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Anticipated displacement and household adaptation on Ghana's eroding coast

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Research Article

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Abstract

Coastal households in Ghana's Volta Delta live with recurrent flooding and shoreline retreat, yet little is known about how expectations of future displacement shape their adaptation. The study surveyed 370 households in four communities of Keta Municipality, two on the seafront sand barrier (Keta, Havedzi) and two in the lagoon (Anyako, Seva), and drew on focus groups (n = 24) and key-informant interviews (n = 3). Adaptation was separated into place-bound strategies (improved fishing or farming practices, disaster preparedness, resilient structures), a portable strategy (income diversification) and mobility (relocation). The number of place-bound strategies was modelled with ordered logit models and each strategy with logit models, using multiple imputation for implausible incomes. Perceived hazard exposure (OR = 2.70 per SD), recent displacement (OR = 2.21) and income (OR = 1.88) were associated with broader place-bound adaptation. Anticipated displacement was associated with narrower place-bound adaptation (OR = 0.38 per SD) but not with diversification. The association was concentrated on the seafront (OR = 0.25), mainly in Keta, rather than the lagoon (OR = 0.76, not significant). On the seafront, households expecting displacement were also less likely to report relocation; in the lagoon they were more likely to do so. Vulnerability appraisal did not consistently predict adaptation. Where land is being lost, expecting displacement is associated with lower use of both protection in place and relocation. Clear decisions about which places will be protected, with support for portable livelihoods and assisted relocation, may matter as much as hazard awareness.

1. Introduction

The eastern shore of Ghana's Volta Delta is one of West Africa's fastest-changing coastlines. East of the Volta estuary, the marine shoreline retreated by an average of about 2.2 m per year between 1895 and 2015, which Appeaning Addo et al. (2020) attribute to reduced sediment supply after the damming of the Volta and to the effects of coastal defences. In Keta Municipality, erosion affects about 60% of the shoreline, and more than 40% of houses in the coastal strip are in poor or dilapidated condition as a result (Adu-Gyamfi et al., 2020). Scenario mapping places 667 structures and 13.6 km of road within the inundation zone of a 5 m extreme sea-level scenario (Tumawu et al., 2024). Groynes and revetments built since the early 2000s have protected parts of the coast but have shifted erosion down-drift towards the border with Togo (Mann et al., 2023). Behind the beach, the communities of the Keta Lagoon face a different hazard: flooding from rainfall, rising lagoon levels and tidal surges, which displaces households and then recedes. For many households in the municipality, displacement is therefore not a single event but a recurring part of life.

Research on household adaptation has identified a familiar set of drivers. Perceived risk and direct experience of hazards tend to raise protective behaviour, although the link between perception and action is often weak (Grothmann & Patt, 2005; Bubeck et al., 2012; Wachinger et al., 2013). Income, assets and access to information determine which responses are feasible (Deressa et al., 2009; Brooks et al., 2005). In Ghana, most quantitative evidence on adaptation comes from farming households (Antwi-Agyei & Nyantakyi-Frimpong, 2021; Guodaar et al., 2023; Baffour-Ata et al., 2025). Work in the

Volta Delta has documented hazard perceptions and coping practices (Mattah et al., 2024), the sociodemographic and geophysical determinants of vulnerability (Atiglo et al., 2022), and the drivers of migration intentions (Abu et al., 2022). Adaptation in place and movement away from risk, however, are usually studied separately.

This separation leaves out a question central to eroding coasts: how does the expectation of being displaced again shape whether households invest in the places they occupy? Two lines of literature point to an answer. The economics of investment under uncertainty holds that the value of an irreversible, location-specific investment falls as the probability of losing the asset rises (Dixit & Pindyck, 1994). The literature on environmental immobility shows that many households at risk do not move, because they cannot afford to, because they are attached to place or livelihood, or because institutions keep them in place (Black et al., 2011, 2013; Penning-Rowsell et al., 2013; Adams, 2016; Ayeb-Karlsson et al., 2018; Zickgraf, 2019; Mallick et al., 2022). Taken together, these suggest that households expecting displacement may withdraw from place-bound adaptation without moving. Whether this happens, and where, has not been tested with household data from West African deltas.

A second, policy-relevant question concerns vulnerability appraisal. Adaptation programmes often assume that households that recognise vulnerability will act on it. Yet appraisals of who is vulnerable, and why, may have little bearing on what a household does if it lacks the means to act (Grothmann & Patt, 2005; Otto et al., 2017).

This study addresses these questions using a household survey (n = 370) and qualitative data from four communities in Keta Municipality. It asks: (i) how hazard exposure, displacement experience and income relate to place-bound adaptation; (ii) whether anticipated displacement is associated with less place-bound adaptation but not with less portable adaptation; (iii) whether that association differs between the seafront, where land is lost, and the lagoon, where inundation recurs and recedes; and (iv), as an exploratory question, whether vulnerability appraisal is associated with adaptation. The paper makes three contributions. First, it measures place-bound, portable and mobility strategies separately, rather than counting adaptation as a single quantity. Second, it identifies anticipated displacement as a strong, setting-specific correlate of lower place-bound adaptation, linking the adaptation and immobility literatures. Third, it integrates survey models with household and institutional accounts to interpret, and to set limits on, the proposed mechanism.

Section 2 sets out the framework and hypotheses. Section 3 describes the study area, data and methods. Section 4 presents the results, Section 5 discusses them, and Section 6 concludes.

2. Conceptual framework and hypotheses

2.1 Three kinds of adaptation

Household responses to coastal hazards differ in how firmly they tie the household to a particular place. Place-bound strategies, such as raising or reinforcing structures, adopting hazard-adjusted fishing or

farming practices, and taking part in community preparedness, yield returns mainly if the household and its assets remain where they are. Portable strategies, notably diversifying into trades or businesses that can be practised elsewhere, retain their value if the household moves. Mobility strategies, such as relocating to safer areas, change the household's exposure rather than its capacity to absorb it (Black et al., 2011; Hino et al., 2017). Treating these as interchangeable, for example by counting strategies, hides the possibility that the same driver pushes them in opposite directions. The analysis therefore uses the number of place-bound strategies as the principal outcome and models the portable and mobility strategies separately (Fig. 1).

2.2 Exposure, experience and capacity

Protection motivation theory holds that protective action follows when people appraise a threat as serious and believe that a response is effective and within their ability (Rogers, 1983). Grothmann and Patt (2005) extended it to climate adaptation by adding perceived adaptive capacity. Frequent exposure to hazards makes the threat concrete, and direct experience of loss is among the most consistent predictors of protective behaviour (Bubeck et al., 2012; Wachinger et al., 2013). Households that have been displaced, or that have resettled after displacement, have also had to rebuild livelihoods, which may itself prompt new practices and income sources. Coping capacity, finally, depends on resources: costly measures such as resilient structures require income or savings (Deressa et al., 2009; Brooks et al., 2005). We expect:

- **H1.** Greater perceived hazard exposure is associated with broader place-bound adaptation.
- **H2.** Recent displacement and resettlement after displacement are associated with broader place-bound adaptation.
- **H3.** Higher income is associated with broader place-bound adaptation, especially costly protective strategies.

