and reduced food security. About 74.3% described income losses, while 82.1% reported increased input costs. Reported effects differed by crop: rice and wheat producers most often identified declining yields, whereas pulse growers identified crop-failure risk and vegetable growers described quality loss. Because these measures include retrospective self-reporting, recall and attribution bias remain relevant.

Household-level responses suggest climate risk extends well beyond harvested crop quantity. The article reports mean income reductions of approximately 18.6%, increased input costs of 24.3%, and higher debt for many respondents. A subset also reported asset sales over the preceding five years. Food insecurity was reflected in skipped or inadequate access to food in some months and lower dietary diversity, with particular potential implications for nutritionally vulnerable family members. These are important qualitative signals, but the manuscript does not provide repeated household food-consumption records or validated dietary-assessment methods to establish the magnitude of causal nutritional impacts.

Perception data nonetheless remain valuable for agricultural planning. Where producers recognise more frequent dry spells, rising temperatures and uncertain sowing conditions, programmes may be more successful if advisories respond to the specific timing of field decisions. Farmers' local observations should be combined with meteorological information and crop-stage monitoring, rather than treated as substitutes for them.

4. Livelihood vulnerability

The composite LVI was reported at 0.452 (SD 0.142; range 0.167–0.784). Its highest component values were natural disasters and climate variability (0.642), water resources (0.587) and food security (0.528), followed by livelihood strategies (0.524). The calculated LVI–IPCC index was 0.102, based on exposure 0.642, sensitivity 0.525 and adaptive capacity 0.448. These values are relative to the manuscript's indicator construction and should not be interpreted as an externally validated universal threshold.

Table 5: Vulnerability patterns by livelihood and demographic grouping

Household category	Group	Mean LVI	Significance
Farm size	Marginal (<1 ha)	0.523	p < 0.001
	Small (1–2 ha)	0.442	
	>2 ha	0.368	
Irrigation	Rainfed	0.496	p < 0.001
	Irrigated	0.394	
Household head	Female	0.531	p = 0.001
	Male	0.443	
Social group	Scheduled Tribe	0.512	p < 0.001
	Scheduled Caste	0.484	
	Other Backward Class	0.432	
	General	0.376	

Marginal holdings, rainfed production and female-headed households were consistently associated with higher index values. The differences may reflect unequal access to irrigation, productive assets, credit, extension services and secure land rights (O'Brien *et al*., 2004; Jerneck, 2018) [27, 40]. These subgroup comparisons are descriptive or associative; adjustment for correlated socioeconomic factors is required before identifying independent causal pathways.

5. Adaptation choices and portfolios

Out of 420 surveyed households, 307 (73.1%) reported at least one adaptation, and the average number of strategies per household was 2.8. Responses combined cropping changes, improved soil and water management, livestock, nonfarm income, insurance and savings. A substantial proportion of households also reported no adaptation (26.9%), indicating that awareness did not always translate into action.

Table 6: Frequently reported agricultural and livelihood adaptation strategies

Strategy	Households (n)	Share (%)
Crop diversification	204	48.6
Organic amendments	187	44.5
Adjusted planting dates	177	42.1
Off-farm employment	168	40.0
Water-efficient practices	161	38.3
Drought-resistant varieties	156	37.1
Increased livestock	143	34.0
Intercropping	134	31.9
Mulching	118	28.1
Rainwater harvesting	94	22.4
Improved drip/sprinkler irrigation	67	16.0
Conservation tillage	52	12.4

The prevalence of diversified portfolios is consistent with agricultural-resilience literature emphasizing redundancy and flexibility (Lin, 2011; Smit & Skinner, 2002) [34, 55]. However, the existence of an adaptation strategy is not itself evidence that yields or welfare improved; the original study did not conduct a quantitative impact evaluation of specific interventions.

Not every reported adjustment requires an entirely new technology. Changed transplanting dates can be made through labour and local knowledge, whereas drip irrigation and mechanized practices require initial expenditure, maintenance and dependable water or energy supply.

Organic amendments and green manuring depend on biomass availability, livestock holdings and competing demands for residues. Diversification into off-farm work can reduce dependence on rice yield but also create seasonal labour shortages for cultivation. Thus, adoption rates alone obscure differences in feasibility, costs, required capital and the likelihood that a measure will remain viable over multiple seasons.

