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Livelihood-Differentiated Climate Adaptations: Assessing Perceived Effectiveness Among Rural Households in Tripura, India

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ABSTRACT

Uniform climate adaptation programmes routinely overlook structural differences in rural livelihood systems, thereby misaligning interventions with community-specific needs. This study examined the perceived effectiveness of ten consolidated climate adaptation strategies among 195 rural households across six income-source-based livelihood categories in Amarpur block (Gomati district) and Kadamtala block (North Tripura district), Tripura, India. Grounded in the Sustainable Livelihoods Framework, the study treats income source as the operational proxy for livelihood type, recognising that households organise their adaptive responses around the assets and risks associated with their predominant income-generating activities. Primary data were gathered through structured household-level interviews and focus group discussions conducted between 2021 and 2023 in high-climate-affected villages. The Garrett Ranking Technique converted respondent-assigned ranks into standardised interval scores for cross-group comparison. Crop and production-based adaptation strategy ranked highest overall (Mean Garrett Score = 62.10), followed by farm-level water adaptation strategy (56.77) and community-based water management strategy (50.46). Kruskal-Wallis H tests confirmed statistically significant inter-group differences for all ten consolidated strategies (H range: 144.42–179.08; df = 5; $p < 0.001$). Spearman rank correlation revealed strong alignment between crop farming and plantation households ($r = +0.964$, $p < 0.001$), whereas migration-dependent households exhibited near-inverse priorities relative to agricultural groups ($r = -0.903$, $p < 0.001$). Early warning and climate preparedness systems registered the lowest aggregate score (Mean GS = 25.19) across all livelihood categories, signalling critical institutional deficits in climate information delivery. These findings underscore the necessity for livelihood-specific policy frameworks that move beyond blanket interventions in northeastern India.

INTRODUCTION

Rural households in developing nations like India bear a disproportionate burden of accelerating climate variability, with communities in India's northeastern states being particularly exposed owing to their dependence on monsoon precipitation, complex hill-valley topography, and limited institutional infrastructure (IPCC, 2022). Within these communities, agriculture remains the dominant occupation, but livelihoods are far from homogeneous: households earn their incomes from crop cultivation, plantation farming, livestock rearing, wage labour, seasonal migration, and diverse non-farm activities, each of which generates a distinct vulnerability profile and a distinct set of adaptive needs. Tripura encapsulates these conditions vividly. The state has recorded progressively erratic monsoon onset, rising temperature extremes, and more frequent flash floods, hailstorms, and mid-season dry spells that affect agricultural productivity and rural income across all livelihood groups (Revi *et al.*, 2014). Yet despite growing investment in climate adaptation policy, most programmes continue to treat rural communities as a homogeneous entity, prescribing uniform interventions irrespective of the distinct livelihood structures that shape vulnerability and adaptive capacity. These divergent livelihood pathways generate fundamentally different resource endowments, risk exposures, and coping capacities (Below *et al.*, 2012; Smit & Wandel, 2006). A crop farmer prioritising on-farm irrigation improvements, for instance, occupies an entirely different adaptation space from a migration-dependent household that values timely weather alerts for safe travel decisions. Conflating these groups within a single intervention framework produces systematic mismatches between policy design and community need.

Empirical evidence comparing perceived adaptation effectiveness across distinct livelihood categories, particularly in northeastern India, remains sparse. Existing studies document adaptation practices among farming communities (Kumar *et al.*, 2016; Tripathi & Mishra, 2017) but rarely employ robust ranking methodologies to systematically contrast effectiveness perceptions across livelihood types, and virtually none extend this comparison to non-farming rural groups such as wage labourers, migrants, and non-farm households. This gap constrains the development of evidence-based, livelihood-sensitive climate policy.

The present study addresses this gap by assessing perceived effectiveness of ten consolidated adaptation strategies among six livelihood groups in two purposively selected blocks Amarpur (Gomati district) and Kadamtala (North Tripura district) using the Garrett Ranking Technique, a validated preference-elicitation tool suited to comparative

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analysis across groups (Garrett & Woodworth, 1969). Three specific objectives guided the enquiry: (i) identifying and consolidating climate adaptation strategies currently practised by rural households across diverse livelihood categories; (ii) assessing perceived effectiveness across these distinct livelihood categories; and (iii) quantifying convergence and divergence in adaptation priorities between livelihood groups. The findings contribute to theoretical understanding of livelihood-differentiated adaptation strategies while providing actionable evidence for context-sensitive climate policy in agrarian regions like the study areas. The study's principal novelty lies in combining the Garrett Ranking Technique with Kruskal-Wallis inference and Spearman correlation to produce the first statistically grounded, livelihood-differentiated mapping of adaptation effectiveness preferences in northeastern India, which is a methodological contribution with direct replicability across other agrarian contexts facing comparable livelihood diversity.

