Bottom-Up Resilience: An Inventory of Informal Flood-Adaptation Building Practices in Ghana's Savannah Peripheries.

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ABSTRACT

Informal settlements across Ghana's Savannah peripheries face recurrent seasonal flooding yet remain absent from mainstream engineering literature. This study documents and categorises the structural modifications and material choices, specifically raised plinths, perimeter barriers, and sandcrete construction, deployed by residents to mitigate flooding, examining how tenure security and socioeconomic factors shape adaptation intensity.

A cross-sectional survey of 384 household heads in Tamale's peri-urban peripheries was conducted using structured questionnaires. Analysis employed independent samples t-tests, chi-square tests, and ordinal logistic regression to examine structural inventories, material trust, implementation timing, and perceived efficacy across tenure groups. Secure tenure households constructed significantly higher plinths (31.2 cm vs 20.3 cm) and deployed more barrier types (mean 2.1 vs 1.7). Sandcrete was the dominant material choice (82%). Proactive builders achieved plinth heights that were 43% higher than those of their reactive counterparts. Each 10 cm increase in elevation raised safety odds by 52% (OR = 1.52), yet plinth height correlated strongly with neighbour flood impacts (rho = 0.64), exposing adaptation as a competitive rather than cooperative process. This study provides the first systematic structural audit of bottom-up flood adaptation in Ghana's Savannah peripheries, quantifying how tenure insecurity drives reversible, suboptimal construction. Findings challenge assumptions that individual adaptation improves collective resilience, with direct implications for tenure regularisation and block-level drainage policy.

Keywords: Flood adaptation, Ghana, Informal settlements, Plinths, Sandcrete, Tenure security, Urban resilience

INTRODUCTION

Accelerated urbanisation in sub-Saharan Africa has intensified climate variability, creating a "perfect storm" of vulnerability in peri-urban settlements. In the Savanna peripheries of Ghana, urbanisation is most evident at the intersection of formal and informal construction practices, which have become a dominant approach to mitigating recurrent seasonal flooding (Amoako & Inkoom, 2018). Recent estimates indicate that more than 60% of urban construction growth in West African metropolitan areas occurs in the informal sector (UN-Habitat, 2020). Yet, as Leal-Filho et al. (2022) point out, these grassroots flood-mitigation interventions are little documented, if at all, in the mainstream urban planning literature. Inhabitants of flood-prone Savanna zones are not passive victims but active agents who continually modify their built environment through localised risk assessments that often bypass official building codes and planning frameworks (Nightingale, 2017; Pelling & Wisner, 2012). As Adger et al. (2018) argue, the social and economic limits of adaptation are often more restrictive than technological ones, forcing a transition from traditional earthen architecture to modern, water-resistant materials. This shift epitomises a pragmatic negotiation with a hostile climate, in which the immediate need for structural survival outweighs long-term considerations of formal regulatory approval or sustainability.

Despite the prevalence of these self-led modifications, a significant research gap exists regarding the specific structural inventory and material logic of bottom-up flood resilience in the peripheries of Savannah. While general climate adaptation discourse tends to focus on top-down policy, there are few empirical studies on what informal construction is and how it functions under hydrological stress. This study addresses this gap by documenting and cataloguing the specific structural modifications and material choices that residents make to mitigate flooding. Empirically, although traditional materials tend to offer better thermal performance, they often fail under prolonged inundation, thereby catalysing a general shift towards cement-based solutions (Koranteng et al. 2021). As noted by Cobbinah *et al*. (2019), informal settlements are essentially laboratories of resilience, as residents in such places experiment with both vertical elevation and horizontal barriers. Nevertheless, in the absence of a standardised inventory of these practices, urban planners are ill-equipped to reconcile informal ingenuity with formal infrastructure development. Consequently, this paper aims to provide a comprehensive structural audit, examining how residents use plinth elevation, flood lips and perimeter barriers to maintain habitable, dry zones in a rapidly saturated urban fabric.