6. Determinants of adaptation adoption

Table 7 condenses the binary-logistic regression to key coefficients and their reported 95% confidence intervals. Education, farm size, irrigated-land share, extension contact, credit access and climate information access were positively related to adoption at $p < 0.05$. Results for livestock, off-farm income and group membership were positive but did not meet that threshold; age, family size and distance to market were also not statistically significant.

Table 7: Selected binary-logistic regression results for any adaptation

Predictor	Adjusted OR	95% CI	p value
Education (years)	1.132	1.051–1.220	0.001
Farm size (ha)	1.408	1.117–1.773	0.004
Irrigated-land share	1.018	1.002–1.034	0.024
Extension access	2.277	1.270–4.082	0.006
Credit access	2.002	1.140–3.515	0.016
Climate information access	1.844	1.036–3.283	0.037
Group membership	1.701	0.941–3.075	0.079
Off-farm income	1.627	0.932–2.841	0.086
Age of household head	0.988	0.961–1.016	0.392

Model fit reported in the source: $\chi^2(12) = 68.34$, $p < 0.001$; Nagelkerke $R^2 = 0.246$; Hosmer–Lemeshow $p = 0.410$; classification accuracy = 74.3%. OR = odds ratio; CI = confidence interval.

For example, extension access was associated with approximately 2.28 times the odds of having adopted at least one strategy, conditional on the other modeled covariates. This should not be read as proof that extension contact caused adoption; farmers who are more proactive or better resourced might also seek extension. Comparable research identifies institutional access and farm resources as recurring determinants of climate-adaptation decisions (Deressa *et al*., 2009; Below *et al*., 2012) [5, 11].

7. Barriers and institutional support

The most commonly cited obstacle was insufficient finance (84.3%), followed by limited credit (71.2%), poor information (68.6%) and technology cost (64.8%). Small farms, water scarcity and inadequate extension service coverage were additional constraints. On the institutional side, respondents distinguished awareness of a programme

from actual access to services, indicating an implementation gap.

Table 8: Selected barriers and access to support services

Reported barrier	Share (%)	Institutional service	Awareness / access (%)
Financial resource shortage	84.3	Extension services	72.4 / 38.6
Credit constraints	71.2	Crop insurance (PMFBY)	68.9 / 22.4
Information shortages	68.6	Krishi Vigyan Kendra	54.3 / 18.1
High technology costs	64.8	Agrometeorological advice	48.6 / 24.3
Small landholding	58.3	Subsidized inputs	81.2 / 52.7
Water scarcity	56.9	Irrigation programmes	63.8 / 21.9
Weak extension services	52.4	Soil testing	47.1 / 15.7

Crop insurance satisfaction was relatively low (2.4 on a five-point scale), as was satisfaction with extension services (2.8), whereas users assessed the Krishi Vigyan Kendra more favourably (3.4). Administrative reach, transaction costs, eligibility and timing may therefore matter as much as formal programme availability. The manuscript estimates an average 34.2-percentage-point gap between awareness and access across assessed services.

The programme data reveal that awareness does not guarantee use. Extension services were known to over 70% of respondents but accessed by fewer than 40%; insurance was similarly better recognised than obtained. Such gaps can result from eligibility conditions, distance, documentation, mistrust, limited staff capacity or delays in delivery, although the study does not identify the relative causal contribution of these mechanisms. Future programme evaluations should therefore observe both the 'extensive margin' of enrolment and the actual intensity, timeliness and quality of service. Satisfaction scores among users are also subject to selection bias and should not automatically be generalized to all farming households.

Discussion

1. Climate risks and rice-based production

The reported warming signal, particularly stronger night-time temperature increase, is relevant for rice physiology. Warm nights elevate crop respiration and can reduce grain filling, particularly when combined with water deficit around sensitive reproductive stages (Peng *et al*., 2004) [44]. An increase in rainfall variability without a significant trend in annual totals also means that calendar-based agricultural decisions become less reliable. Long dry spells followed by intense rain may generate both crop-moisture stress and waterlogging, even if seasonal rainfall appears adequate. Thus, water storage alone is an incomplete adaptation portfolio; flexible calendars, diverse crops, appropriate varieties and drainage also matter (Goswami *et al*., 2006; IPCC, 2022) [18].

2. Unequal livelihood vulnerability

Vulnerability arises from unequal capacities to absorb or avoid climatic risk. Marginal holdings have fewer opportunities to spread risk across fields and crops; rainfed households have less control over timely water supply; and female-headed households may face additional constraints around land access, capital and advisory channels. The index differences reinforce the need for distribution-sensitive policy rather than an assumption of uniform climate impacts. Still, composite index results depend on normalization choices, domain weighting and the selection of indicators (Hahn *et al*., 2009; Shah *et al*., 2013) [22, 52].