LITERATURE REVIEW

Climate adaptation scholarship has progressed considerably over the past three decades. Early framings treated adaptation primarily as a technological or agronomic challenge—a matter of introducing improved seed varieties, irrigation systems, or weather-resistant infrastructure (Smit *et al.*, 2000). While such interventions remain important, they proved insufficient as explanatory frameworks because they could not account for why identically situated households respond to the same climatic stresses in fundamentally different ways. This limitation drove the field toward richer theoretical accounts that foreground socioeconomic, institutional, and livelihood dimensions of adaptive behaviour (Agrawal & Perrin, 2009).

Two theoretical frameworks in particular underpin the present study. The first and primary framework is the Sustainable Livelihoods Framework (SLF), originally developed by Chambers and Conway (1992) and subsequently elaborated by Ellis (2000) and Scoones (2009). The SLF conceptualises rural households as active agents that combine five categories of capital assets—natural, physical, financial, human, and social—to construct livelihood strategies under conditions of vulnerability. A household's livelihood strategy shapes both its exposure to climate risk and the range of adaptive options available to it. Critically, the SLF does not treat income as a mere outcome; rather, it treats income source as a structural indicator of which assets a household depends upon and, therefore, which climate-related shocks threaten it most acutely. A crop-farming household whose natural capital (land and water) is directly disrupted by erratic rainfall occupies a fundamentally different vulnerability space from a migration-dependent household whose financial capital depends on the physical safety and mobility of its absent members. The SLF therefore predicts that livelihood differentiation will produce systematic differentiation in adaptation preferences the central proposition this study tests empirically.

The second theoretical pillar is the Vulnerability Framework, which conceptualises vulnerability as a function of exposure, sensitivity, and adaptive capacity (IPCC, 2022; Smit & Wandel, 2006). Where the SLF illuminates the asset structure that enables or constrains adaptation, the Vulnerability Framework clarifies the risk pathways through which climate hazards translate into welfare impacts: a household's vulnerability is heightened when its exposure to climate stress is high, its livelihood system is sensitive to that stress, and its capacity to adapt is constrained by limited assets or institutional support. Together, these two frameworks yield the following theoretical expectation: households that differ in their income-generating activities will differ in their exposure profiles, their sensitivity to climate hazards, and their adaptive capacity—and hence in their perceptions of which adaptation strategies are effective. This is not merely an empirical prediction but a theoretical necessity rooted in the structure of both frameworks. The present study operationalises this expectation by using income source as a proxy for livelihood type—a methodologically defensible approach, given that income source reflects the dominant activity around which households organise their asset portfolios and risk strategies.

Empirical evidence from multiple contexts confirms the theoretical expectations of the SLF and Vulnerability Framework. Crop-dependent households consistently prioritise agronomic adjustments and water management improvements—responses that protect their natural and physical capital base—while livestock-based systems focus on herd management and fodder security under heat and drought stress (Thornton & Herrero, 2014). Among resource-poor households, social networks and seasonal migration often serve as primary adaptive mechanisms precisely because productive asset investments remain out of reach; these households substitute social capital for the natural and physical capital they lack (Alam *et al.*, 2017; Bryan *et al.*, 2013). South Asian studies echo these patterns: asset-rich Nepali farmers invest in irrigation infrastructure and high-value crops (Gentle & Maraseni, 2012), whereas Bangladeshi households with thin asset bases rely more heavily on kinship networks and circular migration (Bryan *et al.*, 2013).

Within India, heterogeneity in adaptation priorities follows agro-ecological and livelihood gradients in ways broadly consistent with SLF predictions. Semi-arid farming systems emphasise water conservation and crop diversification (Rao *et al.*, 2011), while rain-fed upland systems prioritise stress-tolerant variety adoption and soil management (Tripathi & Mishra, 2017). These patterns reflect the different natural capital configurations of each system. Research from northeastern India, however, remains limited, and systematic, statistically grounded comparisons of livelihood-differentiated adaptation effectiveness are virtually absent from the literature. More importantly, existing studies have rarely

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translated the theoretical propositions of the SLF into testable, quantified comparisons across distinct livelihood categories—a gap this study directly addresses.

The Garrett Ranking Technique (GRT) offers methodological advantages over simple preference listing: it converts ordinal ranks into standardised interval scores through a psychologically calibrated conversion table, enabling meaningful inter-group statistical comparison while minimising the response bias that accompanies rating scales (Garrett & Woodworth, 1969; Singh & Kumar, 2018). The GRT has established utility in agricultural preference research but its application to climate adaptation assessment, particularly in livelihood-differentiated contexts, remains underexplored. This study deploys GRT alongside non-parametric statistical inference to fill both the empirical and methodological gaps identified above. In doing so, it responds to calls within the climate adaptation literature for more rigorous, mixed-methods assessments that move beyond agronomic documentation toward systematic comparison of how adaptation effectiveness is socially and economically differentiated across livelihood groups (Agrawal & Perrin, 2009; Smit & Wandel, 2006).