2.3 Anticipated displacement and the hazard regime

Protection motivation theory concerns whether people act on a threat; it says less about which response they choose when the threat is the loss of the place itself. Here investment-under-uncertainty reasoning complements it. That reasoning holds that an irreversible investment tied to an asset is less attractive the more likely the asset is to be lost (Dixit and Pindyck, 1994). Applied to coastal households, this is our interpretation rather than a proposition of either theory: if a household believes it will soon lose access to its plot, house or landing site, the expected return on place-bound measures falls, while portable strategies keep their value. Relocation is the obvious alternative, but moving is costly and constrained by livelihood, attachment and institutions, so households that expect displacement may neither invest nor move (Black et al., 2013; Adams, 2016; Zickgraf, 2019). We call this proposed pattern anticipatory disinvestment. It differs from low adaptive capacity or poverty-related under-investment in that it is tied to expectations about a specific place rather than to a lack of resources, and so should be observed

after income, education and livelihood are held constant and should affect place-bound but not portable strategies.

The pattern should depend on what displacement means locally. Where inundation is recurrent but temporary, as around the Keta Lagoon, displaced households expect to return, and the value of investing in place is largely preserved. Where the shoreline is retreating, as on the sand barrier, displacement may mean permanent loss of the land itself (Appeaning Addo et al., 2020; Adu-Gyamfi et al., 2020), and expectations of displacement should weigh more heavily on investment. We expect:

- **H4a.** Anticipated displacement is associated with less place-bound adaptation, but not with less portable adaptation.
- **H4b.** This association is stronger on the seafront than in the lagoon communities.

Because relocation can be both a response to expected displacement and something households are prevented from doing, we state no directional hypothesis for it and examine it by setting.

2.4 Vulnerability appraisal

Households also form views about who is vulnerable to displacement and why: whether women, children or people with disabilities are at greater risk, and whether poverty, informal work or poor access to information make households more exposed. Such appraisals reflect awareness of social vulnerability (Cutter, 2003; Otto et al., 2017). The literature points in both directions. Awareness could prompt protective action, as protection motivation theory suggests; but appraisals of other groups' vulnerability are not appraisals of one's own threat or capacity, and the gap between risk perception and action is well documented (Wachinger et al., 2013). Because there is no strong basis for a directional expectation, we treat vulnerability appraisal as an exploratory question rather than a hypothesis.

3. Study area, data and methods

3.1 Study area

Keta Municipality lies on the eastern flank of the Volta Delta in Ghana's Volta Region (Fig. 2). Its settlements occupy two contrasting landforms. Keta and Havedzi stand on the narrow sand barrier that separates the Keta Lagoon from the Gulf of Guinea; Anyako and Seva lie on islands and shores of the lagoon. We classified the communities into two hazard settings by this landform position, which determines the dominant hazard. On the barrier, wave attack, tidal surges and erosion remove land and destroy buildings: the marine shoreline east of the estuary has retreated by about 2.2 m per year over the long term (Appeaning Addo et al., 2020), wave run-up drives most coastal flooding in Keta (Brempong et al., 2023), and defences built since the early 2000s protect some stretches while intensifying erosion down-drift (Mann et al., 2023). In the lagoon communities, flooding from rainfall, lagoon overflow and tidal surges recurs and then recedes. We refer to the first pair as the seafront and the second as the lagoon setting.

The survey data are consistent with this classification. Among households that had lost property to displacement, loss of land was reported almost only on the seafront (10.1% vs 0.9% in the lagoon) and loss of a house or building twice as often (21.2% vs 10.2%), whereas loss of fishing or farming equipment was more common in the lagoon (51.9% vs 38.6%); seafront households were also more likely to report that erosion affected their home sometimes or often (68.8% vs 54.4%) (Table 2). The settings also differ in ways unrelated to hazard: seafront households are better educated and better off, less dependent on fishing, and more likely to receive early warnings, and Keta is the municipal capital with better access to services. These differences are controlled where they are measured, but the comparison rests on two communities in each setting and should not be read as representative of all seafront and lagoon communities. The four communities had a combined population of 15,901 at the 2021 census (Ghana Statistical Service, 2021) and depend heavily on fishing, fish processing and petty trade.

3.2 Design and sampling

The study used a convergent mixed-methods design in which survey and qualitative data were collected in the same period, kept separate during collection, and integrated during interpretation (Creswell & Plano Clark, 2018). Fieldwork took place between April and May 2026 after ethical approval was granted on 25 March 2026.

The four communities were selected purposively because of their repeated exposure to tidal flooding and displacement. The survey sample size of 375 was set using Cochran's (1977) formula (95% confidence, 5% margin of error, $p = 0.5$, finite-population correction for $N = 15{,}901$) and allocated in proportion to the 2021 census population of each community (Anyako 116; Keta 203; Seva 15; Havedzi 41). No up-to-date list of households was available, so the sampling interval in each community was obtained by dividing its census population by its allocated sample size ($k \approx 38–43$), and enumerators selected every k-th dwelling after a randomly chosen starting dwelling. In each selected dwelling, one adult was interviewed face-to-face using KoBoCollect by one of three trained field assistants. The questionnaire was pretested with 40 household heads in Kedzi, a nearby coastal community outside the sample.

The achieved sample matched the planned total but differed slightly in its distribution (Anyako 119; Keta 197; Havedzi 41; Seva 18; total 375). The differences resulted from non-response and replacement in Keta and additional interviews in Anyako and Seva. Five records had a recorded age below the 18-year eligibility threshold (three of 8–9 years, probably entry errors, and two of 15 and 17 years); because the true age could not be verified, all five were excluded, leaving 370 respondents (Anyako 118; Keta 194; Havedzi 40; Seva 18). The regression sample is 366 because four records had no livelihood code. Seva ($n = 18$) and Havedzi ($n = 40$) are small, reflecting their populations but limiting community-specific comparisons; we therefore compare settings, report community-specific estimates where they matter, and test the sensitivity of each result to excluding each community.

The qualitative strand comprised four focus group discussions, one per community, each with six household heads (n = 24), and semi-structured interviews with three officers of the Keta Municipal Assembly: the NADMO (National Disaster Management Organisation) officer, the Planning Officer and the Social Welfare Officer. Focus-group participants were selected purposively for direct experience of displacement and involvement in household livelihood decisions. Discussions and interviews were conducted face-to-face, recorded with consent, transcribed and anonymised. Transcripts were analysed thematically following Braun and Clarke's (2006) six phases: familiarisation through repeated reading; manual coding of all statements relevant to displacement, livelihoods and adaptation; clustering of codes into candidate themes; review of the themes against the coded extracts and the full transcripts; definition and naming of the themes; and write-up. Peer debriefing with colleagues was used to check the coding.

3.3 Measures

Table 1 summarises the measures; Table A3 provides the wording of the main survey questions.

Adaptation. Respondents reported which of five strategies their household currently used: relocation to safer areas, diversification of income sources, improved fishing or farming practices, participation in community disaster-preparedness programmes, and construction of resilient structures. Place-bound breadth, the principal outcome, counts the three place-bound strategies (improved practices, preparedness, resilient structures; 0–3). Diversification (portable) and relocation (mobility) are modelled as separate binary outcomes. The count of all four in-situ strategies used in earlier analyses is retained as a supplementary outcome. The relocation item did not distinguish temporary from permanent moves or specify the destination, so relocation is interpreted as any current move to safer ground rather than as permanent resettlement. The survey also contained a general yes/no adoption question, but its answers contradicted the strategy list for 80 respondents (70 answered "no" yet listed at least one strategy; 10 answered "yes" and listed none), so we rely on the strategy-specific items.