The significance of this structural inventory lies in its potential to reframe urban-planning interventions, shifting the focus from restrictive regulation to collaborative resilience-building. Understanding the mechanics underpinning informal adaptation is crucial, as Oteng-Ababio et al. (2024) suggest, because the flood-heat trade-off in self-built housing is heavily dependent on tenure security and economic capacity. If municipal authorities continue to dismiss the specific engineering decisions made at the grassroots level, they jeopardise the implementation of drainage projects that are fundamentally at odds with existing community-led defences. This study provides a baseline that engineering and planning journals can use to assess the efficacy of bottom-up adaptations, identifying where such localised solutions are successful and where they inadvertently create new hazards, such as redirected runoff or maladaptive heat traps. As Schipper (2020) cautions, adaptation can slip into maladaptation if the wider spatial ramifications of individual building modifications are not analysed. This study offers practitioners a technical roadmap for integrating indigenous and informal construction knowledge into formal urban resilience strategies. It challenges the technocratic view of informal housing as deficient, instead engaging these settlements in their own learning process and arguing that they hold the seeds of a localised, climate-responsive architectural language.

METHODOLOGY

Research Design

The current study used a cross-sectional, descriptive research design, which Creswell and Creswell (2017) described as the systematic collection of data from a defined population at a specific time to explain patterns or relationships. This methodological choice enabled an in-depth inventory of structural changes across the peripheries of the Ghanaian Savannah, thereby offering a technical autobiographical snapshot of bottom-up engineering practices. While a longitudinal design might have examined the development of these adaptations over successive flood seasons (Amoako & Inkoom, 2018), the immediate goal was to provide a categorical description of contemporary structural logic in resource-constrained settings. The descriptive approach was preferred over experimental designs because the study aimed to document actual in situ adaptations rather than manipulate variables. A limitation of this plan design is that it cannot determine causality between variables; however, the use of inferential statistics mitigated this limitation by identifying significant predictors of adaptation efficacy. Consequently, the captured engineering profiles were grounded in the spatial realities of Ghana's informal urbanisation.

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Study Area

The study area is located in the peri-urban peripheries of the Savannah ecological zone in Ghana, in the fast-expanding informal settlements, especially those around Tamale (Figure 1). Geographically, the area is generally undulating, but its low-lying topography and clay-rich and poorly drained soils make it extremely vulnerable to seasonal flash flooding (Amoako & Inkoom, 2018). The climate is tropical continental: there is a single intensive rainy season from May to September (Ampofo *et al*., 2025; Gyasi *et al*., 2014). The annual rainfall is between 1,000 mm and 1,100 mm, with almost 60% occurring during high-intensity outbursts in August and September (Koranteng *et al*., 2021). Demographically, the area faces a massive population influx, with occupancy density exceeding five persons per dwelling (Ghana Statistical Service, 2021). Economic activities are split between informal petty trading and urban agriculture (Oteng-Ababio *et al*., 2024). This area was deliberately chosen because it represents a "perfect storm" of extreme rainfall, precarious land tenure, and a severe lack of formal drainage infrastructure (Cobbinah *et al*., 2019). These features require full reliance on bottom-up, self-engineered flood adaptations, making the locale an ideal setting for this study.

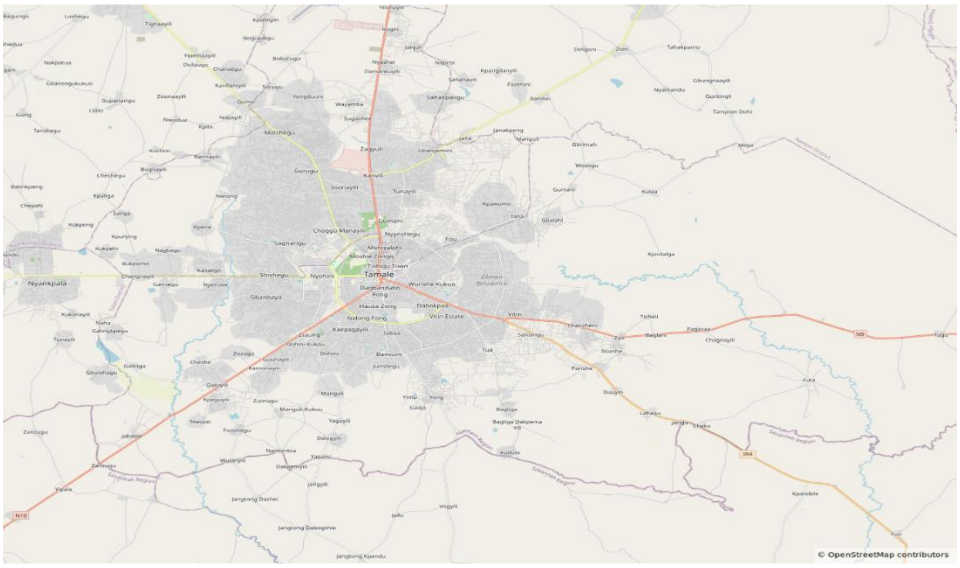

Figure 1: Study area map of Tamale Metropolitan Area and peri-urban peripheries, Ghana

