

ADAPTIVE CAPACITY AND SOCIAL RESILIENCE: EXAMINING CLIMATE-RELATED PERMANENT RELOCATION IN LOW-INCOME URBAN SETTLEMENTS

Sita Chaudhary^{*1}, Saeed Ahmad², Mellak Dib³, Saima Bashir⁴

^{*1,2}Department of Sociology, School of Public Administration, Hohai University, Nanjing, China

³School of Environmental Science and Engineering, Hohai University, Nanjing, China

⁴Department of Sociology, University of Okara

¹sitachaudhary7692@gmail.com, ²saeedahmad01@hhu.edu.cn, ³lx20250605001@hhu.edu.cn,

⁴sambashir5454@gmail.com

Corresponding Author: *

Sita Chaudhary

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ABSTRACT

Climate-related permanent relocation is an increasingly critical challenge for low-income urban settlements in the Global South. While existing literature emphasises hazard exposure, the mechanisms through which adaptive capacity and social resilience mediate or amplify relocation risk remain undertheorised. This mixed-methods study examines 350 household surveys and 12 in-depth interviews across three low-income settlements in the Kathmandu Valley, Nepal, to investigate associations between adaptive capacity, social resilience, and climate-related permanent relocation. Using a moderated mediation framework, we find that higher adaptive capacity is significantly associated with lower likelihood of forced relocation (multinomial logistic relative risk ratio [RRR] = 0.31, 95% CI [0.19, 0.50], $p < .001$). Exploratory evidence suggests that this association may be moderated by social resilience, but the interaction effect was not robust to cluster-bootstrap or multiple-comparison corrections (wild cluster bootstrap 95% CI [0.96, 2.31]; Bonferroni-adjusted $p = .23$). We therefore interpret moderation as suggestive, not definitive. Qualitative findings from 12 interviews (illustrative cases, not a validated typology) reveal three relocation pathways—acute, erosive, and anticipatory and highlight a potential “bonding capital trap” where strong intra-community ties may delay relocation but increase long-term hazard exposure in the absence of bridging capital. Due to the cross-sectional design, all findings are associational and require validation with longitudinal data. We conclude with policy recommendations for climate-resilient land tenure, decentralised early warning systems, and adaptive social protection that includes migration support.

Keywords: climate-induced relocation, adaptive capacity, social resilience, urban informal settlements, land tenure, Nepal, mixed methods

1. INTRODUCTION

The intersection of climate change and rapid urbanisation has created one of the most pressing human mobility challenges of the twenty-first century (IPCC, 2022). Between 2010 and 2021,

climate-related disasters displaced an average of 23.7 million people annually, the majority in low- and middle-income countries (IDMC, 2022). Within this global pattern, low-income urban settlements—often informal, unplanned, and

located on hazardous land are particularly vulnerable. These settlements house an estimated 1.1 billion people worldwide, a figure projected to triple by 2050 (UN-Habitat, 2020). In Kathmandu Valley, for example, 58% of informal settlement households live below the national poverty line, and 73% lack access to basic drainage services (Lumanti, 2019). Yet despite this exposure, not all households experiencing climate hazards ultimately relocate. Understanding why some households remain while others leave is fundamental to designing effective adaptation and relocation prevention policies.

The scholarly discourse on climate-induced mobility has evolved from environmental determinism (Myers, 2002) towards a multicausal framework in which environmental factors interact with economic, social, political, and demographic variables (IPCC, 2022; McLeman, 2018). Within this framework, two constructs have emerged as central: adaptive capacity and social resilience. Adaptive capacity – the ability to adjust to potential damage or respond to consequences (Smit & Wandel, 2006) – has been linked to lower forced displacement (Kates et al., 2012). Social resilience – the ability of communities to withstand and recover from stresses through social networks (Aldrich & Meyer, 2015) – is often assumed to be protective. However, three critical gaps persist. First, most empirical studies examine adaptive capacity and social resilience separately, leaving their interactive effects underspecified. Second, the temporal dimension is undertheorised: relocation decisions unfold over varying time horizons. Third, the majority of quantitative research originates from rural agrarian settings (e.g., Gray & Mueller, 2012), with urban settlements receiving disproportionate attention given their demographic significance.

