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Perceived effectiveness of anticipatory strategies adopted by flood-at-risk households in urban, peri-urban and rural areas in Togo

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ABSTRACT

Floods are one of the natural disasters associated with the highest level of climate risk in Togo, differentially affecting households in urban, peri-urban and rural settings. To deal with these hazards, households adopt anticipatory coping strategies whose perceived effectiveness remains poorly documented. This study aims to assess the perceived effectiveness of anticipatory flood adaptation strategies adopted by households in five flood-prone localities in Togo (Togblékopé, Avegbo, Ogou-Kolidé, Guérin-Kouka and Koulfiekou) as well as their socioeconomic determinants. A cross-sectional survey was conducted, and a Likert scale was used to collect data from 403 households. An overall anticipatory effectiveness score was then constructed by weighted summation of perceived effectiveness levels (TES) assigned to eleven (11) anticipatory strategies and subsequently categorised into three levels (low, moderate, high). The factors influencing perceived effectiveness were identified using an ordered probit regression model (OPM). The majority of households (91.6%) showed low strategy effectiveness. Anticipated securing of household assets (TES=382), use of sandbags (TES=369) and adjustment of the agricultural calendar (TES=317) were among the most effective strategies. Locality of residence ($\beta = 1.44$; $p < 0.001$), gender of the household head ($\beta = 1.35$; $p = 0.002$), monthly income ($\beta = 1.28$; $p < 0.001$), use of intermediate construction materials ($\beta = 2.01$; $p = 0.011$) and reception of warning messages ($\beta = 1.24$; $p = 0.001$) were significantly associated with high effectiveness. This study therefore recommends the implementation of more anticipatory, spatially inclusive flood management policies focused on strengthening endogenous strategies.

Keywords: Floods; Anticipatory strategies; Perceived effectiveness ;Ordered Probit Model ; Climate adaptation.

1. INTRODUCTION

Globally, risks associated with natural disasters are a manifest reality. These hazards threaten the livelihoods of vulnerable populations, particularly households whose incomes fall below the cost of resilience. The 2030 projections are alarming, it is estimated that approximately 325 million people in extreme poverty will live in 49 countries exposed to natural disasters, the majority in South Asia and sub-Saharan Africa [1]. Among climate related impacts, floods stand out as the most recurrent and devastating phenomena [1], [2]. When these risks become unavoidable, humans develop strategies to cope with and to adapt [3]. The goal is to limit the frequency of risks, build resilience when they occur, and recover effectively from damages once the hazard has passed [4]. Adapting to floods generally involves a duality of structural measures (house elevation, construction of drainage systems) and non-structural measures (early warning, community organisation) [5]. The scientific literature often classifies these actions into three categories namely precautionary, reactive, and reconstruction [6] or into two temporal classes of *ex ante* (proactive) and *ex post* (reactive) strategies [7], [8], [9]. For instance, *ex ante* strategies may include diversification of livelihoods, food and water storage, and modification of housing structures. Conversely, *ex post* strategies involve measures taken after flood impact, such as selling assets, borrowing money, or seeking assistance from relatives and humanitarian agencies [10]. Reconstruction strategies, in turn, aim to restore destroyed assets [6]. Their perceived effectiveness refers to an individual's belief that the adaptive actions implemented are capable of reducing or preventing the harmful impacts of a hazard [11], [12]. However, the implementation and effectiveness of these practices vary considerably from one area to another due to differences in socioeconomic status, education, access to information, and financial resources [13], [14]. Consequently, the impact of flood management practices on household resilience is neither uniform nor consistent [15].

According to [16], in Africa despite growing awareness of the importance of anticipatory strategies in flood risk management, the coverage, comprehensive monitoring of attributes, and effectiveness of these strategies remain incomplete. Until now, the integration of flood resilience strategies has remained primarily institutional [17]. National platforms and plans exist (*RT & PNUD, 2009; PNRRC*¹), but to date only the Togolese Red Cross has 100 community-level early warning systems [19]. Existing studies are mostly focused on urban centres [20] such as « Grand Lomé » and major watersheds considered most vulnerable [21]. This focus obscures the vulnerability of rural and peri-urban areas [22], which currently suffer from a lack of precise local-level data [23].

In the current state of knowledge in Togo, study conducted by [24] in the Zio basin found that construction of cement houses with sufficiently elevated foundations is most effective adaptation strategies in 60% of cases. The same study revealed that an early warning system using television (57.7%) and radio (80%) channels is used for

¹ National Platform for Disaster Risk Reduction of Togo

information transmission. Studies by [25] in the Mono basin showed that in terms of non-structural strategies, flood insurance products are not widely offered to households across the territory. [15] examined factors influencing the choice of endogenous flood management practices in the Volta basin and showed that demographic variables such as age and gender play a crucial role in household decision-making. However, despite the recurrence of research, there remains a gap in contextual studies examining factors influencing the effectiveness of these strategies as perceived by households across urban, peri-urban and rural areas. This study therefore aims to empirically examine the anticipatory strategies deployed by households, to assess their perceived effectiveness in flood risk management in urban, peri-urban and rural areas of Togo. This research thus addresses the following questions : (1) What anticipatory strategies do flood-at-risk households deploy? (2) Are these strategies effective from the households' perspective ? (3) What factors influence this effectiveness?