MATERIALS AND METHODS

Study Area

The study was conducted in Amarpur block, Gomati district (23.52°N, 91.65°E) and Kadamtala block, North Tripura district (24.46°N, 92.21°E). These locations were purposively selected following consultation with district agricultural officers, based on livelihood diversity, documented climate vulnerability, and suitability for intensive fieldwork. Both blocks experience a humid subtropical climate with annual rainfall of 2,000–2,500 mm concentrated in June–September. Summer temperatures occasionally exceed 36°C; winter minima approach 10°C. Rice dominates the kharif cropping landscape (approximately 80–85% of cropped area), alongside rubber and tea plantations, pulses, vegetables, and livestock rearing. Irrigation infrastructure is sparse, making production highly contingent on monsoon reliability. Both blocks recorded increasing climate variability over the preceding decade, including delayed monsoon onset, extended dry spells, and episodic flash flooding.

Sampling Design

A multi-stage stratified random sampling procedure was employed in the study. In the first stage, the two blocks—Amarpur and Kadamtala—were purposively selected. In the second stage, villages most affected by climatic events were identified through district-level agricultural statistics and stratified by predominant income source, which served as the operational proxy for livelihood type. This operationalisation is grounded in the Sustainable Livelihoods Framework: since a household's primary income source reflects the activity around which it organises its productive assets, risk exposure, and coping strategies, income source provides a practical and theoretically defensible basis for livelihood classification in field surveys (Ellis, 2000; Scoones, 2009).

Six income-source-based livelihood categories were identified to capture the full spectrum of rural livelihood diversity in the study area: (i) crop farming-dependent households (more than 60% of annual income from seasonal crop cultivation); (ii) plantation-dependent households (primary income from rubber or tea cultivation); (iii) livestock-dependent households (at least 50% of income from animal husbandry); (iv) wage labour-dependent households (primarily agricultural labourers with minimal owned land); (v) migration-dependent households (substantial reliance on remittances from seasonal out-migrants); and (vi) non-farm-based households (petty trade, services, or other non-agricultural activities). The inclusion of migration-dependent and non-farm-based categories alongside crop and livestock households is deliberate and theoretically consistent with the Sustainable Livelihoods Framework, which defines livelihood diversification—including migration and non-farm activity—as a core adaptive strategy available to rural households (Ellis, 2000; Scoones, 2009). In rural Tripura, these groups are integral to the agrarian economy, share the same climate-stressed landscape, and face distinct but equally real climate vulnerabilities. Migration-dependent households, for instance, are affected by climate shocks both directly—through flood damage to homesteads—and indirectly through disrupted mobility and remittance flows. Excluding such groups would have produced an artificially narrow picture of rural climate adaptation and misrepresented the livelihood composition of the study area. Accordingly, the study population is defined as rural households residing in climate-affected villages across two blocks of Tripura, and the sample reflects this breadth of livelihood diversity. Household lists were sourced from Gram Panchayat records. Proportional allocation determined sample size per category, yielding 195 respondents: crop farming (n = 16), plantation-based (n = 117), livestock-based (n = 11), wage labour (n = 23), migration-dependent (n = 17), and non-farm-based (n = 11). This distribution directly reflects the verified livelihood composition of the study area: district-level agricultural census records and Gram Panchayat household registers confirmed that plantation agriculture (rubber and tea) constitutes the dominant rural economy in both Amarpur and Kadamtala blocks, accounting for over 60% of rural households. The larger plantation sub-sample therefore improves statistical precision for the predominant group while proportional allocation ensures no livelihood category is systematically under-represented relative to its actual prevalence.

Data Collection

Primary data collection proceeded across three phases from late 2021 to early 2023. In the first phase, preliminary focus group discussions (FGDs) involving 8–12 purposively selected community members per group

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were conducted in late 2021, following the kharif harvest season. These discussions generated an initial inventory of 24 distinct adaptation practices through participatory listing and iterative group deliberation. In the second phase, structured household interviews were administered during 2022 to household heads; each interview lasted approximately 70–120 minutes and covered livelihood composition, income sources, perceived climate changes, and adaptation effectiveness assessments. In the third phase, verification and supplementary data collection were completed in early 2023 to cross-check responses and fill any gaps. Institutional support was extended from the National Institute of Rural Development and Panchayati Raj (NIRD&PR), Guwahati Regional Centre.

Consolidation of Adaptation Strategies

The 24 practices identified through series of FGDs were consolidated into ten thematic strategy categories through iterative thematic analysis (Braun & Clarke, 2006), guided by the research team and reviewed by agricultural extension experts. Practices sharing adaptation objectives or comparable resource requirements were grouped together while maintaining conceptual distinctiveness across categories. The ten consolidated strategies were: S1 – Livestock Rearing Adaptation; S2 – Crop and Production-Based Adaptation; S3 – Farm-level Water Adaptation; S4 – Community-based Water Management Adaptation; S5 – SHG and Women Network Adaptation; S6 – Social Network and Sharing Adaptation; S7 – Preventive Health Adaptation; S8 – Financial Coping for Health Shocks Adaptation; S9 – Early Warning and Preparedness Adaptation; S10 – Storage and Preservation Adaptation.