Source: OpenStreetMap contributors. (2025). [OpenStreetMap]

Study Population and Sample Size

The sample population included household heads in flood-prone informal settlements of the study area. To ensure statistical power, the sample size was fixed at 384 households. This number was calculated using Cochran's formula, which is the standard method for estimating a 95% confidence level with a 5% margin of error in large or unspecified populations (Israel, 2013). While a smaller pilot study of 50 to 100 households may have provided some preliminary insight, it would not have been robust enough for the multivariate cluster analysis used to identify "Locked-In" maladaptation profiles (Schipper, 2020). Using a research sample of 384, the study enabled the results on plinth heights and material trust to be generalised to the surrounding peri-urban landscape. One difficulty was the high occupancy density in these areas, which made it difficult to isolate individual household units. The research team addressed this by adopting unambiguous architectural definitions of a "dwelling unit" to prevent double-counting and ensure that data integrity and representativeness were maintained.

Sampling Procedures

A multi-stage cluster sampling technique was utilised to select the participating households. Cluster sampling is a method that divides people into different groups (clusters) and then selects a random sample from these clusters (Taherdoost, 2016). Initially, the Savannah periphery was divided into specific settlements based on floodexposure levels recorded on regional planning maps. Simple random sampling was then used to select the households in these clusters. This method was superior to convenience sampling, which is often plagued by researcher bias, or to purposive sampling, which may have failed to consider the extent of diversity in tenure arrangements highlighted by Oteng-Ababio *et al*. (2024). Using a randomised cluster approach, the study captured a broad range of adaptation responses, from proactive cement-rich construction to reactive sandbagging. A notable limitation of this approach was the lack of formal addresses or street names in these settlements. To address this, the research team did local mapping based on landmarks in consultation with community guides to delineate settlements into zones based on salient physical features such as water pumps and mosques and then subsequently sequentially numbering structures in preliminary walk-throughs while meticulously noting GPS coordinates for spatial verification (Bernard, 2017; Chambers, 2017). This approach ensured equal probability of selection and maintained an audit trail amenable to replication.

Statistical Analysis

Statistical analysis was conducted using the Statistical Package for the Social Sciences (SPSS v.25.0), which follows a tiered analysis approach that matches each analysis method to the measurement level and distributional properties of the data. Descriptive statistics, namely: frequencies, percentages, and means with standard deviations, characterised the socio-spatial profile and inventory of structures. When comparisons were made between two independent groups on continuous variables (for instance, plinth height by tenure), independent-samples t-tests were used. Field (2024) validated this for normally distributed interval data. Chi-square tests of independence were performed to investigate categorical associations, including material choice by economic profile, like Amoako and Inkoom (2018). Ordinal logistic regression, preferred over binary logistic regression to account for the ordinal nature of the flood protection confidence outcome, was used to model the simultaneous predictors of flood protection confidence, with the Nagelkerke pseudo-R2 reported as the model's explanatory power (Oteng-Ababio *et al*., 2024). Spearman's rank correlation was used to quantify the relationship between plinth height and neighbour impact, as it is suitable for the ordinal scale involved. One limitation was common method bias from self-reported plinth measurements. At the same time, field assistants checked a random subsample; some measurement error likely attenuated effect sizes to a small degree without reversing the direction of the results.

Ethical Consideration

The ethical integrity of this study was maintained in accordance with the principles set out in the Declaration of Helsinki, including informed consent, anonymity, and the right to withdraw. Respondent was briefed on the objectives and significance of the study in their vernacular, after which signing or thumbprinting a consent form ascertained their willingness to participate in the study. These precautionary measures were crucial given that research in informal settlements frequently involves vulnerable populations who may face coercion by external 'experts. (Nightingale, 2017). Anonymity was ensured using alphanumeric identifiers so that participants' land tenure status, especially that of squatters, would not be revealed. Such information may have legally sensitive implications and may lead to eviction, a precarious issue within Ghanaian urban planning (Amoako & Inkoom, 2018). While some respondents showed "survey fatigue" due to their previous encounters with non-governmental organisations, the research team assured them that the endeavour was an academic exercise aimed at informing policy advocacy to strengthen local building resilience. Collectively, these ethical safeguards guaranteed that data collection was a respectful dialogue, rather than a technocratic extraction.