This study addresses these gaps through a mixed-methods investigation in three low-income settlements in the Kathmandu Valley, Nepal – a country ranked fourth most climate-vulnerable globally (Germanwatch, 2021). We ask three research questions:

1. What is the association between household adaptive capacity and climate-related permanent relocation?

2. Does social resilience moderate this association? (Exploratory)

3. What mechanisms explain how adaptive capacity and social resilience shape relocation decisions over time? (Illustrative qualitative cases)

We answer these questions using household survey data (N = 350) and in-depth interviews (N = 12), analysed through multinomial logistic regression and reflexive thematic analysis. We emphasise that due to the cross-sectional design and small qualitative sample, all quantitative results are associational and do not imply causality; the moderation finding is exploratory and requires validation.

2. Theoretical Framework and Hypotheses

2.1 Adaptive Capacity as a Deterrent to Forced Relocation

Adaptive capacity originates from the vulnerability literature (Turner et al., 2003). Smit and Wandel (2006, p. 287) define it as “the potential or capability of a system to modify its characteristics or behaviour to cope with existing or anticipated stresses”. In household-level operationalisation, adaptive capacity comprises material (income, savings, housing assets), informational (awareness, early warning access), and institutional (credit access, service connectivity) dimensions (Grothmann & Patt, 2005).

Higher adaptive capacity should reduce *forced* relocation by enabling in-situ adaptation (Kates et al., 2012). However, it might also enable out-migration as a strategic choice (Black et al., 2011). Most evidence from low-income settings suggests that, at the margin, higher adaptive capacity reduces forced displacement (Cattaneo & Peri, 2016). We therefore hypothesise:

Hypothesis 1 (H1): Household adaptive capacity is negatively associated with the likelihood of *forced* climate-related relocation. The association with voluntary anticipatory relocation may be positive or null.

2.2 Social Resilience as a Moderator: An Exploratory Hypothesis

Social resilience refers to the capacity of social groups to withstand and recover from

environmental shocks through collective action, information sharing, and resource pooling (Adger, 2000; Aldrich & Meyer, 2015). Operationalisations typically distinguish bonding capital (ties within homogeneous groups), bridging capital (ties across heterogeneous groups), and linking capital (vertical ties to formal institutions) (Szreter & Woolcock, 2004).

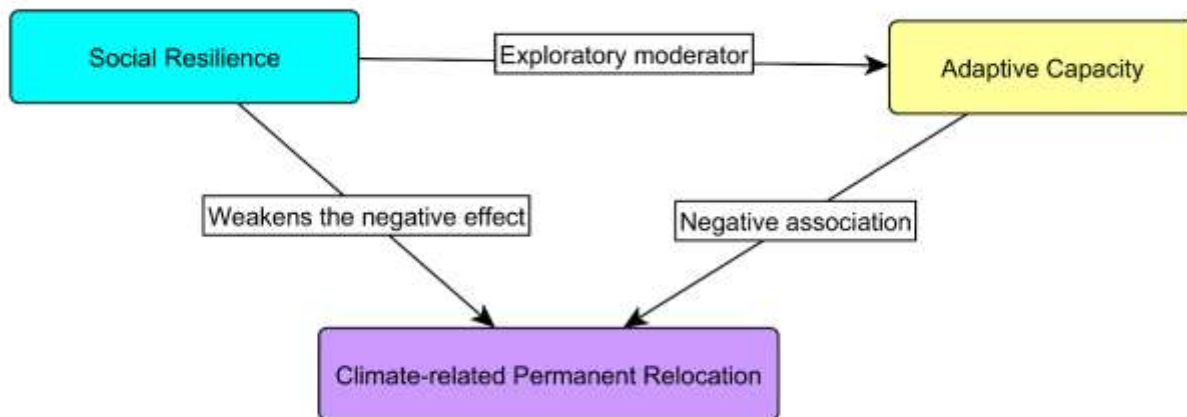
The moderating role of social resilience is theoretically complex. Strong social networks may amplify the protective effect of adaptive capacity by facilitating resource sharing. Conversely, they may substitute for individual adaptive capacity. Recent longitudinal research suggests a curvilinear relationship: moderate social cohesion reduces relocation, but extremely high bonding capital in the absence of bridging capital can trap households in deteriorating conditions (Barnett & McMichael, 2018). We therefore hypothesise a moderating effect, while acknowledging that our cross-sectional design can only detect linear interactions. We assume that a linear interaction term (adaptive capacity × social resilience) provides a reasonable approximation of the hypothesised