Garrett Ranking Technique

Each respondent ranked all ten strategies from most effective (rank 1) to least effective (rank 10) on the basis of personal experience and perceptiveness with climate-related challenges. Ranks were converted to percent positions using the formula:

Percent Position = 100 (Rij − 0.5) / Nj … (1)

where Rij is the rank assigned to strategy i by respondent j, and Nj = 10 (total strategies ranked). Percent positions were then converted to Garrett scores (GS) using standard conversion tables (Garrett & Woodworth, 1969). For a ten-item ranking, the conversion yields: rank 1 = 76, rank 2 = 70, rank 3 = 62, rank 4 = 56, rank 5 = 47, rank 6 = 41, rank 7 = 32, rank 8 = 26, rank 9 = 18, rank 10 = 12. Mean Garrett Scores were computed per strategy overall and within each livelihood group. A midpoint of 47 (corresponding to rank 5) demarcates above-average from below-average perceived effectiveness.

3.6 Statistical Analysis

Descriptive statistics (mean Garrett scores, standard deviations, rankings) were computed for each strategy overall and by livelihood category. The Kruskal-Wallis H test was applied for each strategy to assess whether perceived effectiveness differed significantly across the identified livelihood groups (significance threshold: $p < 0.05$; Siegel & Castellan, 1988). Spearman rank correlation coefficients were calculated for all pairwise combinations of the six identified livelihood groups to quantify convergence or divergence in adaptation priority rankings. All analyses were performed using IBM SPSS Statistics version 26.

RESULTS AND DISCUSSION

Overall Perceived Effectiveness of Adaptation Strategies

Table 1 and Figure 1 present overall mean Garrett scores for the ten consolidated strategies across all 195 respondents. Crop and production-based adaptation ranked first (Mean GS = 62.10), reflecting widespread recognition among respondents—particularly those in agricultural livelihood categories—of agronomic adjustments, altered planting schedules, stress-tolerant variety adoption, and crop diversification as foundational climate responses. This is broadly consistent with evidence from comparable rain-fed agricultural systems that place agronomic adaptation at the core of rural household coping portfolios in agrarian-dominant landscapes (Bryan *et al.*, 2013; Thornton & Herrero, 2014).

Farm-level water adaptation ranked second (Mean GS = 56.77) and community-based water management third (50.46). The prominence of both individual and collective water strategies reflects the acute sensitivity of rain-fed production to precipitation variability. Focus group discussions confirmed that delayed monsoon onset and unpredictable mid-season dry spells were the dominant production constraints in both the study blocks. Strategies scoring above the midpoint threshold of 47 were limited to these three, indicating that the majority of adaptation options rated below the above-average effectiveness threshold overall, though as the group-wise analysis below demonstrates, this masks substantial within-group variation.

SHG and women network adaptation (45.53), storage and preservation (42.47), livestock rearing (41.86), and preventive health adaptation (40.51) fell in the moderate effectiveness band (40–49), indicating household-specific rather than universal relevance. Social network and sharing adaptation (40.10) and financial coping for health shocks (34.99) received lower aggregate scores. Early warning and preparedness ranked last (Mean GS = 25.19), the sole strategy scoring below 30. This finding is particularly significant: it does not imply that respondents view weather forecasting as intrinsically valueless, but rather that the institutional mechanisms for delivering actionable, localised early warning information are critically underdeveloped in the study area. Focus group participants consistently reported lacking access to timely, location-specific forecasts for flash floods, hailstorms, or dry spell projections.

Livelihood-Differentiated Adaptation Priorities

Kruskal-Wallis H tests confirmed statistically significant differences across livelihood groups for all ten adaptation strategies (Table 2). H statistics ranged from 144.42 to

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Table 1: Overall Garrett Ranking of Climate Adaptation Strategies (N = 195)

Rank	Adaptation Strategy	Mean Garrett Score	Effectiveness Band
1	Crop & Production-Based Adaptation	62.10	High (≥50)
2	Farm-level Water Adaptation	56.77	High (≥50)
3	Community-based Water Management	50.46	High (≥50)
4	SHG and Women Network Adaptation	45.53	Moderate (40–49)
5	Storage & Preservation Adaptation	42.47	Moderate (40–49)
6	Livestock Rearing	41.86	Moderate (40–49)
7	Preventive Health Adaptation	40.51	Moderate (40–49)
8	Social Network & Sharing Adaptation	40.10	Moderate (40–49)
9	Financial Coping for Health Shocks	34.99	Low (<40)
10	Early Warning & Preparedness	25.19	Low (<40)