Hazard exposure is the mean of three items on how often flooding, tidal waves and coastal erosion affect the household's area or home (1 = never to 4 = often; Cronbach's $\alpha = 0.77$). Recent displacement indicates whether the household was displaced by flooding, erosion or tidal waves in the past five years, and resettlement whether its current residence resulted from an earlier displacement. Anticipated displacement is the response to "How often do you anticipate being displaced in the next five years?" (never, rarely, sometimes, often; 1–4). The question did not define displacement, but it followed items on displacement from the home by flooding, erosion, or tidal waves, so respondents likely understood it as being forced from their home by these hazards, whether temporarily or permanently; it does not distinguish between the two. It is only weakly related to worry about displacement (Spearman $\rho = -0.09$) and modestly to hazard exposure ($\rho = 0.21$), indicating that it captures an expectation rather than an emotion or a restatement of exposure.

Income is the natural logarithm of reported monthly household income. Forty-one respondents reported values below GHS 100. Thirty-eight of these were between GHS 2 and 15 (most often 5 or 6), followed by

a gap to the next values (32, 50 and then 100). They are far below any plausible monthly household income and most likely abbreviated entries (for example, "5" for 500 or 5,000) whose scale cannot be recovered, so they were set to missing and multiply imputed (Section 3.4) rather than rescaled or retained.

Vulnerability appraisal was measured with thirteen items asking how vulnerable specific groups (women, men, children, persons with disabilities) and households in specific conditions (low income, informal work, fishing or farming, limited finance, low education, limited understanding of early warnings, limited access to awareness campaigns, absence of outreach institutions, and combined education and information deficits) are to climate-induced displacement (1 = low to 3 = high). The items were suitable for factor analysis (KMO = 0.82; Bartlett's $\chi^2(78) = 1597.5$, $p < 0.001$). Parallel analysis (Horn, 1965) suggested two clear factors and a marginal third (eigenvalue 1.24 against a random-data threshold of 1.23); we retained the interpretable two-factor varimax solution. All nine items on income, work, livelihood, education and information loaded on the first factor (0.49–0.77), which we interpret as appraisal of structural (socio-economic and informational) vulnerability; the four items on women, men, children and persons with disabilities loaded on the second (0.38–0.70), interpreted as appraisal of demographic vulnerability (Table A3). We use the mean of each set as a structural ($\alpha = 0.86$) and a demographic ($\alpha = 0.69$) score, because the two capture different beliefs—about the conditions and about the groups that make households vulnerable—that may relate differently to action.

Controls are sex, age, education (five levels, entered as a linear term), household size, years of residence, main livelihood (fishing as reference; trading; formal employment; other, which combines farming and artisanal work because only 16 respondents farmed) and community fixed effects (Anyako as reference). All continuous predictors (exposure, anticipated displacement, income, appraisal scores, age, household size and years of residence) are standardised to mean 0 and SD 1, so their coefficients refer to a one-standard-deviation (SD) increase; binary predictors refer to the presence of the attribute.

Table 1
Measures used in the analysis.

Construct	Measure	Scale/coding	Reliability
Place-bound breadth (principal outcome)	**Count of improved practices, preparedness, resilient structures**	**0–3**	**–**
Portable adaptation	Income diversification	0/1	–
Mobility	Relocation to safer areas	0/1	–
Four-strategy breadth (supplementary)	Place-bound strategies plus diversification	0–4	–
Hazard exposure	Mean frequency of flooding, tidal waves and erosion affecting area or home	1–4, standardised	α = 0.77
Recent displacement	Displaced by flooding, erosion or tidal waves in past 5 years	0/1 (ref.: not displaced)	–
Resettlement	Current residence resulted from earlier displacement	0/1 (ref.: no)	–
Anticipated displacement	Expected frequency of displacement in next 5 years	1–4, standardised	–
Income	Log monthly household income (values < GHS 100 imputed)	Standardised	–
Vulnerability appraisal: structural	Mean of 9 items on income, work, livelihood, education and information	1–3, standardised	α = 0.86
Vulnerability appraisal: demographic	Mean of 4 items on women, men, children, persons with disabilities	1–3, standardised	α = 0.69
Setting	Seafront (Keta, Havedzi) vs lagoon (Anyako, Seva)	0/1 (ref.: lagoon)	–
Controls	Sex (ref.: male); age; education (1–5); household size; years of residence; livelihood (ref.: fishing); community (ref.: Anyako)	Continuous controls standardised	–

3.4 Analysis

Place-bound breadth. Place-bound breadth is an ordered count with only four values, bounded at three and under-dispersed (mean 1.40, variance 1.36), so it was modelled with ordered logit models, which treat each additional strategy as a step up an ordinal scale without assuming an unbounded count distribution. Odds ratios (OR) above one indicate higher odds of using more place-bound strategies. Model 1 includes all drivers and controls. Model 2 adds the interaction between anticipated displacement and the seafront setting; the seafront main effect is absorbed by the community fixed effects. In Model 2, the coefficient on anticipated displacement is its association in the lagoon (the reference setting), and the seafront association is the sum of that coefficient and the interaction; its

standard error was computed from both coefficients and their covariance. Because odds ratios are hard to interpret, we also report predicted breadth at each level of anticipated displacement in each setting, holding other variables at their observed values.

The proportional-odds assumption was tested with the Brant (1990) test in each imputed dataset. Because it was rejected (Section 4.4), we re-estimated Model 2 as a partial proportional-odds model (Williams, 2006) in which the effects of exposure, anticipated displacement and its interaction were allowed to vary across thresholds, and we report Poisson and linear models as further checks.

Strategy-specific models. Each of the five strategies was modelled with a logit model with the same predictors (n = 366 for each outcome; 131–239 users). Average marginal effects (AMEs) are reported because they express associations as changes in the probability of using a strategy, in percentage points, which can be compared across outcomes with different base rates. For continuous predictors, AMEs refer to a one-SD increase; for binary predictors, to the presence of the attribute. Setting-specific AMEs of anticipated displacement come from models adding the anticipation × seafront interaction. To test H4a directly, we compared the AME of anticipated displacement on the expected share of place-bound strategies used (from the ordered logit) with its AME on diversification, and computed the difference in each bootstrap replicate.

Multivariate probit. Because strategy choices may share unobserved determinants, we estimated a five-equation multivariate probit by simulated maximum likelihood (GHK simulator with Halton draws; Cappellari & Jenkins, 2003; Train, 2009) on complete cases as a supplementary check that the separate logits are not distorted by correlated errors.

Missing data. The 41 implausible incomes and two missing household sizes were multiply imputed by chained equations with predictive mean matching (White et al., 2011), using the MICEData implementation in statsmodels (Seabold & Perktold, 2010). The imputation model included all analysis variables, the anticipation × seafront product, the place-bound, four-strategy and strategy-specific outcomes, and the community indicators. After a burn-in of ten cycles, 20 datasets were drawn five cycles apart. Imputed incomes were plausible relative to the observed distribution (median GHS 780, interquartile range 500–1,400, against 800 and 500–2,000 for observed values). Coefficients and their variances were pooled across the 20 datasets with Rubin's (1987) rules; fractions of missing information were below 0.26 for all coefficients. Confidence intervals for AMEs and predictions were obtained by bootstrapping the imputed data (Schomaker & Heumann, 2018): in each imputed dataset, households were resampled with replacement within the community 25 times, giving 500 replicates in all, and 95% percentile intervals were taken from the pooled replicates.