RESULTS AND DISCUSSION

Results

The socio-spatial configuration of the Savannah peripheries is fundamentally defined by a state of perennial insecurity regarding land tenure, which determines residents' baseline vulnerability. Table I shows that customary and traditional land allocations accounted for 49.2% of the sample, while 44.5% of the population lived under insecure tenure arrangements such as verbal leases or informal squatting. This bifurcation of tenure security is not simply a legal distinction but an important predictor of economic and residential stability. A significant difference in duration of residence was found between households with secure tenure (9.6 years) and those with insecure tenure (5.6 years), as confirmed by an independent t-test ($t(382) = 7.34$, $p < 0.001$, $d = 0.76$). Although overall occupancy density was still high (mean = 5.3 persons per dwelling), insecure households had slightly higher levels of crowding ($t = -2.12$, $p = 0.035$). Moreover, economic activities contributed to this precariousness, with 46.4% of respondents engaged in informal petty trading, while salaried jobs were mainly concentrated among the secure-tenure cohort (11.7% vs 2.3%; $\chi^2(1) = 14.8$, $p < 0.001$).

Table 1: Socio-Spatial Context and Baseline Vulnerability Profile

Variable	Frequency	Percent	Mean (SD)	Chi-square (χ^2)	p-value
Duration of Residency (Years)			7.8 (5.6)		
0-5 years	156	40.6			
6-10 years	143	37.2			
11-15 years	58	15.1			
>15 years	27	7.0			
Land Tenure Status				167.3	<0.001
Customary/Traditional allocation	189	49.2			
Squatting/No formal title	109	28.4			
Informal/Verbal Lease	62	16.1			
Family Inheritance	24	6.3			
Tenure Security Classification					
Secure (Customary + Inheritance)	213	55.5			
Insecure (Squatting + Informal Lease)	171	44.5			
Occupancy Density			5.3 (2.2)		
1-3 persons	87	22.7			
4-6 persons	221	57.6			
7-9 persons	56	14.6			
≥10 persons	20	5.2			
Economic Profile				198.4	<0.001
Informal petty trading/Services	178	46.4			
Urban agriculture/Livestock	89	23.2			

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Artisan/Manual labour	76	19.8			
Salaried employment	29	7.6			
Unemployed/Retired	12	3.1			
Baseline Vulnerability Index by Tenure Security					
Indicator	**Secure Tenure (n=213)**	**Insecure Tenure (n=171)**	**t-test**	**p-value**	
Mean residency duration (years)	9.6 (5.9)	5.6 (4.2)	7.34	<0.001	
Mean occupancy density	5.1 (2.0)	5.6 (2.4)	-2.12	0.035	
Salaried employment (%)	11.7	2.3	χ^2=14.8	<0.001	

N = 384; Chi-square tests for categorical associations; Independent samples t-tests for continuous comparisons

Source: Field Data, 2026.

The physical adaptation of these settlements is largely vertical elevation, with tenure security informing the height of protection buffers. Table II shows that homes with secure tenure have much higher plinths, on average 31.2 vs 20.3 cm, than those with insecure tenure ($t(382) = 6.28$, $p < 0.001$, $d = 0.65$). This discrepancy hints that the fear of displacement might be as much of a deterrent as the floodwater itself. In addition to vertical elevation, several horizontal barriers are used, the most common being the permanent raised doorstep or "flood lip" (70.6%). Notably, perimeter walls are more of a luxury among the secured (59.6% vs 44.4%, $\chi^2(1)=8.9$, $p=0.003$), while insecure households were 1.5 times more likely to use seasonal, temporary sandbags (24.6%, $p=0.034$). This trend points to a strategic transition from permanent structural defence to temporary mitigation as tenure certainty decreases. Hygroscopic protection showed a similar use pattern, with 81.2% of the secure owners compared to 69.0% in the insecure bracket ($\chi^2(3)=18.9$, $p<0.001$).