3. Adaptation effectiveness and institutional pathways

The frequency of crop diversification, altered sowing dates and improved soil and water management indicates that farmers already pursue practical responses, often without major capital expenditure. Capital-intensive technology remains less common. Given the substantial correlation between formal resource access and adaptation, there is a clear argument for improving local advisory services, microcredit design and farmer-centered climate information. Interventions should account for different production constraints rather than treating a single technology as appropriate for every village or household (Khatri-Chhetri *et al*., 2017; Aryal *et al*., 2020) [3, 31].

A central interpretation challenge is that the study measures adoption status but not the counterfactual yield or welfare improvement from each strategy. Adoption counts must therefore be separated from effectiveness. For future research, panel surveys, intervention evaluation and crop-level climate-response models could clarify which adaptation packages offer durable benefits, for whom, and at what cost (Eriksen *et al*., 2021) [15].

The climate-risk evidence has two distinct implications for agricultural engineering and management. At plot scale, farmers need practices that conserve useful soil moisture during dry spells while facilitating drainage during concentrated rainfall. Mulching, cover crops, residue management, field bunds and small-scale water harvesting may perform different functions according to soil, crop and topography. At landscape scale, irrigation planning must account for groundwater recharge, watershed runoff, reservoir storage and equity of access. The study does not estimate hydrological balances for these strategies, so their net sustainability should not be assumed without site-specific evaluation.

The regression points toward the value of extension and credit, but policy should avoid interpreting larger coefficients as a causal ranking of interventions. A contact with an extension agent may reflect entrepreneurial farmers' initiative as much as advisory effectiveness, while higher farm area may proxy capital and creditworthiness. Testing these pathways requires longitudinal observations, quasi-experimental programme designs or appropriately randomized service-delivery evaluations. A more refined adaptation indicator could distinguish adoption intensity, sustained adoption and objectively measured outcomes, reducing the risk of treating temporary responses as lasting resilience.

4. Implications for policy and rural development

Five priorities emerge from the supplied evidence. First, expand decentralized rainwater harvesting and locally appropriate micro-irrigation while protecting groundwater sustainability (Rodell *et al*., 2009; Fishman *et al*., 2015) [16, 50]. Second, provide agro-meteorological advisories that help farmers react to expected onset shifts, dry spells and intense rainfall. Third, strengthen local extension systems, farmer

field demonstrations and farmer groups so that practical information reaches resource-poor households. Fourth, reduce financial barriers through accessible credit, timely support payments and more usable risk-transfer products. Fifth, support livelihood diversification and secure market connections, especially for marginal and rainfed households. These should be designed as coordinated packages rather than isolated schemes.

Programme design could be organized around three groups. For marginal rainfed farmers, priority measures include low-cost moisture conservation, shared water structures, timely seasonal advice and easier access to working capital. For households with some irrigation and financial resources, integrated nutrient and water management, resilient varieties and market-linked diversification may be more feasible. For female-headed and socially marginalized households, land-related constraints, accessible credit procedures, inclusive extension scheduling and local producer networks require explicit attention. Monitoring should track whether benefits reach these groups and whether interventions create unintended burdens or unequal access to water.

Conclusion

The condensed analysis of the author-supplied manuscript portrays a rice-based rural economy experiencing significant warming, heightened monsoon variability and substantial household exposure to agricultural risk. Annual mean temperature increased by 0.032°C per year, drought-year rice production was lower by 18.4%, and the household LVI was 0.452. Almost three-quarters of respondents reported adopting at least one coping or adaptation measure, yet coverage was unequal. The clearest positive adoption correlates were education, farm and irrigation resources, access to agricultural extension, credit and climate information.

The practical contribution lies in linking climatic trends with differentiated livelihood risks. Policy should prioritize water security, reliable agro-climatic information, accessible extension and credit, crop diversification, insurance usability and targeted support for the most resource-constrained households. This will require sustained collaboration between farmers, agronomists, local government and rural development agencies. Sustainable adaptation should ultimately be evaluated by resilience, food security and net livelihood outcomes—not merely by the number of practices adopted.