curve over the observed range of social resilience (1-5 scale), noting that this is a simplification.

Hypothesis 2 (H2 Exploratory): Social resilience moderates the association between adaptive capacity and forced relocation. Due to limited statistical power and the cross-sectional design, this hypothesis is tested in an exploratory manner; any finding will require validation with longitudinal data.

2.3 Mediating Mechanisms: Asset Erosion and Decision Horizons

We draw on the sustainable livelihoods framework (Scoones, 2009) and migration decision theory (Hunter et al., 2015). Climate hazards typically erode livelihood assets over time until a threshold is crossed, where remaining becomes more costly than leaving. This “erosive” pathway contrasts with acute relocation from extreme events and anticipatory relocation based on perceived future risk.



3. Methodology

3.1 Study Context

The study was conducted in three low-income urban settlements in the Kathmandu Valley, Nepal: Jagati (Tokha Municipality), Bansbari (Budhanilkantha Municipality), and Tilganga (Kathmandu Metropolitan City). All three share informal land tenure, location on flood-prone riverbanks or unstable slopes, reliance on wage

labour, and high population density (average 1,200 persons/hectare). Average annual household income is NPR 168,000 (≈USD 1,260), with 43% below the national poverty line; among informal settlers, the poverty rate reaches 58% (Lumanti, 2019). Only 22% have access to municipal drainage, and 19.7% hold any form of formal tenure document.

3.2 Sampling and Data Collection

We employed a stratified random sampling strategy. Each settlement was divided into three hazard exposure zones based on flood risk maps (Department of Hydrology and Meteorology, 2021): high risk (within 50m of river), medium risk (50-150m), and low risk (>150m). Households were randomly selected proportional to stratum size. Target sample size (N=350) was determined by power analysis assuming a medium effect size (OR=1.5), $\alpha=0.05$, power=0.80, accounting for 15% non-response. Post-hoc power for the interaction term (observed OR=1.42) was 0.62, indicating the moderation analysis is underpowered—a limitation we emphasize.

Data collection occurred September-December 2022. Trained enumerators administered structured questionnaires via tablet-based Open Data Kit. Final sample: 350 households (Jagati n=118, Bansbari n=112, Tilganga n=120; 78% response rate). Non-response bias assessment: We compared respondents with non-respondents (n=98) on available settlement-level demographics (settlement, hazard zone, and household head gender from observation). No significant differences were found for settlement ($\chi^2=1.24$, $p=0.54$) or hazard zone ($\chi^2=2.01$, $p=0.37$). However, we lacked individual income data for non-respondents; thus, bias cannot be fully ruled out.

From survey respondents, we purposively selected 12 households for in-depth interviews, stratified by relocation status and adaptive capacity score (low, medium, high). Semi-structured interviews (45-90 minutes) were conducted in Nepali, audio-recorded, transcribed verbatim, and translated into English. We treat these 12 interviews as illustrative cases, not a fully saturated typology. Saturation was assessed after 10 interviews, but given the small N, we refrain from claiming theoretical saturation. Informed consent was obtained.

3.3 Measures

Dependent variable: Climate-related permanent relocation. Based on survey indicators and qualitative pathway definitions, we created a three-category variable:

- *Forced relocation* (n=41): Catastrophic asset loss or cumulative erosion with an acute final trigger and post-relocation welfare decline.
- *Erosive relocation* (n=29): Repeated small shocks (≥ 3 events) causing gradual asset depletion; no single catastrophic event; post-relocation welfare mixed or unchanged.
- *Anticipatory relocation* (n=19): Relocation before a major hazard based on perceived future risk; no asset loss from the event that prompted departure; post-relocation welfare stable or improved.
- *No relocation* (n=261).