Source: Primary field survey, 2021–2023. Midpoint threshold = 47

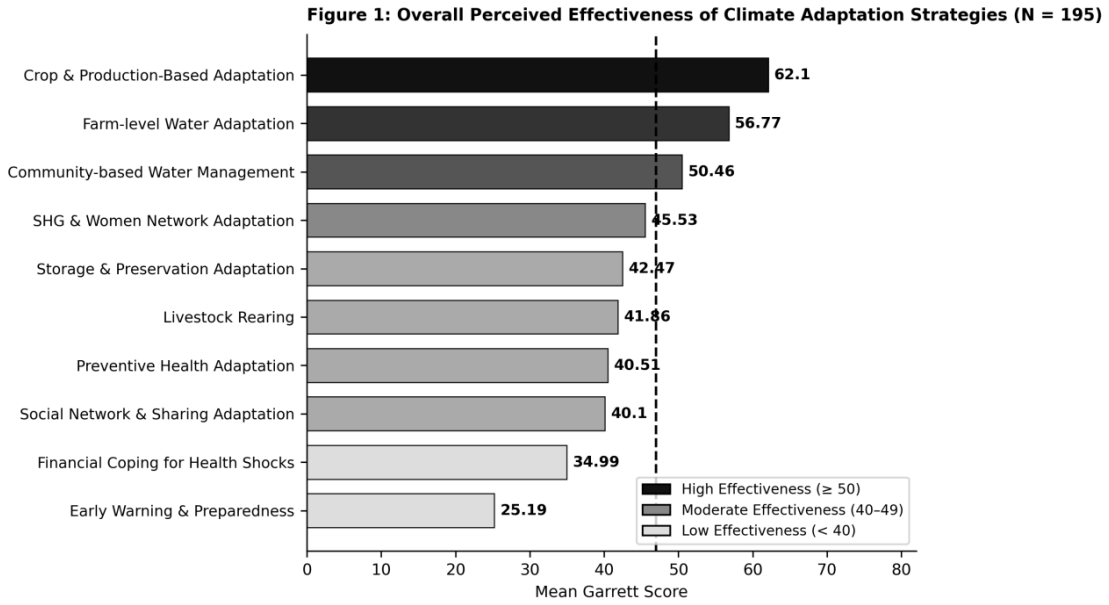


Figure 1: Overall perceived effectiveness of climate adaptation strategies (N = 195). Dashed line denotes midpoint threshold (Garrett Score = 47). Source: Primary Survey between 2021 and 2023

179.08 (df = 5, $p < 0.001$ throughout), providing robust empirical support for the theoretical proposition of the Sustainable Livelihoods Framework: that income-source-based livelihood differentiation systematically shapes perceived adaptation effectiveness. These results validate the study's classification approach and confirm that income source functions as a meaningful proxy for the underlying asset configurations and vulnerability profiles that the SLF predicts will drive adaptation preferences.

Table 3 and Figures 2–3 detail group-wise mean Garrett scores. Crop farming households (n = 16) assigned the highest scores to crop and production-based adaptation (Mean GS = 76), farm-level water adaptation (66.75),

Table 2: Kruskal-Wallis H Test Results for Inter-Group Differences in Perceived Adaptation Effectiveness

Adaptation Strategy	H Statistic	df	p-value	Decision
Livestock Rearing	169.83	5	<0.001	Significant***
Crop & Production-Based Adaptation	160.95	5	<0.001	Significant***
Farm-level Water Adaptation	148.67	5	<0.001	Significant***
Community-based Water Management	159.07	5	<0.001	Significant***
SHG and Women Network Adaptation	144.42	5	<0.001	Significant***
Social Network & Sharing Adaptation	169.87	5	<0.001	Significant***
Preventive Health Adaptation	161.82	5	<0.001	Significant***

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Financial Coping for Health Shocks	158.65	5	<0.001	Significant***
Early Warning & Preparedness	170.08	5	<0.001	Significant***
Storage & Preservation Adaptation	179.08	5	<0.001	Significant***

*Note: *** $p < 0.001$; df = degrees of freedom. Source: Computed from primary survey data during 2021 and 2023 (N = 195)*

and storage and preservation (60.12) a profile centred on managing production continuity in the face of seasonal variability. Plantation-dependent households (n = 117), the largest group, showed broadly similar top priorities: crop and production adaptation (73.51), farm-level water (67.99), and community water management (61.32). The stronger emphasis on collective water infrastructure, compared to crop farmers, is consistent with the long-term capital investment logic of perennial rubber and tea cultivation.

Livestock-dependent households (n = 11) diverged sharply, ranking livestock rearing first (Mean GS = 76), preventive health adaptation second (70), and financial coping for health shocks third (59.27). This profile reflects the vulnerability of animal husbandry to climate-induced disease risk and underscores the importance of health-related coping capacity for households whose primary asset livestock is biologically vulnerable to heat stress and vector-borne disease. Crop and water strategies, which dominated agricultural household rankings, fell to sixth and seventh position respectively in this group.