Robustness. The study re-estimated the place-bound models with complete cases, raw reported income, income omitted, Poisson (HC1) and linear (HC3) specifications, categorical coding of anticipated displacement, worry about displacement added as a further threat appraisal, the four-strategy outcome, and after excluding each community in turn; we also estimated separate anticipation slopes for Keta and Havedzi, and modelled displacement recurrence among recently displaced households. Robustness of

the overall association (Model 1) and of the seafront interaction (Model 2) is reported separately. Statistical significance is assessed at the 5% level throughout. Analyses were run in Python 3 (statsmodels); the code is available with the data (see Data availability).

4. Results

4.1 Household profile

Displacement was near-universal: 81.6% of households had been displaced by flooding, erosion or tidal waves in the past five years, and 41.9% lived where they did because of an earlier displacement (Table 2). This reflects the purposive selection of communities with repeated displacement, so the results describe adaptation among households for whom displacement is a recurring experience rather than among coastal households generally; it also means that recent displacement contrasts the 18.4% not displaced with the majority. Expectations of further displacement were widespread but varied: 33.0% expected never to be displaced in the next five years, while 49.7% expected it sometimes or often. Households used, on average, 1.40 of the three place-bound strategies, and 29.2% used none; 36.2% had diversified their income and 65.1% had relocated to safer areas.

The two settings differed in ways consistent with their hazard regimes, and in other respects. Seafront households were more likely to report erosion affecting their home and, among those who had lost property, to have lost land or a house, whereas lagoon households more often lost fishing or farming equipment. Seafront households were also younger, better educated, better off (median monthly income GHS 1,500 against GHS 700), less dependent on fishing and more likely to receive early warnings. They used more place-bound strategies (1.55 vs 1.14) and were more likely to have relocated (70.9% vs 55.1%). Lagoon households were more often resettled (54.4% vs 34.6%) and more frequently expected displacement (mean 2.74 vs 2.23). Anticipated displacement also varied between the two seafront communities: half of Keta households (50.5%) expected never to be displaced, against one of 40 households in Havedzi, where 87.5% expected displacement sometimes or often.

Table 2
Household characteristics, exposure and adaptation by setting.

Variable	All	Lagoon (Anyako, Seva)	Seafront (Keta, Havedzi)	p
n	370	136	234	
Female respondent	205 (55.4)	80 (58.8)	125 (53.4)	0.368
Age, years	42.55 (13.29)	44.76 (14.10)	41.26 (12.65)	0.015
Education (1–5)	3.18 (1.31)	2.90 (1.27)	3.35 (1.32)	0.001
Household size	6.85 (3.92)	8.60 (4.48)	5.83 (3.14)	< 0.001
Years resident	23 (9–36)	30 (15–44)	20 (8–33)	< 0.001
Monthly income, GHS (valid ≥ 100)	800 (500–2000)	700 (500–975)	1500 (500–2500)	< 0.001
Livelihood: fishing	143 (38.6)	73 (53.7)	70 (29.9)	< 0.001
Livelihood: trading	98 (26.5)	36 (26.5)	62 (26.5)	1.000
Livelihood: formal employment	61 (16.5)	10 (7.4)	51 (21.8)	< 0.001
Livelihood: other	64 (17.3)	16 (11.8)	48 (20.5)	0.045
Receives early warnings	227 (62.2)	69 (51.5)	158 (68.4)	0.002
Displaced in past 5 years	302 (81.6)	108 (79.4)	194 (82.9)	0.485
Current residence result of displacement	155 (41.9)	74 (54.4)	81 (34.6)	< 0.001
Erosion affects the home sometimes or often	235 (63.5)	74 (54.4)	161 (68.8)	0.008
Property lost to displacement: land	20 (6.7)	1 (0.9)	19 (10.1)	0.005
Property lost to displacement: house or building	51 (17.2)	11 (10.2)	40 (21.2)	0.024
Property lost to displacement: fishing or farming equipment	129 (43.4)	56 (51.9)	73 (38.6)	0.037
Hazard exposure (1–4)	2.74 (0.52)	2.71 (0.50)	2.75 (0.53)	0.263
Anticipated displacement (1–4)	2.41 (1.18)	2.74 (1.06)	2.23 (1.21)	< 0.001

Variable	All	Lagoon (Anyako, Seva)	Seafront (Keta, Havedzi)	p
Worry about displacement (1–4)	3.23 (0.84)	3.04 (0.93)	3.35 (0.77)	< 0.001
Improved fishing/farming practices	182 (49.2)	58 (42.6)	124 (53.0)	0.070
Disaster-preparedness participation	166 (44.9)	50 (36.8)	116 (49.6)	0.023
Resilient structures	170 (45.9)	47 (34.6)	123 (52.6)	0.001
Place-bound breadth (0–3)	1.40 (1.16)	1.14 (0.95)	1.55 (1.25)	0.003
Income diversification (portable)	134 (36.2)	57 (41.9)	77 (32.9)	0.104
Relocation to safer areas (mobility)	241 (65.1)	75 (55.1)	166 (70.9)	0.003
Four-strategy breadth (0–4, supplementary)	1.76 (1.21)	1.56 (1.06)	1.88 (1.28)	0.011

Values are n (%) for binary variables, mean (SD) for scales and median (interquartile range) for years of residence and income. p from χ^2 tests (binary) or Mann–Whitney tests (continuous). Early warnings: n = 365. □ Main type of property lost, among the 297 households reporting property loss (lagoon 108, seafront 189). Source: field survey.

4.2 Drivers of place-bound adaptation

Exposure, recent displacement and income were each associated with broader place-bound adaptation (Table 3, Model 1). A one-SD increase in perceived hazard exposure was associated with 2.70 times higher odds of using more place-bound strategies (95% CI 2.09–3.50), recent displacement with 2.21 times higher odds (1.25–3.89) and a one-SD increase in income with 1.88 times higher odds (1.36–2.60), supporting H1 and H3 and the displacement part of H2. Resettlement after displacement was not associated with place-bound breadth (OR = 1.33, 0.81–2.18); as Section 4.3 shows, it was associated instead with diversification and improved practices. Anticipated displacement had the opposite association: each one-SD increase was associated with odds of using more place-bound strategies about 60% lower (OR = 0.38, 0.29–0.50). Neither vulnerability appraisal score was significantly associated with place-bound breadth (structural OR = 1.16; demographic OR = 0.80, p = 0.070).

Adding the interaction between anticipated displacement and the seafront setting improved the model (likelihood-ratio $\chi^2(1) = 18.6$, median across imputations, range 17.7–19.5; AIC lower by 16.6) (Model 2). In this model the coefficient on anticipated displacement refers to the lagoon: there, a one-SD increase was associated with an OR of 0.76 (0.50–1.15, p = 0.197). On the seafront, combining this coefficient with the interaction (OR = 0.33, 0.20–0.55) gives an OR of 0.25 (0.18–0.35, p < 0.001): each one-SD increase in anticipated displacement was associated with odds of using more place-bound strategies about three-quarters lower, supporting H4b. In plain terms, predicted place-bound breadth on the seafront fell from 2.25 strategies (95% CI 2.04–2.45) among households that never expected

displacement to 0.72 (0.51–0.98) among those that expected it often, whereas in the lagoon it fell from 1.34 (1.06–1.65) to 1.03 (0.78–1.29), a difference within the uncertainty of the estimates (Fig. 4a). Associations with exposure, recent displacement and income were similar in both models.