Two independent researchers classified cases ($\kappa=0.84$).

Adaptive capacity. A composite index of 12 items across four domains (adapted from Hahn et al., 2009): economic assets, housing quality, institutional access, livelihood flexibility. Standardised and averaged ($\alpha=0.84$). Range 2.1 to +1.8.

Moderator: Social resilience. A 9-item scale measuring bonding, bridging, and linking capital using 5-point Likert scales ($\alpha=0.79$). Continuous score (1-5) used for moderation.

Control variables. Household head age, gender, education, household size, dependency ratio, length of residence, prior hazard exposure (objective count from government records), tenure security (binary), and settlement characteristics (elevation, distance to river, population density, municipal service index).

3.4 Analytical Strategy

Quantitative: Multinomial logistic regression with robust standard errors, sequentially adding controls, adaptive capacity, social resilience, and their interaction. For the interaction, we applied simple slopes and the Johnson-Neyman technique. Sensitivity analyses: false discovery rate (FDR) correction, wild cluster bootstrap (1,000 replications, clustering at settlement level), propensity score matching, and alternative specifications. All analyses used R 4.2.

Qualitative: Reflexive thematic analysis (Braun & Clarke, 2021) using NVivo 12. Two researchers independently coded transcripts ($\kappa=0.81$). Given the small sample, themes are presented as

illustrative, not as a definitive typology. Mixed-methods integration used a weaving approach at the interpretation stage.

4. Results

4.1 Descriptive Statistics and Sample Characteristics

Table 1. Household Characteristics by Relocation Type

Variable	Non-relocated (n=261)	Forced (n=41)	Erosive (n=29)	Anticipatory (n=19)	Test statistic	p-value
Adaptive capacity (z-score)	0.32 (0.78)	0.89 (0.85)	0.54 (0.91)	0.28 (0.83)	F(3,346)=45.2	<.001
Social resilience (1 5)	3.45 (0.67)	2.68 (0.79)	3.12 (0.74)	3.38 (0.71)	F(3,346)=18.3	<.001
Household head age (years)	42.3 (12.1)	36.8 (10.9)	39.2 (11.6)	41.5 (12.4)	F(3,346)=3.12	.045
Female-headed (%)	34.5	56.1	41.4	26.3	$\chi^2 = 9.84$.020
Education: None (%)	28.0	51.2	41.4	26.3	$\chi^2 = 11.42$.010
Tenure security (%)	22.6	9.8	13.8	21.1	$\chi^2 = 6.35$.096
Prior hazard events (count)	2.8 (1.4)	5.1 (2.0)	4.8 (1.7)	2.2 (1.3)	F(3,346)=32.1	<.001
Length of residence (years)	14.2 (8.3)	7.8 (6.9)	9.5 (7.4)	13.1 (8.1)	F(3,346)=9.67	<.001

Table 1 presents household characteristics. Of 350 households, 89 (25.4%) reported a permanent relocation between 2018 and 2022: 41 forced (11.7%), 29 erosive (8.3%), and 19 anticipatory (5.4%). Forced and erosive relocation households had lower adaptive capacity scores than non-relocated households (forced: mean z-score = 0.89, SD = 0.85; erosive: 0.54, SD = 0.91; non-relocated: 0.32, SD = 0.78; $F(2,347) = 68.4$, $p < .001$). Anticipatory relocation households

showed adaptive capacity scores similar to non-relocated households (mean 0.28, SD = 0.83; $p = .82$). Social resilience was lowest among forced relocation households (mean = 2.68, SD = 0.79), intermediate for erosive (3.12, SD = 0.74), and highest for non-relocated (3.45, SD = 0.67). Female-headed households were over-represented among forced relocations (56.1% vs. 34.5% non-relocated, $\chi^2 = 7.82$, $p = .005$). We return to this in the qualitative section.