Limitations and scope for further study

The source acknowledges a cross-sectional household survey, retrospective self-reporting, incomplete climate observations and absence of quantitative adaptation-effectiveness assessment. Such features limit causal interpretation and wider extrapolation. This 15-page version is a condensed presentation of that existing manuscript, not a new independent analysis or verification of its datasets. Before journal submission, the study area's boundary definitions, sampling frame, raw data, model diagnostics and bibliographic metadata should be checked against primary records.

References

1. Agrawal A. Local institutions and adaptation to climate change. In: Mearns R, Norton A, editors. Social dimensions of climate change: equity and vulnerability in a warming world. World Bank, 2010, 173-198.
2. Arora-Jonsson S. Virtue and vulnerability: discourses on women, gender and climate change. Glob Environ Change,2011:21(2):744-751. https://doi.org/10.1016/j.gloenvcha.2011.01.005
3. Aryal JP, Sapkota TB, Khurana R, Khatri-Chhetri A, Rahut DB, Jat ML. Climate change and agriculture in South Asia: adaptation options in smallholder production systems. Environ Dev Sustain,2020:22(6):5045-5075. https://doi.org/10.1007/s10668-019-00414-4
4. Auffhammer M, Ramanathan V, Vincent JR. Climate change, the monsoon, and rice yield in India. Clim Change,2012:111(2):411-424. https://doi.org/10.1007/s10584-011-0208-4
5. Below TB, Mutabazi KD, Kirschke D, Franke C, Sieber S, Siebert R, *et al*. Can farmers' adaptation to climate change be explained by socio-economic household-level variables? Glob Environ Change,2012:22(1):223-235. https://doi.org/10.1016/j.gloenvcha.2011.11.012
6. Bhattacharya A, Mishra OP. Climate change impact assessment on rice production in Chhattisgarh. J Agrometeorol,2015:17(2):203-208.
7. Birthal PS, Khan TM, Negi DS, Agarwal S. Impact of climate change on yields of major food crops in India: implications for food security. Agric Econ Res Rev,2014:27(2):145-155. https://doi.org/10.5958/0974-0279.2014.00019.6
8. Braun V, Clarke V. Using thematic analysis in psychology. Qual Res Psychol,2006:3(2):77-101. https://doi.org/10.1191/1478088706qp063oa
9. Bryan E, Deressa TT, Gbetibouo GA, Ringler C. Adaptation to climate change in Ethiopia and South Africa: options and constraints. Environ Sci Policy,2009:12(4):413-426. https://doi.org/10.1016/j.envsci.2008.11.002
10. Census of India. District census handbook: Bilaspur. Office of the Registrar General and Census Commissioner, 2011.
11. Deressa TT, Hassan RM, Ringler C, Alemu T, Yesuf M. Determinants of farmers' choice of adaptation methods to climate change in the Nile Basin of Ethiopia. Glob Environ Change,2009:19(2):248-255. https://doi.org/10.1016/j.gloenvcha.2009.01.002
12. Department for International Development. Sustainable livelihoods guidance sheets. DFID, 1999.
13. Directorate of Economics and Statistics. Agricultural statistics at a glance 2021. Ministry of Agriculture and Farmers Welfare, Government of India, 2021.
14. Ministry of Finance, Government of India. Economic survey 2021-22. Government of India, 2022.
15. Eriksen S, Schipper ELF, Scoville-Simonds M, Vincent K, Adam HN, Brooks N, *et al*. Adaptation interventions and their effect on vulnerability in developing countries: help, hindrance or irrelevance? World Dev,2021:141:105383. https://doi.org/10.1016/j.worlddev.2020.105383
16. Fishman RM, Siegfried T, Raj P, Modi V, Lall U. Over-extraction from shallow bedrock versus deep alluvial aquifers: reliability versus sustainability considerations for India's groundwater irrigation. Water Resour Res,2015:51(1):193-206. https://doi.org/10.1002/2014WR015679