Keta drove the seafront association. Estimated separately, the anticipation OR was 0.22 (0.15–0.32) in Keta and 0.69 (0.25–1.88) in Havedzi, and when Keta was excluded the association of anticipated displacement with place-bound breadth disappeared (b = − 0.02, p = 0.94; Table A1). This is partly a matter of data: almost all Havedzi households expected displacement, so there is little variation from which to estimate an association there. The seafront result is therefore best read as evidence from Keta, the larger seafront community, rather than from seafront communities in general.

Table 3
Ordered logit models of place-bound adaptation breadth (0–3), pooled over 20 imputations (n = 366).

Predictor	Model 1 OR [95% CI]	Model 2 OR [95% CI]
Hazard exposure (SD)	2.70*** [2.09, 3.50]	2.60*** [2.00, 3.37]
Displaced in the past 5 years	2.21** [1.25, 3.89]	1.81* [1.02, 3.23]
Resettled after displacement	1.33 [0.81, 2.18]	1.30 [0.79, 2.14]
Anticipated displacement (SD)□	0.38*** [0.29, 0.50]	0.76 [0.50, 1.15]
Income, log (SD)	1.88*** [1.36, 2.60]	1.90*** [1.36, 2.64]
Vulnerability appraisal: structural (SD)	1.16 [0.93, 1.45]	1.16 [0.92, 1.45]
Vulnerability appraisal: demographic (SD)	0.80 [0.62, 1.02]	0.72* [0.56, 0.93]
Female respondent	1.03 [0.65, 1.63]	0.94 [0.59, 1.50]
Age (SD)	1.25 [0.92, 1.70]	1.24 [0.91, 1.68]
Education (level)	0.88 [0.72, 1.07]	0.94 [0.77, 1.15]
Household size (SD)	1.11 [0.86, 1.44]	1.11 [0.85, 1.43]
Years of residence (SD)	1.10 [0.80, 1.52]	1.14 [0.83, 1.58]
Livelihood: trading	0.77 [0.43, 1.35]	0.88 [0.49, 1.57]
Livelihood: formal employment	0.87 [0.39, 1.95]	0.86 [0.38, 1.95]
Livelihood: other (farming, artisanal)	2.51** [1.28, 4.90]	2.69** [1.37, 5.28]
Community: Keta	1.55 [0.89, 2.68]	1.71 [0.98, 2.96]
Community: Seva	0.27* [0.09, 0.88]	0.32 [0.10, 1.03]
Community: Havedzi	0.86 [0.38, 1.96]	1.49 [0.63, 3.54]
Anticipated displacement × seafront	–	0.33*** [0.20, 0.55]
Implied anticipated displacement OR, seafront□	–	0.25*** [0.18, 0.35]
McFadden pseudo-R^2 (imputation 1)	0.225	0.243
AIC (imputation 1)	815.3	799.0

OR = odds ratio of using more place-bound strategies; OR > 1 indicates higher odds of a higher breadth category. Continuous predictors are standardised (SD = one-standard-deviation increase). References: male; fishing; Anyako; lagoon. The seafront main effect is absorbed by community fixed effects. Confidence intervals and p-values from Rubin's rules. □ In Model 2, the association in the lagoon

(reference setting). □ Sum of the lagoon coefficient and the interaction, with variance from both coefficients and their covariance. * p < 0.05, ** p < 0.01, *** p < 0.001.

4.3 Place-bound, portable and mobility strategies

The drivers acted on different kinds of adaptation (Table 4; Fig. 3). Exposure was associated with a 11.5–15.4 percentage-point higher probability of using each place-bound strategy per SD and 9.3 points more relocation, but not with diversification. Recent displacement was associated mainly with improved practices (+ 18.4 points), and resettlement with diversification (+ 22.0) and improved practices (+ 19.2), consistent with households rebuilding livelihoods after a move. Income was associated with the costlier protective strategies, preparedness (+ 10.7) and resilient structures (+ 7.1), and with slightly less diversification (− 6.5).

Anticipated displacement was associated with 11–13 points lower use of each place-bound strategy, but not with diversification (+ 1.1, CI − 4.7 to 6.6), supporting H4a. Directly compared, a one-SD rise in anticipated displacement was associated with a 13.6-point lower expected share of place-bound strategies used (95% CI − 17.3 to − 10.4), and the difference from its association with diversification was − 14.8 points (− 21.5 to − 8.0). Because the two settings had opposite associations with relocation, the pooled AME for relocation was close to zero (+ 2.2).

The setting contrast was sharpest for resilient structures and relocation (Table 4, lower rows; Fig. 4). On the seafront, a one-SD rise in anticipated displacement was associated with 18.7 points lower use of resilient structures (95% CI − 23.5 to − 14.0), 15.5 points fewer improved practices, 12.8 points less preparedness and 8.2 points less relocation (− 14.4 to − 2.3). In practical terms, the predicted probability of relocation on the seafront fell from 0.80 among households that never expected displacement to 0.58 among those that expected it often (Fig. 4c). In the lagoon, the same rise was associated with 21.5 points more relocation (predicted probability rising from 0.19 to 0.81) and no lower use of structures or practices; only preparedness was lower in both settings. Diversification was unrelated to anticipated displacement in either setting (Fig. 4b). Structural appraisal was associated with more relocation (+ 7.0) and less diversification (− 7.5), and demographic appraisal with fewer improved practices (− 8.0); neither was consistently associated with place-bound adaptation.

Table 4
Average marginal effects on the probability of using each strategy (percentage points, 95% bootstrap CI), n = 366.

Predictor	Improved practices	Preparedness	Resilient structures	Diversification	Relocation
Kind of strategy	**Place-bound**	**Place-bound**	**Place-bound**	**Portable**	**Mobility**
Users (n)	180	164	168	131	239
Hazard exposure (+ 1 SD)	15.4* [10.1, 20.7]	11.5* [7.1, 17.0]	14.2* [9.1, 20.1]	0.5 [− 4.2, 5.2]	9.3* [4.5, 15.2]
Displaced in past 5 years	18.4* [4.0, 31.8]	11.4 [− 1.4, 23.8]	6.6 [− 6.3, 17.8]	7.2 [− 4.9, 19.1]	−1.4 [− 13.7, 10.7]
Resettled after displacement	19.2* [8.2, 30.6]	−2.5 [− 12.3, 8.3]	−2.4 [− 13.6, 8.9]	22.0* [10.7, 33.1]	−7.1 [− 18.3, 5.1]
Anticipated displacement (+ 1 SD)	−13.0* [− 18.5, − 8.0]	−13.3* [− 18.7, − 8.6]	−11.4* [− 16.3, − 6.3]	1.1 [− 4.7, 6.6]	2.2 [− 3.5, 7.8]
Income (+ 1 SD)	6.5 [− 0.8, 14.3]	10.7* [4.9, 17.7]	7.1* [2.7, 13.3]	−6.5* [− 12.2, − 0.3]	1.0 [− 6.5, 8.6]
Appraisal: structural (+ 1 SD)	0.3 [− 3.9, 5.1]	4.1 [− 1.3, 9.3]	2.5 [− 2.6, 7.7]	−7.5* [− 12.5, − 3.1]	7.0* [1.7, 12.0]
Appraisal: demographic (+ 1 SD)	−8.0* [− 13.2, − 3.1]	−4.2 [− 9.2, 0.9]	2.1 [− 3.2, 7.5]	−4.0 [− 9.3, 0.7]	4.9 [− 0.1, 10.8]
Anticipated displacement (+ 1 SD), lagoon	−3.4 [− 14.4, 6.6]	−13.5* [− 24.7, − 3.9]	8.2 [− 0.2, 17.0]	1.3 [− 11.6, 12.5]	21.5* [13.9, 29.8]
Anticipated displacement (+ 1 SD), seafront	−15.5* [− 20.4, − 10.0]	−12.8* [− 18.1, − 7.8]	−18.7* [− 23.5, − 14.0]	0.9 [− 5.4, 6.9]	−8.2* [− 14.4, − 2.3]
Interaction p (anticipation × seafront)	0.005	0.587	< 0.001	0.969	< 0.001