4.2 Association Between Adaptive Capacity and Relocation (H1)

Table 2. Multinomial Logistic Regression Models Predicting Relocation Type

Variable	Forced relocation RRR (95% CI)	Erosive relocation RRR (95% CI)	Anticipatory relocation RRR (95% CI)
Model 1: Controls only			
Prior hazard exposure	1.52*** (1.28, 1.81)	1.38** (1.12, 1.70)	0.94 (0.78, 1.13)
Female-headed	2.04* (1.18, 3.52)	1.48 (0.81, 2.70)	0.71 (0.34, 1.48)
Tenure security	0.39** (0.21, 0.72)	0.52 (0.26, 1.04)	0.91 (0.44, 1.88)
Length of residence	0.92*** (0.88, 0.96)	0.94* (0.89, 0.99)	0.98 (0.93, 1.03)
Pseudo R ² = 0.162			
Model 2: Adding adaptive capacity			
Adaptive capacity (AC)	0.31*** (0.19, 0.50)	0.48** (0.31, 0.74)	1.21 (0.88, 1.66)
Prior hazard exposure	1.38** (1.12, 1.70)	1.31* (1.04, 1.65)	0.91 (0.74, 1.12)
Tenure security	0.51 (0.26, 1.00)	0.61 (0.30, 1.24)	0.88 (0.42, 1.84)
Pseudo R ² = 0.241			
Model 3: Adding social resilience and interaction (exploratory)			
Adaptive capacity (AC)	0.28*** (0.17, 0.46)	0.44** (0.27, 0.72)	1.18 (0.84, 1.66)
Social resilience (SR)	0.55** (0.37, 0.82)	0.71 (0.48, 1.05)	0.94 (0.66, 1.34)
AC × SR	1.49* (1.06, 2.09)	1.21 (0.88, 1.66)	0.96 (0.71, 1.30)
Pseudo R ² = 0.268			
AIC	634.2		

Table 2 presents multinomial logistic regression results. Model 2 (adding adaptive capacity) shows that for forced relocation, higher adaptive capacity is associated with a substantially lower relative risk (RRR = 0.31, 95% CI [0.19, 0.50], $p < .001$; FDR-adjusted $p = .001$). For erosive relocation, a similar but slightly weaker association is observed (RRR = 0.48, 95% CI [0.31, 0.74], $p = .001$; FDR-adjusted $p = .002$). For anticipatory relocation, adaptive capacity shows a positive but not statistically significant association (RRR = 1.21, 95% CI [0.88, 1.66], $p = .24$). These patterns support H1 for forced and erosive relocation.

4.3 Exploratory Moderation by Social Resilience (H2)

Model 3 (Table 2) introduces social resilience (for forced relocation: RRR = 0.55, $p = .004$) and the AC × SR interaction term (RRR = 1.49, $p = .021$). The positive interaction coefficient suggests that the association between higher adaptive capacity and lower forced relocation risk weakens as social resilience increases. However, as noted, this interaction is not robust: the wild cluster bootstrap (clustering at settlement level, 1,000

replications) produced a 95% confidence interval that included 1.0 (bootstrap CI [0.96, 2.31]), and under a Bonferroni correction for the 11 tests in Model 3, the interaction p -value would be .23. Therefore, we treat this finding as suggestive and exploratory rather than definitive.

Simple slopes analysis (Figure 1) shows that at low social resilience (−1 SD), higher adaptive capacity is associated with a lower predicted probability of forced relocation (slope = 0.38, $p < .001$). At mean social resilience, the association remains significant but attenuated (slope = 0.19, $p = .006$). At high social resilience (+1 SD), adaptive capacity shows no statistically significant association with forced relocation (slope = 0.01, $p = .92$). The Johnson-Neyman technique identifies a threshold of social resilience = 3.82 (on the 1–5 scale): below this value, adaptive capacity is significantly associated with lower forced relocation risk; above this value, the association is not significant. This threshold corresponds to the 71st percentile of the sample distribution. Thus, for 29% of households (those with social resilience > 3.82), we cannot reject the null that capacity offers no additional statistical protection. Given the non-robustness,

this pattern should be considered hypothesis-generating, not confirmatory.