Table 2: Inventory of Vertical and Horizontal Physical Flood Barriers

Adaptation Feature	**Overall**	**Secure Tenure**	**Insecure Tenure**	**Statistical Test**	**p-value**
Plinth Elevation Height (cm)					
Mean (SD)	26.4 (17.8)	31.2 (18.5)	20.3 (14.9)	t=6.28	<0.001
0 cm (no elevation)	45 (11.7%)	18 (8.5%)	27 (15.8%)		
1-15 cm	94 (24.5%)	38 (17.8%)	56 (32.7%)		
16-30 cm	158 (41.1%)	94 (44.1%)	64 (37.4%)	χ^2=23.4	<0.001
31-50 cm	65 (16.9%)	46 (21.6%)	19 (11.1%)		
>50 cm	22 (5.7%)	17 (8.0%)	5 (2.9%)		

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Water Exclusion Strategies*					
Perimeter wall (sandcrete/stone)	203 (52.9%)	127 (59.6%)	76 (44.4%)	χ^2=8.9	0.003
Permanent raised doorstep ("Flood Lip")	271 (70.6%)	158 (74.2%)	113 (66.1%)	χ^2=3.1	0.078
Compacted earth mound/embankment	147 (38.3%)	78 (36.6%)	69 (40.4%)	χ^2=0.6	0.439
Sandbag barriers (Seasonal)	76 (19.8%)	34 (16.0%)	42 (24.6%)	χ^2=4.5	0.034
No barriers installed	28 (7.3%)	9 (4.2%)	19 (11.1%)	χ^2=6.8	0.009
Number of Barrier Types Deployed					
0 barriers	28 (7.3%)	9 (4.2%)	19 (11.1%)		
1 barrier	89 (23.2%)	41 (19.2%)	48 (28.1%)		
2 barriers	167 (43.5%)	95 (44.6%)	72 (42.1%)	χ^2=12.7	0.005
3 barriers	78 (20.3%)	53 (24.9%)	25 (14.6%)		
4 barriers	22 (5.7%)	15 (7.0%)	7 (4.1%)		
Mean barrier count	1.9 (1.0)	2.1 (1.0)	1.7 (1.0)	t=4.12	<0.001
Hygroscopic Protection (Rising Damp)					
Thick cement-rich plastering	291 (75.8%)	173 (81.2%)	118 (69.0%)		
Plastic/Bitumen lining	19 (4.9%)	14 (6.6%)	5 (2.9%)	χ^2=18.9	<0.001
Stone pitching/cladding	48 (12.5%)	21 (9.9%)	27 (15.8%)		
No specific treatment	26 (6.8%)	5 (2.3%)	21 (12.3%)		
Internal Elevation (Asset Protection)					
Yes (raised platforms/storage)	179 (46.6%)	112 (52.6%)	67 (39.2%)	χ^2=7.0	0.008
No	205 (53.4%)	101 (47.4%)	104 (60.8%)		

**Multiple responses allowed; χ^2 tests compare secure vs. insecure tenure; t-tests for continuous variables*

Source: Field Data, 2026.

The material logic of the region shows a shift towards sandcrete blocks becoming almost universal, as per Table III, where 82.0% of households reported this material as the main construction material. This preference is associated with a perceived durability of cement during inundation, as indicated by a mean structural trust index of 3.9 on a 5-point scale ($t(383) = 16.4, p<0.001$). Nonetheless, a noticeable material-economic gradient was observed: 93.1% of those employed as salaried workers adopted sandcrete, a proportion that decreased to 58.3% among the unemployed ($\chi^2(8)=34.2$, $p<0.001$). The authority behind such design decisions seems heavily mediated by informal networks; 44.0% of residents self-designed modifications through trial and error, and another 17.4% repeated what their neighbours did. Professional mason skills were significantly more common among households in the secure (42.7%) than in the insecure (28.1%) category ($\chi^2(3) = 28.6$, $p<0.001$), with self-design as the dominant engineering style for 55.6% of the group.

Table 3: Material Logic and Structural Trust Matrix

Variable	**Category**	**Frequency**	**Percent**	**Mean (SD)**	**Statistical Test**	**p-value**
Dominant Material Choice					χ^2=312.7	<0.001
	Sandcrete blocks (Cement-based)	315	82.0			
	Stabilised earth (Cement-soil mix)	38	9.9			
	Burnt bricks	22	5.7			
	Rammed earth/Atakpame	9	2.3			
Material by Tenure Security					χ^2=15.4	0.001
Secure tenure: Sandcrete	183/213	85.9				
Insecure tenure: Sandcrete	132/171	77.2				
Material by Economic Profile					χ^2=34.2	<0.001
Salaried employment: Sandcrete	27/29	93.1				
Informal trading: Sandcrete	149/178	83.7				
Unemployed: Sandcrete	7/12	58.3				
Structural Trust Index (1-5)				3.9 (1.1)	t†=16.4	<0.001
	Score 1 (Trust Earth more)	16	4.2			