2. Materials and methods

2.1 Study area

Avegbo and Togblékopé in the Maritime Region, between Togo and Benin, on the Agoméglozou-Athiémé border, the village of Avegbo is located at 6°33'N latitude and 1°42'E longitude, while the Togblékopé city town is situated between 6°14' and 6°18'N and between 1°11' and 1°14'E (Fig 1). Both localities, located in the coastal sedimentary basin, experience a sub-equatorial climate [26], with mean annual rainfall ranging from 850 and 1,400 mm [27]. The village of Ogou-Kolidé is situated in the northeast of the Est-Mono 1 commune (Fig 1) around 7°56'N latitude and 1°21'E longitude. The rainfall regime is influenced by a humid tropical climate [28]. Annual precipitation varies from 1,800 mm to 1,000 mm. In terms of temperature, it is the warmest locality in the region, with an annual average of approximately 27°C [28]. Guérin-Kouka and Koulfiekou in the northwest of the Dankpen 1 commune, the village of Koulfiekou and the Guérin-Kouka city town are located at 9°59'07"N and 0°24'16"E, and between 9°34' and 9°53'N and between 0°22' and 0°40'E respectively (Fig 1). The climate is humid tropical, characterised by two seasons: a dry season from November to March and a wet season from April to October. The average annual rainfall recorded over the past six decades is 1,310 mm $\pm$ 96.9 mm [29]. The wettest months are July, August and September. The landscape is dominated by the vast Oti plain, with low altitudes not exceeding 200 m, making it a floodplain [30].

The hydrology of the study area is largely dominated by the Mono, Zio and Oti rivers. The Mono River, the most important in the Mono basin, extends 560 km from north to south and hosts a hydroelectric dam at Nangbéto, located approximately 150 km from the Atlantic coast [31]. The Zio River watershed, situated between 6°08'00" and 7°18'00"N and between 0°36'00" and 1°15'00"E, drains an area of approximately 3,400 km² [32]. The Oti constitutes a major sub-basin of the Volta system and is located between 11°05' and 10°96'N and between 0°12' and 0°95'E [30].

These localities were selected on the basis of three considerations. First, their proximity to a watercourse in a watershed where flood damage is considerable [21], [24], [33]. Second, these localities have been affected by flooding in recent years and have been identified as flood-risk areas by the National Civil Protection Agency (NCPA). Third, the presence of a functional and dynamic endogenous structure capable of facilitating fieldwork.

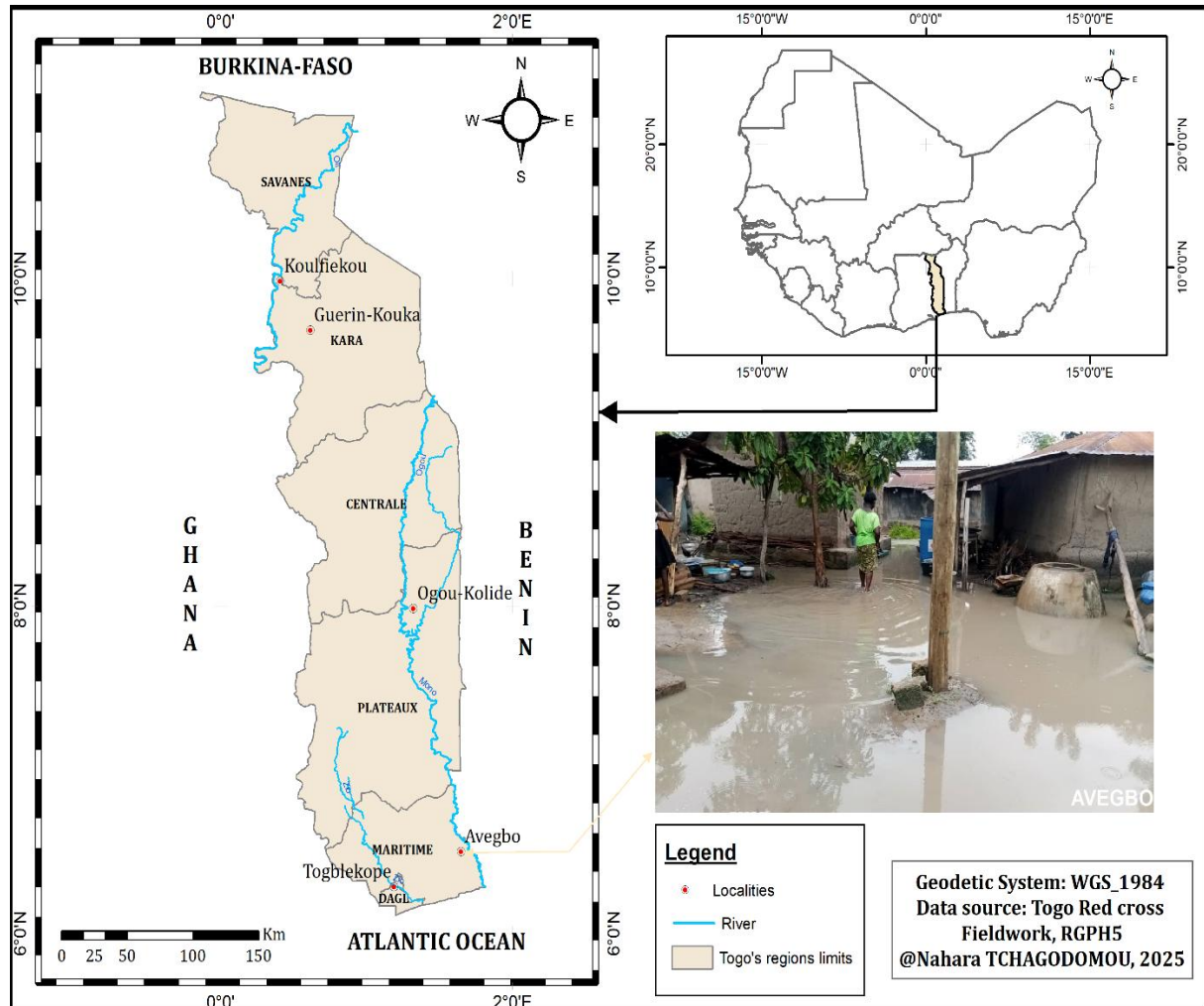


Fig 1: Geographic map showing the location of the study area (5 localities distributed across 3 regions)