AME = average marginal effect: change in the probability of using the strategy, in percentage points, for a one-SD increase in a continuous predictor or the presence of a binary attribute. From logit models with all controls (Table 3), averaged over 20 imputations; setting-specific rows from models adding the anticipation × seafront interaction. 95% percentile intervals from 500 bootstrap replicates (households resampled within community, 25 per imputed dataset). Interaction p from Rubin's rules. * 95% CI excludes zero.

4.4 Robustness

Table A1 separates the robustness of the overall association (Model 1) from that of the seafront interaction (Model 2). Both held in complete-case estimation (n = 323), with raw reported income or income omitted, in Poisson and linear models, after adding worry about displacement, and with the four-strategy outcome used in earlier analyses. Worry was not associated with place-bound breadth (b = 0.14, p = 0.20), so the negative association of anticipated displacement is not an artefact of fear or anxiety. Coded categorically, each level of anticipated displacement was associated with narrower place-bound adaptation than "never", and most of the difference lay between "never" and "rarely" (b = − 2.05, − 2.43 and − 2.55 for rarely, sometimes and often), suggesting that any expectation of displacement, rather than its expected frequency, marks the difference. Among recently displaced households (n = 298), the number of past displacements was not associated with breadth once anticipated displacement was included (b = − 0.26, p = 0.37).

The Brant test rejected the proportional-odds assumption (median $\chi^2(38) = 120.6$ across imputations, $p < 0.001$), mainly for the community indicators, exposure, anticipated displacement and its interaction. In a partial proportional-odds model, exposure was positively associated with breadth at every threshold, and on the seafront anticipated displacement was negatively associated with using at least one, at least two and all three place-bound strategies, with larger coefficients at higher thresholds (b = − 0.53, − 1.30 and − 2.32; Table A1). In the lagoon, anticipated displacement was associated only with a lower probability of using any place-bound strategy (b = − 0.66, p = 0.013), not with using more of them. The conclusions therefore do not depend on the proportional-odds assumption.

Excluding Havedzi, Seva or Anyako left the seafront association unchanged (b between − 1.28 and − 1.50, all $p < 0.001$), but excluding Keta removed both the overall association and the interaction (Section 4.2). The overall association and the seafront contrast are thus robust to specification but not to the composition of the seafront sample. The multivariate probit (complete cases, n = 323) showed that strategy choices were correlated (Table A2), most strongly improved practices with resilient structures ($\rho = 0.53$, SE 0.17, p = 0.002); the other nine correlations were smaller and none was significant at the 5% level. Estimates changed by less than 0.002 when the number of Halton draws was increased from 200 to 500 or 1,000. The key-driver coefficients had the same signs and similar magnitudes as in separate probit models, so the strategy-specific results are not an artefact of treating the strategies independently.

4.5 Household and institutional accounts

The qualitative analysis produced four themes. They are presented here as context for the survey associations; the focus groups and interviews were not designed to probe investment decisions and cannot by themselves establish the mechanism.

Theme 1

Recurrent displacement and depletion of household resources. Participants described displacement as a cycle of leaving and returning rather than a single move

We were born into it, and we have grown alongside water. When the water comes, we run, and when it leaves, we return. **(FGD, Keta, male)**

My family had to move into my brother's house in a different community for almost two weeks. When we returned, our room was filled with mud. **(FGD, Seva, male)**

After people had lost nets and gear and found shelter, it was hard to get money to buy those things back **(FGD, Seva, male)**,

Many households struggle to rebuild their livelihoods after each flood, keeping them in a cycle of poverty. **(KII, NADMO officer, Keta Municipal Assembly)**

Theme 2

Livelihood dependence and attachment to exposed places. Livelihoods and ancestry tied households to the shore

If we venture too far from the sea, it's hard for us to live because fishing is our expertise. **(FGD, Seva, male)**

Our ancestors lived here, and we feel connected to this place, so relocating is not easy for us. **(FGD, Havedzi, female)**

Theme 3

Barriers to relocation. Officials described organised relocation as contested

Relocation programmes are fiercely opposed because people rarely want to leave their homes and jobs, even when their lives are at risk. **(KII, Planning Officer, Keta Municipal Assembly)**

Theme 4

Livelihood changes after displacement. Repeated hazard experience prompted households to add income sources

The floods have made me realise that relying solely on the sea is no longer safe… many of us are considering doing something additional alongside fishing. **(FGD, Keta, male)**

Households are seeing the need because of the yearly floods. (KII, Planning Officer, Keta Municipal Assembly)

5. Discussion

5.1 Exposure and experience prompt adaptation; income enables it

Households that perceived more frequent hazards, and those recently displaced, used more place-bound strategies. This is consistent with protection motivation theory and broader evidence that experience of loss is among the strongest predictors of protective action (Grothmann & Patt, 2005; Bubeck et al., 2012). Separating the outcomes adds precision. Exposure was associated with protective and practice-based strategies and with relocation, but not with diversification, suggesting that households first respond to hazards by defending and adjusting what they already do. Resettlement, by contrast, was linked to diversification and new practices rather than to protective investment, which matches the focus-group accounts of households rebuilding livelihoods after a move and recognising that "relying solely on the sea is no longer safe". Income mattered mainly for preparedness and resilient structures, the strategies that require cash or time away from work, in line with evidence that resources determine which responses are feasible (Deressa et al., 2009; Brooks et al., 2005). Because most respondents had been displaced recently, these associations reflect differences among households experiencing repeated displacement.

5.2 Anticipated displacement and place-bound adaptation on the seafront

The central finding is that expecting future displacement was associated with substantially narrower place-bound adaptation, not with diversification, and that the association was concentrated on the seafront, where land is being lost. Three features of the pattern are consistent with the proposed interpretation of anticipatory disinvestment. First, the association was selective: it applied to the three place-bound strategies but not to diversification, whose value survives a move, as investment-under-uncertainty reasoning predicts (Dixit & Pindyck, 1994). Second, it was absent or weak in the lagoon, where displaced households expect to return, and where anticipation was instead associated with more relocation, plausibly temporary. Third, on the seafront, anticipation was associated with less relocation and less protection: households there that expected to be displaced were less likely to report protecting their homes and less likely to report having moved to safer ground.