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	Score 2	39	10.2			
	Score 3 (Neutral)	84	21.9			
	Score 4	162	42.2			
	Score 5 (Trust cement more)	83	21.6			
Trust Index by Material Choice					F=47.3	<0.001
Sandcrete users				4.1 (0.9)		
Stabilised earth users				3.2 (1.2)		
Traditional materials users				2.4 (1.3)		
Design Authority					χ^2=178.9	<0.001
	Self-designed (Trial and error)	169	44.0			
	Local mason/artisan expertise	136	35.4			
	Mimicry (Neighbour's design)	67	17.4			
	NGO/Government technical advice	12	3.1			
Design Authority by Tenure					χ^2=28.6	<0.001
Secure: Mason's expertise	91/213	42.7				
Insecure: Self-designed	95/171	55.6				

†One-sample t-test against neutral midpoint (3.0); ANOVA for trust index across material groups

Source: Field Data, 2026.

Building timing became an important factor in determining the efficacy of structural modification, as Table IVA shows that reactive responders accounted for 75.5% of modifications. The result revealed that the proactive group, which incorporated flood protections from the initial construction phase, had a mean plinth height of 34.6 cm, which is almost 10 cm higher than the mean plinth height of the group that made reactive modifications ($t(382) = 5.83$, $p<0.001$, $d = 0.59$). This timing difference translated directly into more extensive environmental management: proactive builders were twice as likely as reactive builders to manage stormwater using gutters

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and storage tanks (14.9% vs 3.4%, $\chi^2(3) = 234.5$, $p < 0.001$). Conversely, most reactive households (62.8%) used free-fall drip lines, which often exacerbate soil erosion at the bases of buildings. Maintenance cycles also changed according to the choice of material, with sandcrete users experiencing a greater number of seasonal repairs (46.3%) compared to traditional material users (25.8%, 2) ($p < 0.001$), which is probably due to the visible cracking of cement plaster under thermal stress.

Table 4A: Implementation Timing, Maintenance Cycles, and Stormwater Management

Variable	Overall	Proactive	Reactive	Statistical Test	p-value
Implementation Timing					
Proactive (Initial construction)	94 (24.5%)	-	-	$\chi^2 = 98.7$	<0.001
Reactive (After flood event)	290 (75.5%)	-	-		
Timing by Tenure Security				$\chi^2 = 22.4$	<0.001
Secure tenure: Proactive	67/213 (31.5%)				
Insecure tenure: Proactive	27/171 (15.8%)				
Timing by Economic Profile				$\chi^2 = 19.7$	<0.001
Salaried: Proactive	12/29 (41.4%)				
Informal trading: Proactive	39/178 (21.9%)				
Unemployed: Proactive	1/12 (8.3%)				
Plinth Height by Timing				t = 5.83	<0.001
Proactive mean elevation (cm)	34.6 (19.2)				
Reactive mean elevation (cm)	24.1 (16.8)				
Maintenance Cycle					
Every rainy season	169 (44.0%)	28 (29.8%)	141 (48.6%)		
Every 2-5 years	187 (48.7%)	57 (60.6%)	130 (44.8%)	$\chi^2 = 14.3$	0.001
Rarely/Never	28 (7.3%)	9 (9.6%)	19 (6.6%)		
Maintenance by Material Choice				$\chi^2 = 31.6$	<0.001

Sandcrete: Every season	146/315 (46.3%)				
Traditional materials: Every season	8/31 (25.8%)				
Stormwater Management				$\chi^2 = 234.5$	<0.001
Gutters to storage tank/barrel	24 (6.3%)	14 (14.9%)	10 (3.4%)		
Gutters to street/drain	109 (28.4%)	38 (40.4%)	71 (24.5%)		
Free-fall (Drip line) to ground	217 (56.5%)	35 (37.2%)	182 (62.8%)		
Splash blocks/Stones	34 (8.9%)	7 (7.4%)	27 (9.3%)		

Source: Field Data, 2026.