2.2. Dataset

The data primary are used for this study . A household survey was conducted between February 12 and 19, 2026. Households constituted the data collection units. A questionnaire configured in CPro (Census and Survey Processing System) [34] was used to collect information on household socio-demographic characteristics, flood risk perception, previous flood experience, access to early warning systems, and the perceived effectiveness of various anticipatory strategies adopted by households. A sample of 335 households was calculated using the SCHWARTZ formula below [24], [35]. Data from the 5th General Population and Housing Census (RGPH5) were used

for calculation. In total, 403 valid questionnaires were recorded in the field to ensure population representativeness and data quality. Respondents were at least 18 years of age at the time of the survey.

$$n = \frac{tp^2 \times P(1-P) \times N}{tp^2 \times (1-P) + (N-1) \times y^2} \quad (1)$$

Where: n : sample size = 347; N : target household size = 7,243; P : expected proportion of a population response (set at 0.5 by default to obtain the largest possible sample); tp : sampling confidence interval = 1.96; y : sampling margin of error = 5%.

A stratified random sampling method was then used to proportionally distribute the number of households to be surveyed in each village according to its population size. To facilitate data collection, we were assisted by members of the CRIAP-C (Community Early Warning Information Feedback Committees), CVD (Village Development Committees) and CDQ (Neighbourhood Development Committees) [36], [37] and local languages used during the data collection were Mina, Naouda, Bagouda, Konkomba, Tchokossi and French. The study adopted a quantitative technical approach.

2.3 Data processing

2.3.1 Ranking of anticipatory adaptation strategies

The ranking of anticipatory flood adaptation strategies was carried out using an ordinal weighting method adapted from previous studies on the evaluation of flood adaptation strategy effectiveness [38], [39], [40]. For each strategy, a weighted effectiveness score was calculated by multiplying the observed frequencies in each perceived effectiveness category by the corresponding weight [40]. The Total Effectiveness Score (TES) for each strategy corresponded to the sum of the weighted scores obtained across all categories, expressed mathematically as follows:

$$TES = \sum_{i=0}^4 (n_i \times w_i)$$

where TES represents the total effectiveness score of the strategy, n_i the number of households in category i , and w_i the weight assigned to effectiveness level i . Strategies were then ranked in descending order of total perceived effectiveness score, with higher scores indicating strategies judged most effective by households.

An overall anticipatory effectiveness score was constructed by summing the perceived effectiveness scores assigned to all anticipatory strategies adopted by households [40]. The observed score ranged from 0 to 44, with higher values reflecting better overall perceived effectiveness. The distribution of this score was assessed using a graphical method and the Shapiro-Wilk normality test.

2.3.1 Empirical modelling

a. Dependent variable

The dependent variable was the overall perceived effectiveness score of anticipatory flood adaptation strategies adopted by households. For each strategy implemented, households assigned a perceived effectiveness level according to a five-category ordinal Likert scale ranging from 0 to 4 [39], [41], [42]: $w_i = 0$: strategy not used / not applicable; $w_i = 1$: not effective at all; $w_i = 2$: slightly effective; $w_i = 3$: moderately effective; and $w_i = 4$: very effective.

Only strategies actually adopted were subject to explicit evaluation, with unused strategies coded as zero (0) in the overall score construction. To facilitate result interpretation and econometric analyses, the score was categorised into three ordered levels based on theoretical intervals [40]: Low effectiveness (0–14); Moderate effectiveness (15–29); and High effectiveness (30–44).

b. Explanatory variables

The explanatory variables are data collected from households and were grouped into three analytical dimensions summarised in Table 1.

Table 1: Description of main variables used in the OPM

Variable	Dimensions	Variable type	Modalities / Description
Overall anticipatory effectiveness score	PE	Discrete quantitative	Sum of effectiveness scores of anticipatory strategies
Overall anticipatory effectiveness category	PE	Ordinal	Low effectiveness / Moderate effectiveness / High effectiveness
Locality of residence	SDC	Nominal categorical	Togblékopé, Avegbo, Ogou-Kolidé, Guérin-Kouka, Koulfiekou
Settlement type	SDC	Nominal categorical	Urban, peri-urban, rural
Sex of household head	SDC	Binary	Male / Female
Age of household head	SDC	Continuous quantitative	Age in years
Household size	SDC	Discrete quantitative	Number of household members
Education level of household head	SDC	Ordinal categorical	None, primary, secondary, higher
Occupation of household head	SDC	Nominal categorical	Farming/livestock, trade, civil service, craftsman/transport, other
Monthly household income	SDC	Ordinal categorical	Monthly income categories
Health insurance	SDC	Binary	Yes / No

Family health insurance coverage	SDC	Binary	Yes / No
Duration of residence in the area	SDC	Ordinal categorical	≤5 years, 6–10 years, 11–20 years, >20 years
Perception of locality as flood-prone area	PE	Binary	Yes / No
Perceived flood frequency	PE	Ordinal categorical	Rare, occasional, frequent, very frequent
Flood occurrence periods	PE	Multiple categorical	Months of flood occurrence
Perceived causes of floods	PE	Multiple categorical	Excessive rainfall, river overflow, urbanization, inadequate drainage
Household previously affected by flood	PE	Binary	Yes / No
Water level during floods	PE	Ordinal categorical	Estimated water rise level
Housing construction type	PE	Nominal categorical	Precarious, intermediate, sustainable materials
Distance to watercourse	PE	Ordinal categorical	<1 km, 1–5 km, >5 km, no watercourse, unknown
Reception of flood warning messages	IAWS	Binary	Yes / No
Alert dissemination channels	IAWS	Multiple categorical	Radio, television, SMS, social media, local authorities, word of mouth, etc.
Understanding of warning messages	IAWS	Binary	Yes / No
Anticipatory adaptation strategies	PE	Multiple categorical	Strategies implemented before floods
Perceived effectiveness of anticipatory strategies	PE	Ordinal	Not effective at all to very effective