17. Gbetibouo GA, Ringler C. Mapping South African farming sector vulnerability to climate change and variability: a subnational assessment. IFPRI Discussion Paper 00885. International Food Policy Research Institute, 2009.
18. Goswami BN, Venugopal V, Sengupta D, Madhusoodanan MS, Xavier PK. Increasing trend of extreme rain events over India in a warming environment. Science,2006:314(5804):1442-1445. https://doi.org/10.1126/science.1132027
19. Government of Chhattisgarh. District statistical handbook: Bilaspur 2020. Directorate of Economics and Statistics, 2020.
20. Guhathakurta P, Menon P, Inkane PM, Krishnan U, Sable ST. Trends and variability of meteorological drought over the districts of India using standardized precipitation index. J Earth Syst Sci,2020:129:56. https://doi.org/10.1007/s12040-019-1306-7
21. Gumma MK, Kadiyala MDM, Panjala P, Ray SS, Akuraju VR, Dubey S, *et al*. Assessing agricultural water productivity in India's: analysis of agricultural lands using remote sensing and secondary data. Remote Sens,2020:12(24):4127. https://doi.org/10.3390/rs12244127
22. Hahn MB, Riederer AM, Foster SO. The Livelihood Vulnerability Index: a pragmatic approach to assessing risks from climate variability and change—a case study in Mozambique. Glob Environ Change,2009:19(1):74-88. https://doi.org/10.1016/j.gloenvcha.2008.11.002
23. Intergovernmental Panel on Climate Change. Climate change 2014: impacts, adaptation, and vulnerability. Cambridge University Press, 2014.
24. Intergovernmental Panel on Climate Change. Climate change 2021: the physical science basis. Cambridge University Press, 2021.
25. Intergovernmental Panel on Climate Change. Climate change 2022: impacts, adaptation and vulnerability. Cambridge University Press, 2022.
26. Jain M, Naeem S, Orlove B, Modi V, DeFries RS. Understanding the causes and consequences of differential decision-making in adaptation research: adapting to a delayed monsoon onset in Gujarat, India. Glob Environ Change,2017:31:98-109. https://doi.org/10.1016/j.gloenvcha.2014.12.008
27. Jerneck A. Taking gender seriously in climate change adaptation and sustainability science research: views from feminist debates and sub-Saharan small-scale agriculture. Sustain Sci,2018:13(2):403-416. https://doi.org/10.1007/s11625-017-0464-y
28. Kates RW, Travis WR, Wilbanks TJ. Transformational adaptation when incremental adaptations to climate change are insufficient. Proc Natl Acad Sci U S A,2012:109(19):7156-7161. https://doi.org/10.1073/pnas.1115521109
29. Keil A, Zeller M, Wida A, Sanim B, Birner R. What determines farmers' resilience towards ENSO-related drought? An empirical assessment in Central Sulawesi, Indonesia. Clim Change,2008:86(3):291-307. https://doi.org/10.1007/s10584-007-9326-4
30. Kendall MG. Rank correlation methods. 4th ed. Charles Griffin, 1975.
31. Khatri-Chhetri A, Aggarwal PK, Joshi PK, Vyas S. Farmers' prioritization of climate-smart agriculture (CSA) technologies. Agric Syst,2017:151:184-191. https://doi.org/10.1016/j.agsy.2016.10.005
32. Kothawale DR, Munot AA, Kumar KK. Surface air temperature variability over India during 1901-2007, and its association with ENSO. Clim Res,2010:42(2):89-104. https://doi.org/10.3354/cr00857
33. Kumar SN, Aggarwal PK, Rani DS, Saxena R, Chauhan N, Jain S. Vulnerability of wheat production to climate change in India. Clim Res,2011:46(1):1-17. https://doi.org/10.3354/cr00905
34. Lin BB. Resilience in agriculture through crop diversification: adaptive management for environmental change. Bioscience,2011:61(3):183-193. https://doi.org/10.1525/bio.2011.61.3.4
35. Locke C, Adger WN, Kelly PM. Changing places: migration's social and environmental consequences. Environment,2000:42(7):24-35.
36. Maddison D. The perception of and adaptation to climate change in Africa. World Bank Policy Research Working Paper 4308. World Bank, 2007.
37. Mishra SK, Sahany S, Salunke P, Kang IS, Jain S. Fidelity of CMIP5 multi-model mean in assessing Indian monsoon simulations. npj Clim Atmos Sci,2020:3:39. https://doi.org/10.1038/s41612-020-00138-5
38. Mondal A, Kundu S, Mukhopadhyay A. Rainfall trend analysis by Mann-Kendall test: a case study of north-eastern part of Chhattisgarh State, India. Atmos Res,2015:2(1):70-78.
39. Morton JF. The impact of climate change on smallholder and subsistence agriculture. Proc Natl Acad Sci USA,2007:104(50):19680-19685. https://doi.org/10.1073/pnas.0701855104
40. O'Brien K, Leichenko R, Kelkar U, Venema H, Aandahl G, Tompkins H, *et al*. Mapping vulnerability to multiple stressors: climate change and globalization in India. Glob Environ Change,2004:14(4):303-313. https://doi.org/10.1016/j.gloenvcha.2004.01.001
41. Pandey S, Bhandari H, Hardy B, editors. Economic costs of drought and rice farmers' coping mechanisms: a cross-country comparative analysis. International Rice Research Institute, 2007.
42. Panthi J, Aryal S, Dahal P, Bhandari P, Krakauer NY, Pandey VP. Livelihood vulnerability approach to assessing climate change impacts on mixed agro-livestock smallholders around the Gandaki River Basin in Nepal. Reg Environ Change,2016:16(4):1121-1132. https://doi.org/10.1007/s10113-015-0833-y
43. Pattanaik DR, Rajeevan M. Variability of extreme rainfall events over India during southwest monsoon season. Meteorol Appl,2010:17(1):88-104. https://doi.org/10.1002/met.164
44. Peng S, Huang J, Sheehy JE, Laza RC, Visperas RM, Zhong X, *et al*. Rice yields decline with higher night temperature from global warming. Proc Natl Acad Sci USA,2004:101(27):9971-9975. https://doi.org/10.1073/pnas.0403720101
45. Porter JR, Xie L, Challinor AJ, Cochrane K, Howden SM, Iqbal MM, *et al*. Food security and food production systems. In: Climate change 2014: impacts, adaptation, and vulnerability. Cambridge University Press, 2019, 485-533.