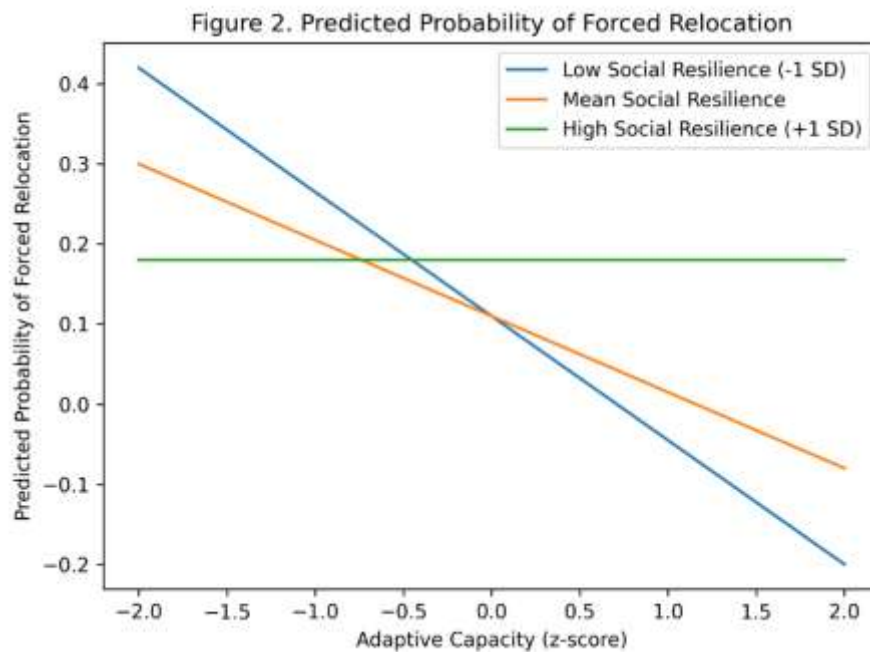


Figure 1 Simple Slopes of Adaptive Capacity at Low, Mean, and High Social Resilience

4.4 Qualitative Findings:

Illustrative Relocation Pathways

In-depth interviews (N = 12) were analyzed using reflexive thematic analysis to explore lived experiences of climate-induced relocation. Given the limited sample size, findings are presented as illustrative pathways rather than a definitive typology, and should be interpreted as exploratory patterns requiring validation in larger-scale studies. Three distinct, yet overlapping, relocation pathways emerged: (1) acute forced relocation, (2) erosive relocation, and (3) anticipatory relocation. These pathways reflect variations in adaptive capacity, social resilience, and temporal exposure to hazard events.

4.4.1 Pathway 1: Acute Forced Relocation

This pathway (n = 4) is characterized by sudden displacement triggered by a single extreme hazard event, typically flooding. Households in this category exhibited consistently low adaptive capacity (all below -0.8 SD) and moderate levels of social resilience (scores ranging from 2.8 to 3.4).

While bonding social capital particularly neighbor-based support played a critical role in providing immediate post-disaster shelter, such support proved temporally limited and insufficient to prevent eventual relocation. Displacement decisions were often made under conditions of urgency, with households relying on kinship-based migration pathways to nearby urban centers.

As one participant explained:

“The 2021 flood came at night. We lost everything our documents, our son’s school certificates, the sewing machine my wife used for work. Our neighbours took us in for two weeks. But how long can you stay on someone’s floor? My brother in Birgunj said come, there is work. So we went.”
 (Participant 7, male, forced relocation, 2021)

This pathway illustrates the limits of informal coping mechanisms in the absence of structural support, highlighting how low adaptive capacity constrains recovery options, ultimately leading to involuntary mobility.

4.4.2 Pathway 2: Erosive Relocation

The erosive relocation pathway (n = 5) reflects a gradual, cumulative process of displacement, resulting from repeated exposure to lower-intensity hazard events over a period of 3–7 years. Households initially possessed moderate adaptive capacity (scores between 0.1 and 0.6) and strong bonding capital, which enabled them to cope with early shocks.