These are associations, and the interpretation that expectations reduce the incentive to invest remains a proposed mechanism rather than a demonstrated pathway. What would distinguish anticipatory disinvestment from related explanations? It differs from ordinary low adaptive capacity and poverty-related under-investment because it was observed with income, education and livelihood held constant and because it did not extend to diversification, which also requires resources. It differs from maladaptation, which concerns actions that increase vulnerability, because it concerns inaction. And it overlaps with, but is not the same as, involuntary immobility: the lower relocation on the seafront is consistent with constrained mobility (Black et al., 2013; Zickgraf, 2019), but the data cannot tell whether households who did not move wished to and could not, or preferred to stay (Adams, 2016; Mallick et al., 2022). The focus groups described both constraint (the cost of replacing gear, a livelihood that cannot be practised far from the sea) and attachment, so the most defensible reading is that seafront immobility reflects a combination of the two.

Alternative explanations deserve equal attention. The most important is reverse causation: households without resilient structures may expect displacement because they are unprotected. Some features of the data do not fit this as a complete explanation: anticipation was equally associated with fewer improved fishing and farming practices, which do not protect dwellings; the association was weak in the lagoon, where the same reasoning would apply; and the association was unchanged when exposure and recent displacement were controlled. But none of these rules reverses causation, and it may account for part of the association. A second explanation is location within the seafront. Keta is partly protected by the Keta Sea Defence Project while other stretches are not (Mann et al., 2023), and households behind defended stretches may both expect less displacement and invest more because their homes are protected. Half of Keta households expected never to be displaced, and the association rests almost entirely on Keta; without household locations relative to the defences, we cannot separate an effect of expectations from an effect of protection status. Both explanations point to the need for panel data and geolocated households.

The dependence on Keta also sets the argument's geographical scope. In Havedzi, which lies down-drift of the main defences and where almost all households expected displacement, there was too little variation in expectations to estimate the association. The results therefore show that, within Keta, expecting displacement is strongly associated with lower place-bound adaptation; they suggest, but do not establish, that the same holds on other eroding seafronts.

The findings link the adaptation literature to research on immobility and complement work from other deltas. In Bangladesh, permanent movement away from hazard-prone areas is rare and occurs mainly where land is eroded (Penning-Rowsell et al., 2013), and non-migration in coastal communities is shaped by land ownership, social ties and household resources (Mallick et al., 2022). In the Volta Delta, exposure to erosion raises migration intentions (Abu et al., 2022). Our results add that, at the household level, expectations of displacement on an eroding seafront are associated less with local relocation than with lower use of protective measures, while longer-distance migration, which we did not measure, remains a possible response. If lower protection leaves homes more exposed, it could make the expected displacement more likely; this possibility is consistent with the data but cannot be tested with a single cross-section.

5.3 Vulnerability appraisal and action

Appraisals of vulnerability were not consistently associated with adaptation. Neither score was significantly associated with place-bound breadth in Model 1; demographic appraisal was associated with fewer improved practices and structural appraisal with more relocation and less diversification. These scattered associations do not form a pattern of broader adaptation among households that recognise vulnerability. This is consistent with the gap between risk perception and behaviour documented elsewhere (Wachinger et al., 2013) and with the view that social vulnerability is rooted in constraints rather than awareness (Cutter, 2003; Otto et al., 2017). For targeting, it suggests that awareness of vulnerability is a poor proxy for adaptive need or capacity.

5.4 Implications for policy

The study did not measure the credibility of government decisions on protection or retreat, so it cannot show that policy uncertainty causes lower adaptation. The implications below follow from the associations observed and should be treated as hypotheses for policy design.

Coastal protection and land-use planning (national coastal agencies, Keta Municipal Assembly). If expectations of displacement discourage investment in place, clearer, publicly communicated decisions about which stretches of coast will be defended and which will not could reduce that uncertainty, in line with arguments for strategic rather than reactive retreat (Hino et al., 2017; Siders et al., 2019). Where protection is planned, expectations of loss are less likely to undermine support for resilient structures and improved practices.

Managed retreat where protection is not feasible (municipal and national government). Retreat is not a simple solution. It requires consultation with affected households, adequate compensation, suitable land and the protection of livelihoods; the opposition to relocation described by the Planning Officer shows what happens without them. Because fishing households cannot easily live far from the sea, relocation sites close to landing beaches and markets, with secured access to fishing and trading, are more likely to be accepted than distant resettlement.

Livelihood and finance support (Social Welfare, NGOs, financial institutions). Where retreat is likely, support for portable livelihoods, such as skills and income sources that survive a move, matches the strategy that expectations of displacement did not discourage. Because income was associated with preparedness and resilient structures, access to finance for these measures is likely to matter more than awareness campaigns alone.

Short-term preparedness (NADMO). Preparedness was lower among households expecting displacement in both settings, so community preparedness programmes warrant attention everywhere, including among households that expect to be displaced again.

5.5 Limitations

Five limitations qualify the findings. First, the data are cross-sectional, so the direction of the relationship between anticipated displacement and adaptation cannot be established. Second, the seafront result rests on Keta (n = 194): it disappeared when Keta was excluded, and the small Seva (n = 18) and Havedzi (n = 40) samples limit comparisons between communities. Third, adaptation was recorded as current use or non-use of each strategy, without information on intensity, quality, effectiveness or timing, and the relocation item did not distinguish temporary from permanent moves. Fourth, the four communities were selected purposively for their exposure to displacement, and most households had been displaced recently, so the findings should not be generalised to the whole Volta Delta or Ghana's coastline. Fifth, the focus groups and interviews describe the conditions surrounding displacement, the costs of rebuilding and the barriers to moving, but were not designed to probe investment decisions and do not

establish the mechanism. Panel data that follow households' expectations and adaptation over time, and geospatial data that place households relative to the shoreline and to coastal defences, would address the first, second and fifth limitations.

6. Conclusion

In four coastal communities of Ghana's Volta Delta, households that perceived more frequent hazards or had recently been displaced used more place-bound adaptation strategies, and higher income was associated with the costlier protective measures. Households that expected to be displaced again used fewer place-bound strategies, but did not diversify their income any less. On the seafront, mainly in Keta, households that expected displacement were less likely to report using protective measures and also less likely to report having relocated. In the lagoon, the same expectation was associated with more relocation and little difference in place-bound adaptation. Appraisals of who is vulnerable were not consistently associated with adaptation.

The study's contribution is to show that anticipated displacement is associated with the kind of adaptation households pursue, distinguishing place-bound from portable and mobility strategies, and that on an eroding seafront it is associated with lower use of both protection and relocation, linking adaptation to environmental immobility. Whether expectations drive these choices, or follow from them, can only be settled with longitudinal data that link household expectations and adaptation to measured shoreline change.

Declarations

Author Contribution

E.B. wrote the main manuscript text, prepared figures and reviewed the manuscript.