PE : Perception and Experience, SDC : Socio Demographic Characteristic, IAWS : Information Access and Warning Systems

c. Analytical approach: Ordered Probit Model (OPM)

To identify determinants associated with the level of perceived anticipatory effectiveness, an ordered probit regression was used. This choice was motivated by the ordinal nature of the dependent variable and the use in the literature of ordered logit and probit models for analysing such data [43]. The model rests on the existence of a continuous latent variable y_i^* representing the underlying level of anticipatory effectiveness, with the observed categories resulting from the crossing of ordered thresholds [5], [43], [44]. The model is mathematically written as:

$$y_i^* = X_i\beta + \varepsilon_i \quad \varepsilon_i | X_i \sim N(0,1)$$

where y_i^* is the continuous latent variable of perceived anticipatory effectiveness, X_i the vector of explanatory variables, β the vector of parameters to be estimated, and ε_i the error term assumed to follow a standard normal distribution.

Marginal effects were also calculated for each category to obtain an interpretation in terms of probability change [39], [43]. Multicollinearity between explanatory variables was assessed using the Variance Inflation Factor (VIF) [5]. VIF values below the critical threshold of 5 were considered to indicate the absence of problematic multicollinearity. The fitted model was assessed using the Wald test, Nagelkerke pseudo- R^2 , and log-likelihood.

2.4 Descriptive statistics

This section presents the socio-demographic, environmental, and perceptual characteristics of households. Categorical variables were summarised using frequencies and proportions ; quantitative variables by mean and standard deviation or median and interquartile range according to data distribution. Comparisons between localities were made using Pearson's Chi-square test (or Fisher's exact test when expected counts were insufficient) for categorical variables [45], and the Kruskal-Wallis test for non-normally distributed quantitative variables. In the event of a significant Kruskal-Wallis result, post-hoc comparisons were performed using Dunn's test with Bonferroni correction. The statistical significance threshold was $p < 0.05$. All analyses were performed using R version 4.4.1.

3. RESULTS

3.1 Descriptive statistics of respondents

A total of 403 households were included in the study. The socio-demographic characteristics of these households are summarised in (Table 2). The majority resided in Togblékopé (68.0%), resulting in a high proportion in an urban setting (86.8%). Respondents were predominantly male (76.4%) compared with 23.6% female, indicating a predominantly male household leadership structure. The age distribution showed a mean of 46.0 ± 13.3 years, indicating that the population is mainly composed of middle-aged individuals. The average household size was 6.7 ± 4.0 persons, with

significant differences between localities observed for age of household head and household size ($p < 0.05$). Regarding education level, approximately one third of respondents had primary (35.0%) or secondary (35.2%) education, 9.2% had reached higher education, while 20.6% had no formal education. The main occupations were craftsmen/transport (25.1%), farming/livestock (24.6%) and trade (21.1%). More than half of households (55.1%) had a monthly income below 50,000 FCFA and only 10.4% had health insurance. Among households with health insurance, 57.1% (24/42) reported full coverage for all family members. Duration of residence varied significantly across study localities ($p < 0.001$). 32.3% of respondents had lived in their area for more than 20 years, followed by 26.1% for 6–10 years, 23.1% for ≤ 5 years and 18.6% for 11–20 years.

Table 2 : Socio-demographic characteristics of sampled households

Variables	Overall (N=403)	Togblékopé (N=274)	Avegbo (N=18)	Ogou- Kolidé (N=15)	Guérin- Kouka (N=76)	Koulfiekou (N=20)	p- value
Settlement type							<0.001
Urban	350 (86.8)	274 (100.0)	0 (0.0)	0 (0.0)	76 (100.0)	0 (0.0)	
Peri-urban	20 (5.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	20 (100.0)	
Rural	33 (8.2)	0 (0.0)	18 (100.0)	15 (100.0)	0 (0.0)	0 (0.0)	
Sex of household head							0.13
Male	308 (76.4)	204 (74.5)	11 (61.1)	14 (93.3)	63 (82.9)	16 (80.0)	
Female	95 (23.6)	70 (25.5)	7 (38.9)	1 (6.7)	13 (17.1)	4 (20.0)	
Age of household head (years)	46.0 $\pm$ 13.3	44.9 $\pm$ 13.2	55.7 $\pm$ 11.5	47.8 $\pm$ 12.4	48.2 $\pm$ 13.5	43.6 $\pm$ 12.5	0.002
Household size	6.7 $\pm$ 4.0	5.8 $\pm$ 2.8	8.7 $\pm$ 4.0	6.2 $\pm$ 3.3	8.1 $\pm$ 6.1	10.8 $\pm$ 4.9	<0.001
Education level of household head							<0.001
None	83 (20.6)	41 (15.0)	7 (38.9)	4 (26.7)	21 (27.6)	10 (50.0)	
Primary	141 (35.0)	111 (40.5)	6 (33.3)	2 (13.3)	16 (21.1)	6 (30.0)	
Secondary	142 (35.2)	100 (36.5)	4 (22.2)	9 (60.0)	25 (32.9)	4 (20.0)	
Higher	37 (9.2)	22 (8.0)	1 (5.6)	0 (0.0)	14 (18.4)	0 (0.0)	