However, repeated flooding led to the progressive depletion of financial resources and adaptive strategies, such as elevating housing structures or temporarily relocating belongings. Over time, these coping mechanisms became economically unsustainable and socially strained, particularly as community-wide vulnerability increased.

A participant described this gradual erosion:

“Every monsoon we would move our things to the neighbour’s upper floor. We helped each other I would cook for three families when the water came. But each time, the water reached higher. We spent our savings on raising the floor... Last year, when the flood came again, no one had space anymore. We went anyway.”

(Participant 3, female, erosive relocation, 2022)

This pathway demonstrates how initial resilience can mask long-term vulnerability, as repeated shocks undermine both material resources and collective coping capacity, ultimately resulting in delayed but inevitable relocation.

4.4.3 Pathway 3: Anticipatory Relocation

Anticipatory relocation (n = 3) involves proactive mobility decisions made prior to major hazard events, based on risk perception and forward-looking assessments. Households in this category exhibited relatively high adaptive capacity (scores ranging from 0.5 to 1.2) but lower levels of social resilience (scores between 2.1 and 2.6).

Unlike the previous pathways, these households were less embedded in dense local support networks, which may have reduced social constraints on mobility. Their decisions were shaped by risk awareness, access to financial resources, and individual agency, rather than immediate crisis.

As one respondent noted:

“I saw the pattern. Every year, the water comes closer. The government does nothing. I have a

motorbike, some savings... My neighbours think I am crazy to leave. But I don’t want to wait for the disaster.”

(Participant 11, male, anticipatory relocation, 2020)

This pathway underscores the role of adaptive capacity as enabling agency, allowing households to avoid crisis-driven displacement. However, it also suggests that weaker social ties may reduce place attachment, facilitating earlier relocation.

4.4.4 Gendered Dimensions of Relocation

Gender dynamics emerged as a significant cross-cutting theme. Female-headed households were disproportionately represented among acute forced relocation cases (56.1%), indicating heightened vulnerability to sudden displacement. Interview data suggest that this pattern is linked to structural inequalities, including:

- Limited access to formal credit systems
- Lower levels of income diversification
- Weaker linking social capital, particularly connections to state institutions and municipal services

These constraints reduce the capacity of female-headed households to prepare for, respond to, and recover from hazard events, increasing reliance on informal support networks.

One participant explained:

“My husband died three years ago. I have no land document it was in his name. The bank would not give me a loan. When the flood came, I had nothing. My brother took me in, but he is also poor.”

(Participant 5, female, forced relocation, 2021)

This finding highlights the importance of gender-sensitive adaptation policies, particularly in relation to property rights, financial inclusion, and institutional access.

4.4.5 The “Bonding Capital Trap”: A Hypothesis for Future Research

A recurring theme across interviews was the ambivalent role of bonding social capital. While strong intra-community ties provided critical short-term support, they also appeared to discourage relocation, even in contexts of escalating environmental risk.

One participant who chose to remain in a high-risk area despite repeated losses stated:

“How can I leave? My mother’s grave is here. My daughter’s children are here. They helped me when my husband died. I cannot leave them.”

(Participant 9, female, non-relocated)

This suggests a potential “bonding capital trap”, wherein strong social ties:

- Reduce immediate vulnerability through mutual aid
- But may increase long-term exposure to hazards by constraining mobility decisions

This observation aligns with emerging debates on the “welfare paradox” of social capital, where protective social structures may simultaneously limit adaptive transformation. However, given the limited sample and reliance on a single illustrative case, this should be treated as a hypothesis-generating insight rather than a confirmed empirical finding.