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Figures

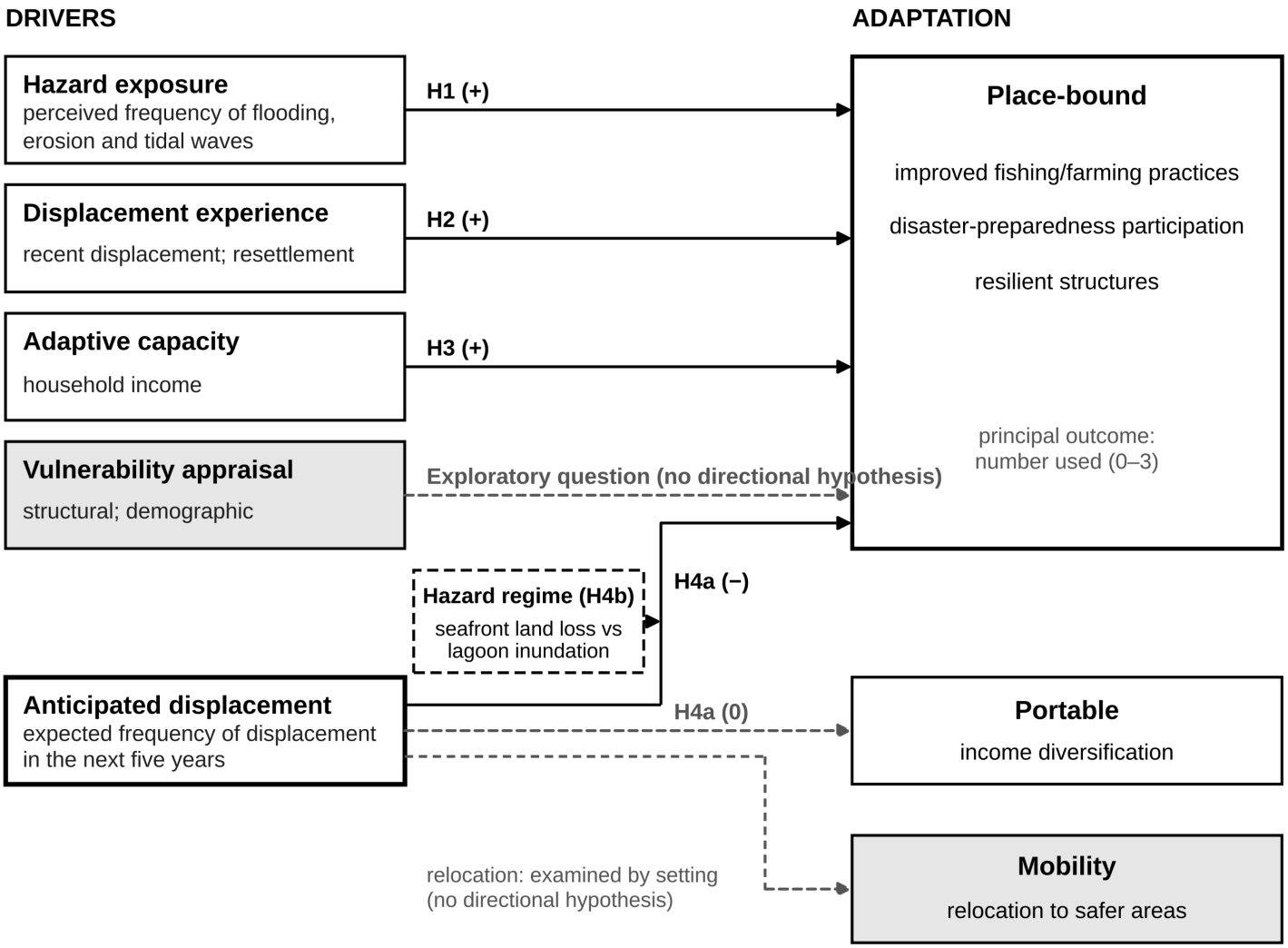


Figure 1

Conceptual framework. Drivers are linked to three separately measured kinds of adaptation. H1–H3 and H4a refer to place-bound adaptation; H4a also predicts no association with portable adaptation; the hazard regime is expected to condition the association between anticipated displacement and place-bound adaptation (H4b). Relocation and vulnerability appraisal are examined without directional hypotheses. Source: author's construct.

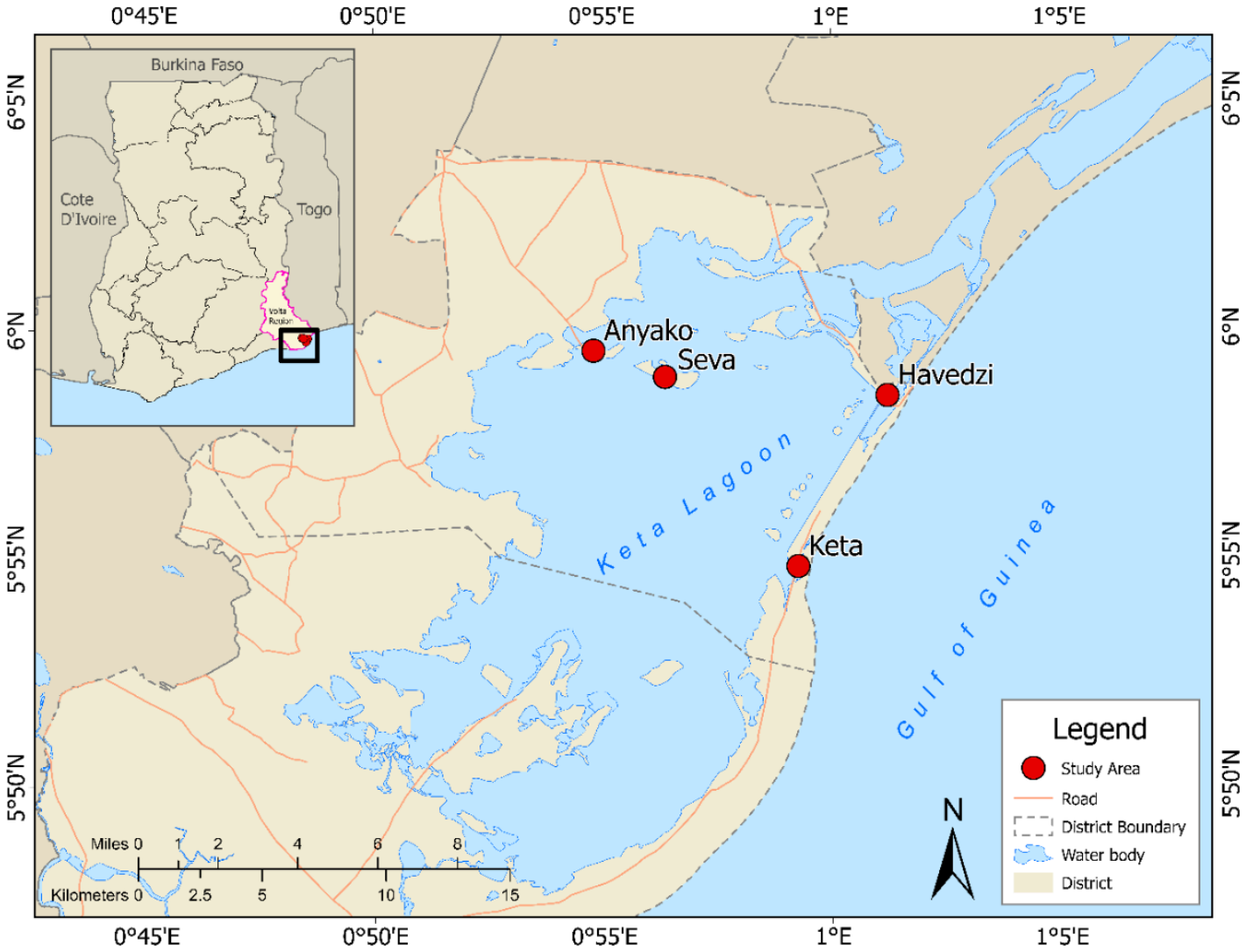


Figure 2

Study area and the four study communities in Keta Municipality. Keta and Havedzi lie on the seafront sand barrier; Anyako and Seva lie in the Keta Lagoon. Source: Geological Survey Department, KNUST.

Supplementary Files

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- Appendix.docx