Occupation of household head							<0.001
Farming/Livestock	99 (24.6)	35 (12.8)	14 (77.8)	11 (73.3)	20 (26.3)	19 (95.0)	
Trade/Commerce	85 (21.1)	72 (26.3)	0 (0.0)	0 (0.0)	12 (15.8)	1 (5.0)	
Employee/Civil servant	47 (11.7)	28 (10.2)	1 (5.6)	3 (20.0)	15 (19.7)	0 (0.0)	
Craftsman/Worker/Transport	101 (25.1)	80 (29.2)	3 (16.7)	1 (6.7)	17 (22.4)	0 (0.0)	
Unemployed/Other	71 (17.6)	59 (21.5)	0 (0.0)	0 (0.0)	12 (15.8)	0 (0.0)	
Monthly household income							0.031
< 50,000 FCFA	222 (55.1)	150 (54.7)	7 (38.9)	10 (66.7)	42 (55.3)	13 (65.0)	
50,000–100,000 FCFA	155 (38.5)	113 (41.2)	10 (55.6)	4 (26.7)	24 (31.6)	4 (20.0)	
> 100,000 FCFA	26 (6.5)	11 (4.0)	1 (5.6)	1 (6.7)	10 (13.1)	3 (15.0)	
Household health insurance							0.008
No	361 (89.6)	250 (91.2)	18 (100.0)	13 (86.7)	60 (78.9)	20 (100.0)	
Yes	42 (10.4)	24 (8.8)	0 (0.0)	2 (13.3)	16 (21.1)	0 (0.0)	
Duration of residence							<0.001
≤ 5 years	93 (23.1)	86 (31.4)	0 (0.0)	0 (0.0)	6 (7.9)	1 (5.0)	
6–10 years	105 (26.1)	87 (31.8)	1 (5.6)	0 (0.0)	16 (21.1)	1 (5.0)	
11–20 years	75 (18.6)	58 (21.2)	0 (0.0)	0 (0.0)	13 (17.1)	4 (20.0)	
> 20 years	130 (32.3)	43 (15.7)	17 (94.4)	15 (100.0)	41 (53.9)	14 (70.0)	

NB: Data presented as n (%) for categorical variables and mean ± standard deviation (SD) for continuous variables. Comparisons between localities were performed using Pearson's Chi-square test or Fisher's exact test for categorical variables, and the Kruskal-Wallis test for continuous variables.

3.2 Flood vulnerability perception and household experience

The majority of households perceived their locality as exposed to floods (97.8%). Floods were primarily perceived as frequent (60.7%) or very frequent (18.8%), with significant variation across localities ($p < 0.001$). Approximately 76.4% of households reported having previously been affected by flood, with significant difference between localities ($p = 0.009$). The maximum water level during the last flood was most often

between 0.5 and 0.99 m (54.5%). The majority of households lived in housing built with durable materials (61.5%), while 33.0% resided in close proximity to a watercourse (< 1 km). Significant differences between localities were observed for construction materials and distance to watercourses ($p < 0.001$). Flood occurrence periods were mainly reported between June and September, with a peak observed in August (38.2%) and September (34.2%) (Fig 2). Variations across localities were also observed (Fig 2). The main perceived causes of floods were excessive rainfall (80.4%), soil impermeability (55.6%) and the absence or failure of drainage systems (35.7%) (Fig 3).