Wage labour-dependent households (n = 23) exhibited a health-and-social-protection orientation: preventive health adaptation ranked first (74.74), financial coping second (68.09), and SHG and women network adaptation third (62.00). This pattern is consistent with the precarious position of landless labourers who lack productive assets and whose livelihoods are directly threatened by physical incapacity. Migration-dependent households (n = 17) produced the most distinctive profile: early warning and preparedness ranked first (Mean GS = 76), followed by financial coping (70) and preventive health (60.76). The primacy of early warning systems for this group ranked last by all agricultural categories plausibly reflects the importance of weather information for travel safety and migration timing. Non-farm-based households (n = 11) closely resembled the wage labour group, with preventive health (70), financial coping (66.73), and social network adaptation (62) leading their rankings.

Convergence and Divergence in Adaptation Priorities

Spearman rank correlation analysis of group-level priority rankings (Table 4; Figure 4) revealed two distinct livelihood clusters with markedly different adaptation priority structures. Crop farming and plantation households exhibited near-perfect rank alignment ($r = +0.964$, $p < 0.001$), confirming shared reliance on production and water management strategies. This

Table 3: Group-wise Mean Garrett Scores and Rankings by Livelihood Category

Strategy	Overall Rank | Score	Crop Farming (n=16)	Plantation (n=117)	Livestock (n=11)	Wage Labour (n=23)	Migration (n=17)	Non-Farm (n=11)
Crop & Prod. Adaptation	#1 | 62.10	#1 | 76	#1 | 73.51	#6 | 41	#6 | 41.26	#8 | 26	#6 | 41
Farm-level Water Adapt.	#2 | 56.77	#2 | 66.75	#2 | 67.99	#7 | 31.64	#7 | 33.04	#7 | 32	#7 | 36
Comm. Water Management	#3 | 50.46	#5 | 45.31	#3 | 61.32	#8 | 26	#8 | 28.83	#6 | 42.24	#8 | 24.73
SHG & Women Network	#4 | 45.53	#6 | 42.81	#6 | 41.58	#5 | 47	#3 | 62	#5 | 45.29	#4 | 56
Storage & Preservation	#5 | 42.47	#3 | 60.12	#4 | 55.81	#10 | 13.82	#10 | 12.52	#10 | 12	#10 | 13.27
Livestock Rearing	#6 | 41.86	#4 | 56	#5 | 46.48	#1 | 76	#9 | 17.48	#9 | 19.71	#9 | 23.27
Preventive Health	#7 | 40.51	#8 | 27.31	#8 | 27.10	#2 | 70	#1 | 74.74	#3 | 60.76	#1 | 70
Social Network & Sharing	#8 | 40.10	#7 | 33.88	#7 | 32.17	#4 | 56	#4 | 54.96	#4 | 56	#3 | 62
Financial Coping (Health)	#9 | 34.99	#9 | 19.81	#9 | 20.21	#3 | 59.27	#2 | 68.09	#2 | 70	#2 | 66.73
Early Warning & Prepar.	#10 | 25.19	#10 | 12	#10 | 13.82	#9 | 19.27	#5 | 47.09	#1 | 76	#5 | 47

Note: Values shown as Rank | Mean Garrett Score within each livelihood group. Source: Primary field survey, 2021–2023

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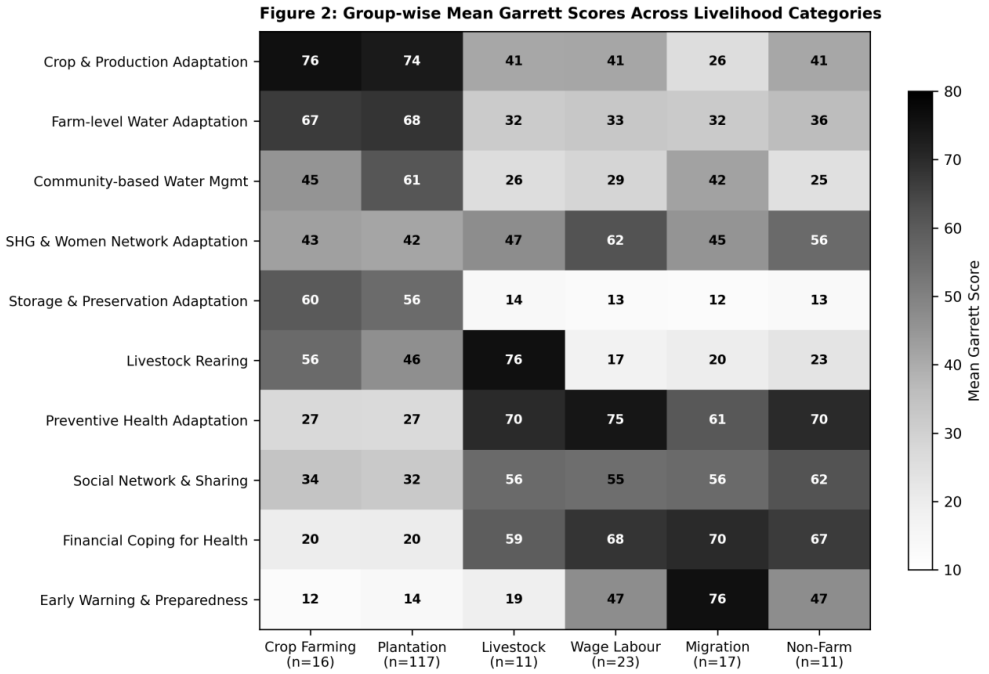