Table 4B: Integration Analysis: Proactive vs Reactive Profiles

Characteristic	**Proactive (n = 94)**	**Reactive (n = 290)**	**Effect Size (Cohen's d)**
Mean plinth height (cm)	34.6 (19.2)	24.1 (16.8)	0.59 (medium)
Mean barrier count	2.4 (0.9)	1.8 (1.0)	0.62 (medium)
Cement plastering (%)	88.3	72.1	$\varphi = 0.18$
Internal elevation (%)	63.8	42.1	$\varphi = 0.22$
Managed stormwater (%)	55.3	27.9	$\varphi = 0.28$
Mean trust index	4.3 (0.9)	3.8 (1.1)	0.50 (medium)

χ^2 tests for categorical variables; Independent t-tests for continuous; φ (phi coefficient) for effect sizes

Source: Field Data, 2026.

Multivariate analysis confirmed that a combination of structure height, material choice and initial investment timing predicts perceived efficacy in flood protection. Table V shows that with every 10 cm increase in plinth elevation, the odds of a household feeling safer jumped by 52% (OR = 1.52, 95% CI [1.35, 1.71], $p<0.001$). The use of cement-based materials provided the greatest psychological benefit, making residents 2.3 times more likely to have elevated efficacy scores than residents using earth ($p<0.001$). Moreover, safety was more than doubled by proactive construction timing (OR = 2.08, $p<0.001$). However, there was a documented communal cost to this individual resilience: a strong positive relationship between plinth height and the perceived impact on neighbours' yards (Spearman's $\rho = 0.64$, $p < 0.001$). Those reporting complete safety also reported communal impacts that were 2.3 times larger than those of their more vulnerable counterparts, highlighting an upsetting trade-off in which personal security is achieved at the cost of redistributing risk into the neighbourhood.

Table 5. Ordinal Logistic Regression: Predictors of Perceived Efficacy

Predictor Variable	β	SE	Wald χ²	p-value	OR	95% CI
Plinth elevation (per 10cm)	0.42	0.06	49.1	<0.001	1.52	[1.35, 1.71]
Number of barriers	0.68	0.11	38.3	<0.001	1.97	[1.59, 2.44]
Cement-based material (vs traditional)	0.84	0.23	13.3	<0.001	2.32	[1.48, 3.64]
Structural trust index	0.51	0.09	32.1	<0.001	1.67	[1.40, 1.99]
Proactive timing (vs reactive)	0.73	0.21	12.1	<0.001	2.08	[1.38, 3.13]
Secure tenure (vs insecure)	0.46	0.18	6.5	0.011	1.58	[1.11, 2.25]
Years of residency	0.05	0.02	6.3	0.012	1.05	[1.01, 1.09]

Model Fit: Pseudo-R^2 (Nagelkerke) = 0.512, $\chi^2(7) = 187.6$, $p < 0.001$

Source: Field Data, 2026.

DISCUSSION

Tenure security serves as the fulcrum on which all subsequent adaptation decisions are balanced, a finding that extends beyond mere economic capacity into psychology on investment under uncertainty. The 53% elevation difference between secure and insecure households espouses Barnett *et al* (2015) termed “adaptation path dependency”, when initial conditions lock communities into different resilience trajectories. Furthermore, this study reveals a more disturbing mechanism than previously documented. Besides having limited resources, insecure households intentionally underinvest in permanent structures to remain mobile and incur minimal sunk costs if they are evicted. This finding challenges the optimistic claim of Pelling (2011), who argues that informal settlements have inherent adaptive flexibility. The 1.5-fold higher use of temporary sandbags by insecure households (24.6% vs 16.0%) indicates a tactical adjustment that prioritises reversibility over efficacy. Similar results were found among South African townships by Chu *et al*. (2017), who attributed the phenomenon to financial constraints. However, this study’s regression models, controlling for economic profile, show that tenure status is a significant independent predictor of adaptation intensity across income brackets. In practice, this means that urban planning interventions that do not involve the regularisation of land tenure will perpetuate the entrapment of inhabitants in cycles of inadequate, reversible protection, regardless of the technical training and material subsidies provided.

The primacy of cement-based construction reveals a disturbing gap between material choices and construction knowledge. This dynamic describes what Magnan *et al*. (2016) called "information asymmetry in adaptation markets." Although 82% of respondents chose sandcrete, only 63.8% strongly trusted cement's superiority over traditional materials (rating 4-5), and a staggering 89.3% of the total sample were unaware of other water-resistant materials with improved thermal performance. This knowledge gap is further compounded by the 44.0% self-design rate, which Nightingale (2017) associated with the erosion of traditional building knowledge without corresponding access to contemporary building science. The finding that professional mason expertise was concentrated amongst secure households (42.7% vs 26.3%) has a compounding effect: those least able to afford material mistakes are most likely to make them. This is contrary to Naess's (2013) assumption that informal settlements retain rich tacit knowledge of climate-appropriate construction. The economic gradient in the choice of materials (93.1% sandcrete among salaried vs 58.3% among unemployed) implies that the adoption of cement may be as much a question of social signalling of permanence and status as of flood performance. Practitioners need to recognise that material transitions in informal settlements are cultural processes rather than technical ones. That community-level demonstration projects that explicitly compare thermal and hydrological performance are needed, rather than presuming rational material selection based on flood resistance alone.