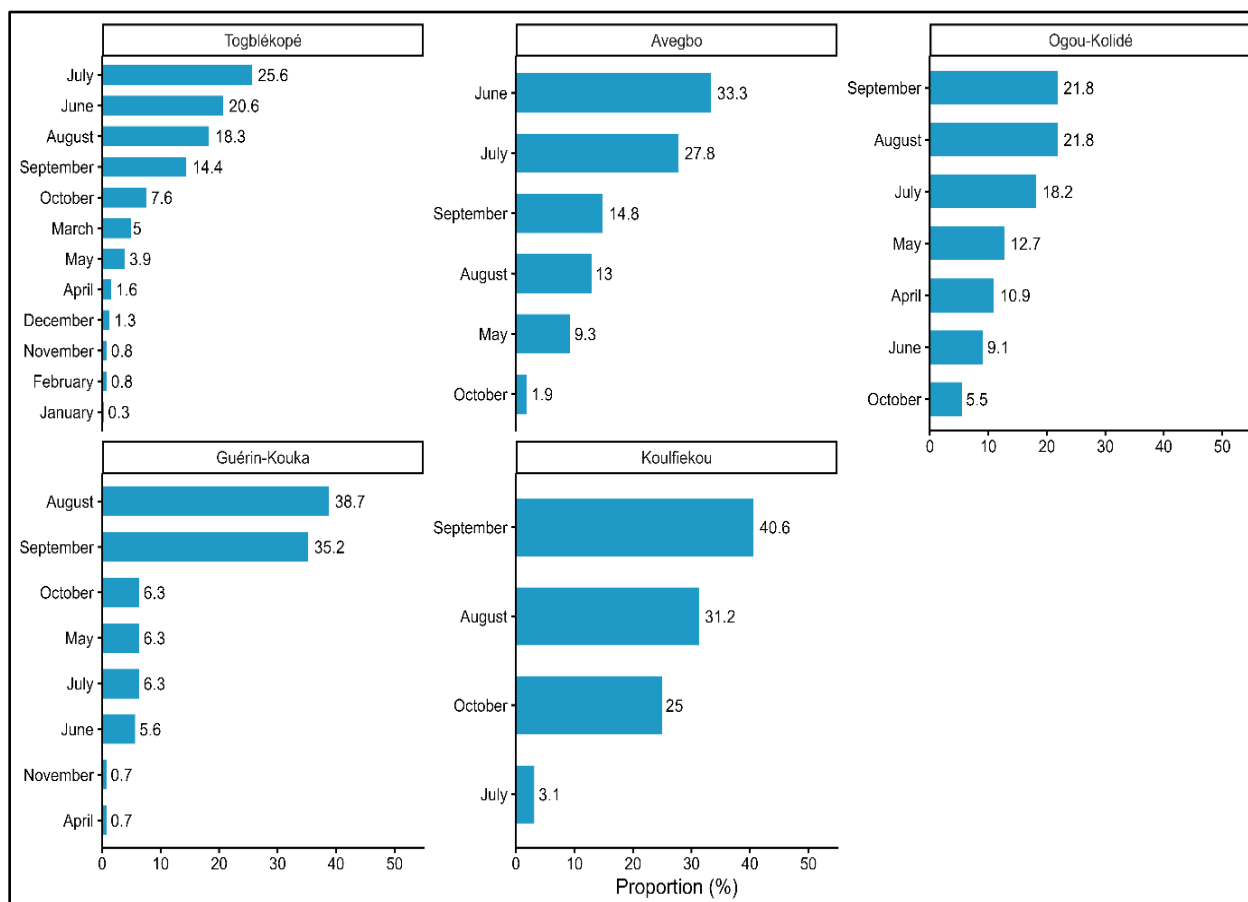


Fig 2. Flood occurrence periods by locality

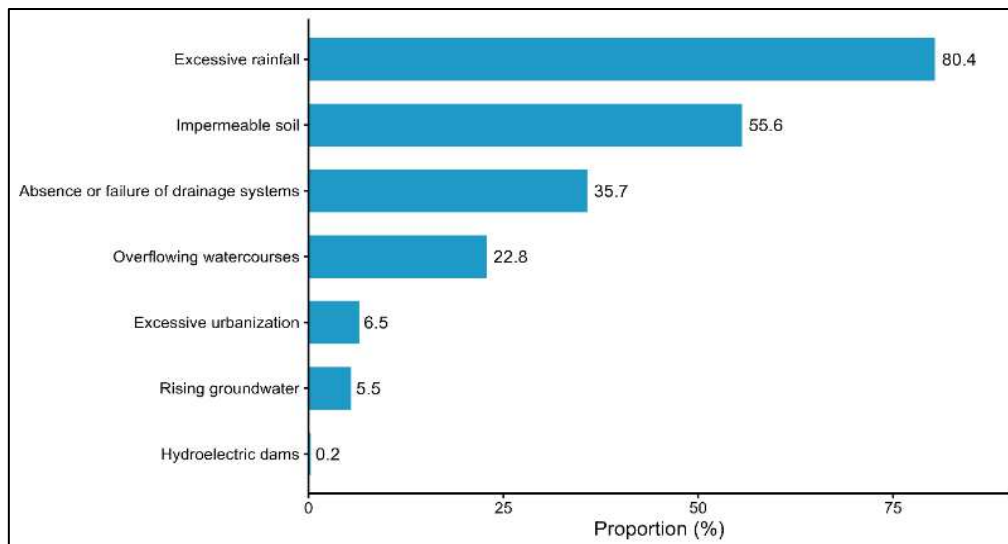


Fig 3. Perceived causes of floods by households

3.3 Access to information and flood warning systems

Nearly half of households reported receiving flood warning messages (45.2%), with significant differences across study localities ($p < 0.001$). Message reception was particularly high in Avegbo (100.0%) and Koulfiekou (95.0%), in contrast to Togblékopé where only 36.9% of households reported receiving alerts. Among households receiving warning messages, almost all declared understanding them (97.3%). The main alert dissemination channels were radio (28.8%), word of mouth (15.6%) and community leaders (8.7%).

3.4 Anticipatory flood adaptation strategies

Table 3 presents the ranking of anticipatory flood adaptation strategies according to their overall perceived effectiveness score (TES). Anticipated securing of household assets was perceived as the most effective strategy, with a total effectiveness score of 382 points, followed by the use of sandbags (TES = 369 points), adjustment of the agricultural calendar (TES = 317 points) and development of drainage canals or evacuation drains (TES = 313 points). Elevation of housing foundations and construction of embankments also showed relatively high effectiveness scores, with 282 and 257 points respectively. In contrast, early warning systems (TES = 120 points) and precautionary savings (TES = 105 points) were among the strategies with the lowest effectiveness scores. Our findings suggest a predominance of physical protection strategies for housing and assets among the anticipatory strategies perceived as most effective by households.

Table 3. Ranking of anticipatory flood adaptation strategies according to perceived effectiveness score (TES)

Anticipatory strategies	Effectiveness range (n)	Total effectiveness score	Rank

	Not used (0)	Not effective (1)	Slightly effective (2)	Moderately effective (3)	Effective / Very effective (4)		
Anticipated securing of household assets	0	1	24	21	336	382	1
Use of sandbags	0	15	62	60	232	369	2
Adjustment of agricultural calendar	0	3	34	36	244	317	3
Development of drainage canals or evacuation drains	0	1	30	30	252	313	4
Elevation of housing foundations	0	11	46	21	204	282	5
Construction of embankments	0	7	72	66	112	257	6
Construction of protective walls	0	7	26	9	212	254	7
Water and food storage	0	1	24	27	152	204	8
Reinforcement of construction walls	0	4	12	15	136	167	9
Early warning systems	0	8	4	0	108	120	10
Precautionary savings	0	0	6	3	96	105	11

NB : Effectiveness scores were calculated based on weighted perceived effectiveness levels assigned by households to each anticipatory adaptation strategy. Response options ranged from 0 = 'Not used / Not exposed' to 4 = 'Effective / Very effective'. The total effectiveness score corresponds to the sum of weighted scores obtained for each strategy.