Figure 2: Heatmap of group-wise mean Garrett scores across livelihood categories. Darker shading indicates higher perceived effectiveness

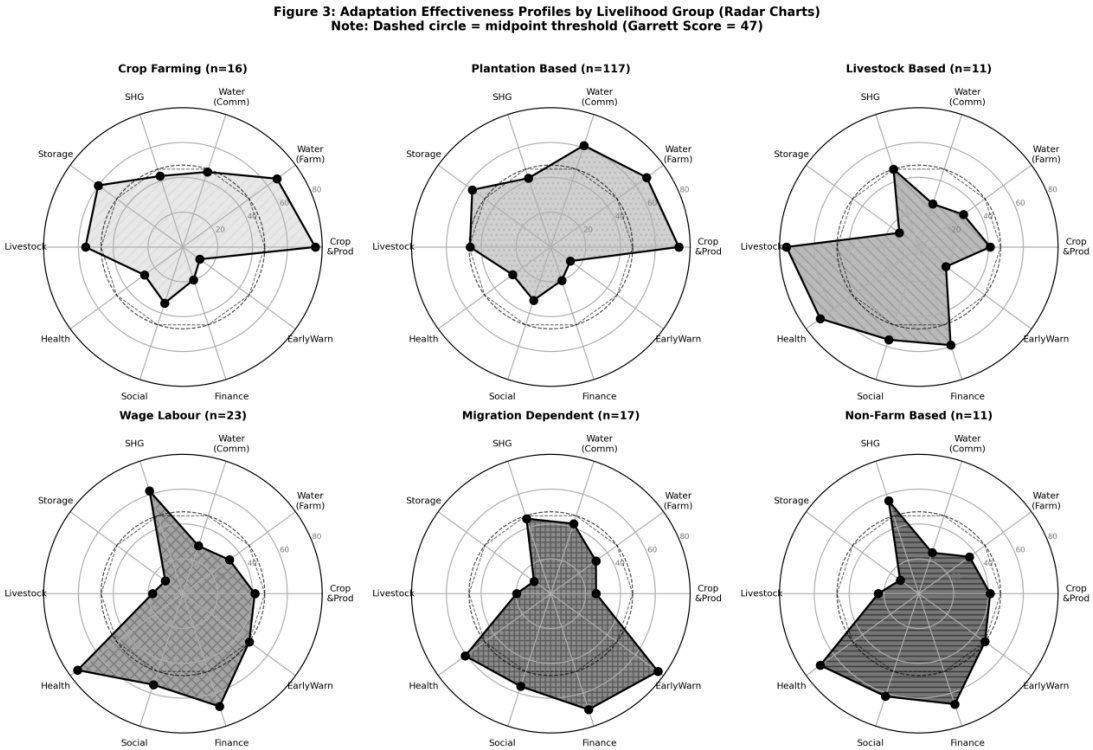


Figure 3: Adaptation effectiveness profiles by livelihood group (radar charts). Dashed circle marks the midpoint threshold (Garrett Score = 47)

convergence supports the practical possibility of cluster-based extension programming that efficiently serves both groups through overlapping intervention packages.

Wage labour and non-farm households similarly formed a tight cluster ($r = +0.988$, $p < 0.001$), both centred on health, financial coping, and social protection strategies. This near-perfect agreement driven by shared landlessness and physical-labour dependency—implies that a tailored social protection pathway could address both groups simultaneously. Migration-dependent households aligned moderately with the wage labour–non-farm cluster ($r = +0.806$ and $+0.818$ respectively, $p < 0.01$) while exhibiting their own distinctive characteristic: the highest ranking for early warning systems (Mean GS = 76).

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Agricultural and non-agricultural clusters showed strongly negative inter-cluster correlations: crop farming versus migration ($r = -0.903$, $p < 0.001$); plantation versus migration ($r = -0.818$, $p < 0.01$); crop farming versus non-farm ($r = -0.673$, $p < 0.05$). Strategies ranked at the top of agricultural household priorities (crop production adaptation, farm water) ranked at or near the bottom for migration and non-farm households, and vice versa. Livestock-based households occupied an independent position, showing no statistically significant correlation with any other group (all $p > 0.05$), consistent with their uniquely health-centred and production-system-specific adaptation profile. These findings provide robust empirical support for livelihood cluster-based climate policy design rather than universal intervention packages.