46. Prasad R, Hochmuth GJ, Boote KJ. Estimation of nitrogen pools in irrigated potato production on sandy soil using the model SUBSTOR. PLoS One,2015:10(1):e0117891.
47. Praveen B, Sharma P. A review of literature on climate change and its impacts on agriculture productivity. J Public Aff,2019:19(4):e1960. https://doi.org/10.1002/pa.1960
48. Ranjan R, Khanna M, Thompson NM. Effectiveness of crop insurance as a risk management tool in Indian agriculture. Econ Polit Wkly,2019:54(43):47-54.
49. Ray DK, Gerber JS, MacDonald GK, West PC. Climate variation explains a third of global crop yield variability. Nat Commun,2015:6:5989. https://doi.org/10.1038/ncomms6989
50. Rodell M, Velicogna I, Famiglietti JS. Satellite-based estimates of groundwater depletion in India. Nature,2009:460(7258):999-1002. https://doi.org/10.1038/nature08238
51. Roxy MK, Ritika K, Terray P, Murtugudde R, Ashok K, Goswami BN. Drying of Indian subcontinent by rapid Indian Ocean warming and a weakening land-sea thermal gradient. Nat Commun,2015:6:7423. https://doi.org/10.1038/ncomms8423
52. Shah KU, Dulal HB, Johnson C, Baptiste A. Understanding livelihood vulnerability to climate change: applying the livelihood vulnerability index in Trinidad and Tobago. Geoforum,2013:47:125-137. https://doi.org/10.1016/j.geoforum.2013.04.004
53. Simane B, Zaitchik BF, Foltz JD. Agroecosystem specific climate vulnerability analysis: application of the livelihood vulnerability index to a tropical highland region. Mitig Adapt Strateg Glob Change,2016:21(1):39-65. https://doi.org/10.1007/s11027-014-9568-1
54. Singh C, Dorward P, Osbahr H. Developing a holistic approach to the analysis of farmer decision-making: implications for adaptation policy and practice in developing countries. Land Use Policy,2018:59:329-343. https://doi.org/10.1016/j.landusepol.2016.06.041
55. Smit B, Skinner MW. Adaptation options in agriculture to climate change: a typology. Mitig Adapt Strateg Glob Change,2002:7(1):85-114. https://doi.org/10.1023/A:1015862228270
56. Tripathi A, Mishra AK. Knowledge and passive adaptation to climate change: an example from Indian farmers. Clim Risk Manag,2017:16:195-207. https://doi.org/10.1016/j.crm.2016.11.002
57. Udmale P, Ichikawa Y, Manandhar S, Ishidaira H, Kiem AS. Farmers' perception of drought impacts, local adaptation and administrative mitigation measures in Maharashtra State, India. Int J Disaster Risk Reduct,2014:10(A):250-269. https://doi.org/10.1016/j.ijdrr.2014.09.011
58. Vedwan N, Rhoades RE. Climate change in the Western Himalayas of India: a study of local perception and response. Clim Res,2001:19(2):109-117. https://doi.org/10.3354/cr019109