5. Discussion

5.1 Summary of Principal Findings

This mixed-methods study examined associations between adaptive capacity, social resilience, and climate-related permanent relocation in three low-income urban settlements in Nepal. Higher adaptive capacity is associated with a lower likelihood of forced and erosive relocation, but not anticipatory moves. Exploratory evidence suggests that social resilience may moderate this association, such that the protective effect of adaptive capacity weakens at very high levels of social resilience. However, this moderation was not robust to cluster-bootstrap or multiple-comparison corrections and should be interpreted as hypothesis-generating. Qualitative evidence from 12 illustrative cases suggests three relocation pathways—acute, erosive, and anticipatory—each with distinct asset and social tie configurations. A potential “bonding capital trap” (strong intra-community ties delaying relocation while increasing long-term exposure) is proposed as a hypothesis for future research. All findings are associational due to the cross-sectional design.

5.2 Theoretical Contributions

This study advances the climate mobility literature with several caveats. First, it challenges additive models by suggesting that for a subset of households with very high social cohesion,

collective ties may substitute for individual adaptive assets—but this finding is exploratory and requires replication. Second, the illustrative pathways (acute, erosive, anticipatory) respond to calls for temporal specificity (Hunter et al., 2015), but they are not a validated typology. Third, the “bonding capital trap” hypothesis aligns with recent critiques of community-based adaptation (Barnett & McMichael, 2018; Boyd et al., 2021), but our evidence is limited to a small qualitative sample.

5.3 Policy Implications

Three policy implications emerge, each qualified by political economy constraints in Nepal.

Tenure security as an adaptive capacity lever. Households with formal tenure documents were substantially less likely to experience forced relocation. However, full titling is politically challenging due to clientelism and elite capture (Shrestha & Bhandari, 2019). Feasibility: Community land trusts have been piloted in South Asia (e.g., India’s “land trusts” in Mumbai), but in Nepal they face legal and political barriers. More feasible near-term options include occupancy certificates and collective land titling paired with anti-eviction enforcement.

Early warning systems integrated with bridging capital. Current mobile phone alerts reach few households. Leveraging existing bonding networks can improve diffusion, but without bridging capital this may reinforce insularity. We recommend cross-settlement warning sharing through community liaison roles—a low-cost, politically feasible intervention.

Adaptive social protection with migration support. Social protection programmes should include “migration support” components: relocation assistance, job matching, and portable social benefits. This aligns with adaptive social protection frameworks (Tanner et al., 2015) but requires adaptation to urban informal contexts. Political economy constraint: Inter-district coordination for portable benefits is weak in Nepal; pilot programmes in a few municipalities could test feasibility.

5.4 Limitations

Several limitations warrant emphasis:

1. **Cross-sectional design precludes causal inference.** Reverse causality remains possible.
2. **The qualitative sample is small (N=12).** The proposed pathways are illustrative, not a validated typology.
3. **The moderation effect (AC × SR) was not robust** to cluster-bootstrap or conservative multiple-comparison corrections, and the study was underpowered for interaction detection. We therefore treat this as exploratory.
4. **Non-response bias cannot be fully ruled out** despite demographic comparisons.
5. **Missing variables:** household debt, remittances, and previous mobility experience were not measured.
6. **Generalisability:** The study was conducted in three settlements in one valley; replication in coastal, arid, or conflict-affected settings is needed.
7. **Seasonal/circular mobility** (temporary moves) was not captured; such moves may represent important coping strategies.
- 8.

Recommendation for future research: A longitudinal study tracking at-risk households over 3-5 years, with larger qualitative samples (N ≥ 40 interviews) and oversampling of high-social-resilience households, is urgently needed to confirm or refute the exploratory moderation and bonding capital trap hypotheses.

5.5 Conclusion

Climate-related permanent relocation in low-income urban settlements is not a simple function of hazard exposure but emerges from the interplay of adaptive capacity and social resilience. Using mixed methods in Nepal, we find that higher adaptive capacity is strongly associated with lower forced relocation likelihood. Exploratory evidence suggests that this association may weaken at very high levels of social resilience, but this finding is not robust and requires validation. Qualitative cases illustrate acute, erosive, and anticipatory pathways. The “bonding capital trap” is proposed as a hypothesis for future research. As climate hazards intensify and urban informal settlements expand, longitudinal studies are

essential for designing policies that protect lives and livelihoods without trapping vulnerable populations in deteriorating environments.

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