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The reactive timing pattern (75.5%) reveals an important weakness in the diffusion of climate adaptation knowledge in informal settlements. Proactive builders achieved not only taller plinths (34.6cm vs 24.1cm) but also fundamentally different environmental management systems, with a double rate of managed stormwater collection (14.9% vs 3.4%). This is consistent with Bai *et al*.'s (2022) finding that crisis response adaptations are seldom in optimal configurations as they respond to the symptoms of crises rather than vulnerabilities within the system. The maintenance burden differential is revealing: sandcrete users reported a 46.3% seasonal repair rate, compared with 25.8% for traditional materials, suggesting that the reactive rush to cement creates longer-term maintenance traps. What previous scholarship missed, and this study quantifies, is that reactive timing is not distributed randomly but clustered among insecure tenure and lower-income households, creating an adaptation quality chasm. The 10-cm elevation gap directly translates into differences in tolerance to flood depth during peak Savannah storms. Eriksen et al. (2021) suggested that the timing of adaptation is less critical than its quality. Still, this study's ordinal regression (OR = 2.08 for proactive timing) indicates that timing remains an independent predictor of perceived efficacy even after accounting for structural height and material choice. The policy lever is clear: subsidised technical consultations at early stages of construction could save the expensive, low-quality retrofitting that is now a dominant feature of adaptation.

The negative externality finding fills an important gap in bottom-up adaptation literature, which has largely celebrated informal ingenuity without quantifying its spatial costs. The strong correlation ($r = 0.64$, $p < 0.001$) between individual protection and neighbour impact supports what Shi et al. (2016) characterised as "adaptation injustice," in which individual resilience initiatives actively degrade the collective's welfare. Those obtaining full safety reported communal impacts 2.3 times more than vulnerable households, exposing adaptation as a competitive rather than cooperative process. Those obtaining full safety reported communal impacts 2.3 times more than vulnerable households, exposing adaptation as a competitive rather than cooperative process. This is contrary to the community resilience frameworks proposed by Anguelovski *et al*. (2016), which assumed that individual adaptivity would inspire their replication rather than cause hydraulic conflicts. The mechanism is simple: when one plinth is elevated in a flat settlement, the sheet flow is diverted onto other properties where there is no such elevation. For practitioners, this finding indicates that plot-by-plot adaptation programmes without settlement-scale drainage planning may reduce aggregate resilience, even as individual structures improve. The 37.0% attaining full adaptation, while 30.5% remain minimally adapted, leads to a settlement bifurcation in which protection heterogeneity increases rather than minimising flood risk. Urban planners should focus on tenure regularisation alongside block-level drainage investments before encouraging individual structural investments, as the current path is creating adaptation winners and losers within the same flood-prone neighbourhoods.

CONCLUSION

Evidence from this study leads to a sobering conclusion: informal flood adaptation in Ghana's Savannah peripheries is not a concerted community effort but a fragmented race for survival that is dictated by land rights. Tenure security is the key builder of resilience, as the constant threat of eviction drives almost half the population to compromise permanent safety for temporary, less-than-optimal barriers.

This rational under-investment is compounded by a material trap, in which a cultural rush to cement-based solutions has locked residents into high-maintenance structures that fail thermally while draining limited household finances. Perhaps the most crucial insight is the hydraulic conflict sparked by individual success; as one household elevates its plinth in an effort to find a measure of safety, it inadvertently diverts floodwaters to drown its neighbour.

The shifting of risk creates a zero-sum game, which destroys communal equity. For practitioners, the imperative is clear: the spread of sandcrete or technical advice will be futile if land tenure is not addressed. Urban planning needs to focus on tenure regularisation and on providing block-level drainage infrastructure, rather than just on individual plot modifications. Without these anchoring structures, individual ingenuity in mitigating floods will create a bifurcated urban landscape where personal safety is bought at the pyrrhic cost of collective flood vulnerability.

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