Table 4: Spearman Rank Correlation Matrix of Adaptation Priorities Across Livelihood Groups

Livelihood Group	Crop Farming	Plantation	Livestock	Livestock Wage Labour	Migration	Non-Farm
Crop Farming (n=16)	1.000	0.964***	−0.212ns	−0.661*	−0.903***	−0.673*
Plantation (n=117)	0.964***	1.000	−0.273ns	−0.624ns	−0.818**	−0.636*
Livestock (n=11)	−0.212ns	−0.273ns	1.000	0.479ns	0.164ns	0.491ns
Wage Labour (n=23)	−0.661*	−0.624ns	0.479ns	1.000	0.806**	0.988***
Migration (n=17)	−0.903***	−0.818**	0.164ns	0.806**	1.000	0.818**
Non-Farm (n=11)	−0.673*	−0.636*	0.491ns	0.988***	0.818**	1.000

*Note: *** $p < 0.001$; ** $p < 0.01$; * $p < 0.05$; ns = not significant. Source: Computed from primary survey data during the year 2021-2023 (N = 195)*

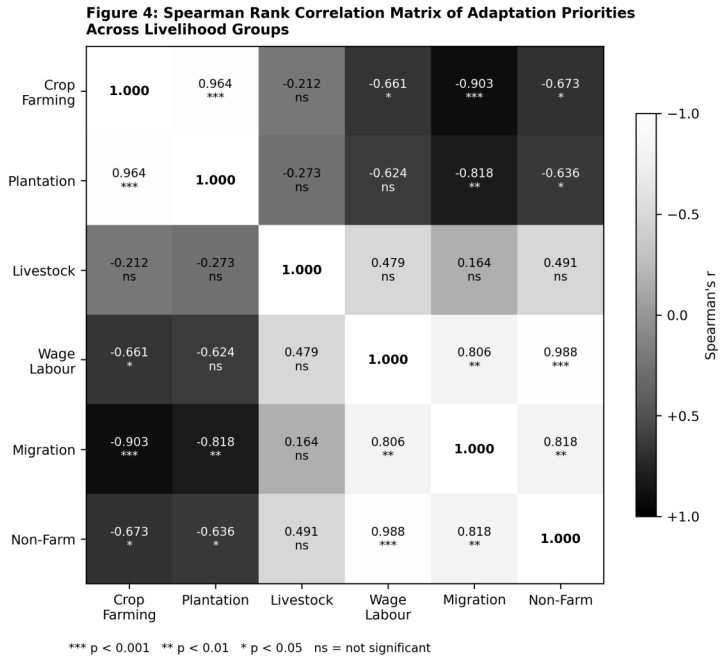


Figure 4: Spearman rank correlation matrix of adaptation priorities across livelihood groups. Darker shading = stronger positive correlation; lighter shading = stronger negative correlation

CONCLUSION

This study provides systematic empirical evidence that income-source-based livelihood type is a powerful determinant of perceived climate adaptation effectiveness among rural households in Tripura. The findings thus validate the core theoretical proposition of the Sustainable Livelihoods Framework: that households organise their adaptive priorities around the asset configurations and vulnerability pathways associated with their predominant livelihood activity. Kruskal-Wallis H tests confirmed highly significant inter-group differences for all ten strategies (H range: 144.42–179.08; $p < 0.001$), while Spearman correlation analysis delineated two principal livelihood clusters with near-inverse priority structures: an agricultural cluster (crop farming and plantation households) centred on production and water management, and a non-agricultural cluster (wage labour, migration-dependent, and non-farm households) oriented toward health, financial coping, and social protection. Livestock-based households occupied an independent intermediate position characterised by health and production-system-specific priorities.

Four policy implications follow directly from these findings. First, cluster-based extension services can

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efficiently serve crop farming and plantation households with overlapping intervention packages, given their near-perfect priority alignment (r = +0.964). Second, wage labour and non-farm households—whose near-identical profiles (r = +0.988) reflect shared landlessness and labour-market vulnerability—require social protection instruments that address health risks, financial resilience, and women's group-based coping, rather than agricultural production support. Third, the lowest-ranked strategy across all livelihood groups—early warning and preparedness (Mean GS = 25.19)—signals a universal institutional failure that demands targeted public investment in localised climate information infrastructure, regardless of livelihood composition. Fourth, migration-dependent households represent a particularly underserved segment: the strategy they rank highest (early warning systems; Mean GS = 76) is precisely that which agricultural groups rank last—a stark illustration of how uniform policies systematically marginalise mobile, non-farm-dependent populations.

Several limitations warrant acknowledgement. The cross-sectional design precludes assessment of how adaptation effectiveness perceptions shift across seasons or following specific climatic events. The study captures perceived rather than objectively measured effectiveness; while household perceptions of adaptation effectiveness remain policy-relevant as determinants of adoption decisions, future research should triangulate these with biophysical outcome data. Small sub-group samples—particularly for livestock-based (n = 11) and non-farm (n = 11) categories—limit statistical power for pairwise post-hoc comparisons. Geographic restriction to two blocks in Tripura constrains generalisability, though the livelihood-differentiation framework is transferable to comparable agrarian contexts. Future research should pursue longitudinal designs, expand minor livelihood group samples, and investigate political economy barriers to the tailored policy approaches these findings support.

Conflict of Interest

The author declares no conflict of interest. This research received no external funding. The views expressed are entirely those of the author and do not represent the positions of the affiliated institution or any government body.

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