3.5 Perceived anticipatory effectiveness

The observed score ranged from 0 to 44, with higher scores reflecting better effectiveness. The score showed a mean of 6.87 ± 7.78 and a median of 5 (IQR: 2–9). Graphical examination of the overall anticipatory effectiveness score through the density curve (Fig 4) revealed a right-skewed distribution, characterised by a strong concentration of households around low effectiveness scores and the presence of a few high extreme values. The Shapiro-Wilk normality test confirmed non-normality of the overall anticipatory effectiveness score distribution ($W = 0.73$; $p < 0.001$). Consequently, subsequent comparative analyses primarily relied on non-parametric statistical methods. The majority of households (91.6%) showed low anticipatory effectiveness, while 5.0% and 3.5% were moderate and high respectively (Table 4).

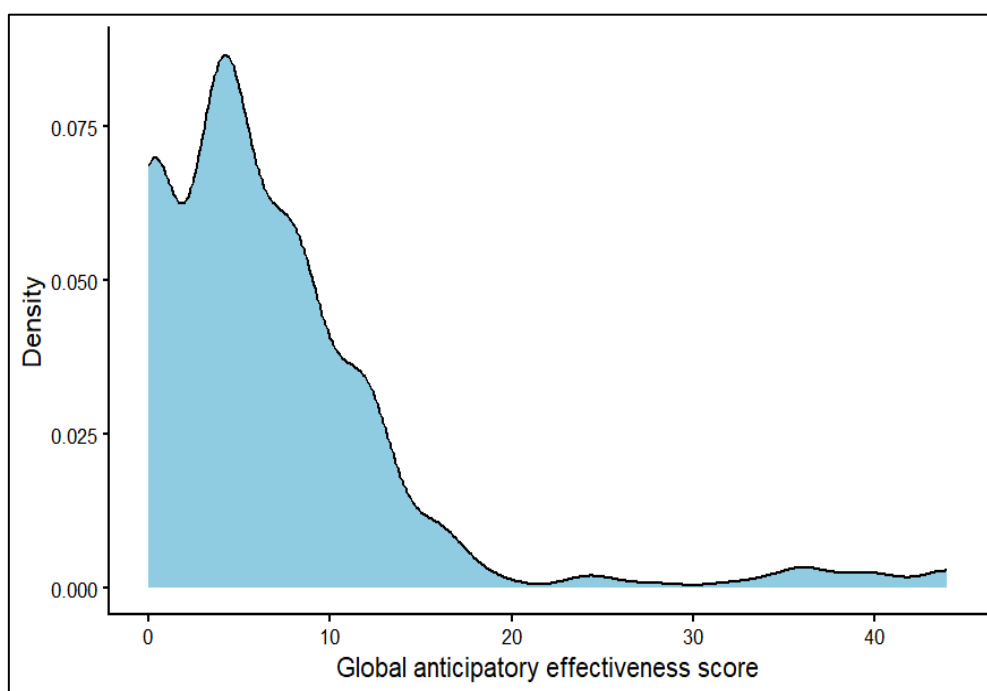


Fig 4. Density curve illustrating the skewness of the overall household anticipatory effectiveness score.

Table 4. Categorisation of the overall household anticipatory effectiveness score

Effectiveness category	Score range	n (%)	Mean $\pm$ SD	Median (IQR)
Low effectiveness	0–14	369 (91.6)	5.05 ± 3.96	4 (2–8)
Moderate effectiveness	15–29	20 (5.0)	18.1 ± 3.89	16 (16–19)
High effectiveness	30–44	14 (3.5)	38.86 ± 4.05	39 (36–43)

NB: SD: standard deviation; IQR: interquartile range.

The analysis of (Table 5) reveals a distribution of anticipatory effectiveness score categories varied across study localities. The highest proportions of households with high effectiveness were observed in Guérin-Kouka (14.5%) and Koufiekou (15.0%), while no households in Togblékopé, Avegbo or Ogou-Kolidé were classified in this category. Pearson's Chi-square test showed a statistically significant association between study localities and effectiveness categories ($\chi^2 = 56.76$; $df = 8$; $p < 0.001$),

suggesting significant spatial heterogeneity in anticipatory effectiveness levels across localities.

Table 5. Distribution of overall anticipatory effectiveness score categories by study locality

Locality	Effectiveness category	n	%
Togblékopé	Low effectiveness	266	97.1
	Moderate effectiveness	8	2.9
	High effectiveness	0	0.0
Avegbo	Low effectiveness	17	94.4
	Moderate effectiveness	1	5.6
	High effectiveness	0	0.0
Ogou-Kolidé	Low effectiveness	14	93.3
	Moderate effectiveness	1	6.7
	High effectiveness	0	0.0
Guérin-Kouka	Low effectiveness	57	75.0
	Moderate effectiveness	8	10.5
	High effectiveness	11	14.5
Koulfiekou	Low effectiveness	15	75.0
	Moderate effectiveness	2	10.0
	High effectiveness	3	15.0

Note: Pearson's Chi-square test: $\chi^2 = 56.76$; $df = 8$; $p < 0.001$.

Overall anticipatory effectiveness scores also varied across study localities. The highest mean scores were observed in Guérin-Kouka (12.66 ± 12.22) and Koulfiekou (12.40 ± 12.78), while Togblékopé, Avegbo and Ogou-Kolidé showed the lowest mean scores (4.84 ± 4.32), (6.22 ± 4.28) and (8.07 ± 4.67) respectively. Kruskal-Wallis test results showed a statistically significant difference in scores between localities (Kruskal-Wallis $\chi^2 = 45.60$; $df = 4$; $p < 0.001$). Post-hoc comparisons using Dunn's test with Bonferroni correction revealed significant differences mainly between Togblékopé and Guérin-Kouka (adjusted $p < 0.001$) and between Togblékopé and Koulfiekou (adjusted $p = 0.017$) (Table 6).

Table 6. Post-hoc comparisons of the overall anticipatory effectiveness score between localities (Dunn's test with Bonferroni correction)

Comparison	Z statistic	Adjusted p	Significance
Togblékopé vs Avegbo	1.26	1.000	NS
Togblékopé vs Ogou-Kolidé	2.42	0.153	NS
Togblékopé vs Guérin-Kouka	6.07	<0.001	****
Togblékopé vs Koulfiekou	3.13	0.017	*
Avegbo vs Ogou-Kolidé	0.96	1.000	NS
Avegbo vs Guérin-Kouka	1.83	0.671	NS
Avegbo vs Koulfiekou	1.29	1.000	NS

Ogou-Kolidé vs Guérin-Kouka	0.51	1.000	NS
Ogou-Kolidé vs Koulfiekou	0.24	1.000	NS
Guérin-Kouka vs Koulfiekou	-0.25	1.000	NS

NS: not significant; * $p < 0.05$; **** $p < 0.0001$.

3.6 Ordered probit model results and marginal effects

The multicollinearity diagnostic showed VIF values ranging from 1.13 to 4.08, all below the critical threshold of 5, suggesting the absence of problematic multicollinearity between the explanatory variables included in the model. Tolerance values ranged from 0.25 to 0.89, remaining above the minimum acceptable threshold of 0.10. The ordered probit model showed a statistically significant overall fit (Wald $\chi^2 = 127.98$; $p < 0.001$). The Nagelkerke pseudo- R^2 was estimated at 0.54, indicating that the model explained approximately 54% of the observed variability in anticipatory effectiveness categories. The log-likelihood value was -75.64. The marginal effects derived from the model (OPM) showed that several factors were significantly associated with anticipatory effectiveness categories in households facing floods (Table 7).

Households residing in Guérin-Kouka had a significantly higher probability of belonging to the high anticipatory effectiveness category compared with those in Togblékopé ($\beta = 1.44$; $p < 0.001$). Marginal effects indicated a 14% decrease in the probability of being classified in the low effectiveness category and a 13% increase in the probability of belonging to the high effectiveness category. Female-headed households also had a higher probability of belonging to the high anticipatory effectiveness category compared with male-headed households ($\beta = 1.35$; $p = 0.002$). Monthly household income was determinant of anticipatory effectiveness. Households with a monthly income between 50,000 and 100,000 FCFA had a significantly higher probability of belonging to the high anticipatory effectiveness category compared with those earning below 50,000 FCFA ($\beta = 1.28$; $p < 0.001$). Regarding housing characteristics, households living in housing built with intermediate materials (mud brick, sheet metal) had a higher probability of belonging to the high anticipatory effectiveness category compared with those in precarious construction ($\beta = 2.01$; $p = 0.011$). Conversely, households located more than 5 km from a watercourse had a significantly higher probability of belonging to the low anticipatory effectiveness category compared with households living in close proximity to a watercourse ($\beta = -1.54$; $p = 0.012$).

Finally, reception of flood warning messages was significantly associated with better anticipatory effectiveness. Households receiving warning messages had a higher probability of belonging to the high anticipatory effectiveness category compared with those not receiving them ($\beta = 1.24$; $p = 0.001$).

Table 7. Results of the ordered probit regression model and marginal effects of overall anticipatory effectiveness categories of flood-facing households

			Effet marginal (dy/dx)
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Variables	β Coefficient (p-value)	z- value	Low effectiveness (p-value)	Moderate effectiveness (p-value)	High effectiveness (p-value)
Locality					
Togblékopé (Ref.)	—	—	—	—	—
Avegbo	-2,84 (0,001)	-3,24	0,16 (0,003)	-0,10 (0,005)	-0,06 (0,018)
Ogou-Kolidé	-1,60 (0,040)	-2,06	0,10 (0,056)	-0,06 (0,061)	-0,04 (0,102)
Guérin-Kouka	1,44 (<0,001)	3,75	-0,14 (<0,001)	0,01 (0,918)	0,13 (<0,001)
Koulfiekou	0,73 (0,163)	1,40	-0,07 (0,188)	0,01 (0,850)	0,06 (0,160)
Sex of household head					
Male (Ref.)	—	—	—	—	—
Female	1,35 (0,002)	3,17	-0,13 (0,002)	0,01 (0,895)	0,12 (0,002)
Age of household head	-0,01 (0,281)	-1,08	0,00 (0,281)	0,00 (0,286)	0,00 (0,293)
Household size	0,00 (0,892)	0,14	0,00 (0,892)	0,00 (0,892)	0,00 (0,892)
Education level of household head					
None (Ref.)	—	—	—	—	—
Primary	-0,61 (0,134)	-1,50	0,04 (0,159)	-0,03 (0,164)	-0,01 (0,195)
Secondary	-0,28 (0,464)	-0,73	0,02 (0,480)	-0,01 (0,480)	-0,01 (0,489)
Higher	0,06 (0,912)	0,11	-0,01 (0,912)	0,00 (0,912)	0,00 (0,913)
Occupation of household head					
Farming/Livestock (Ref.)	—	—	—	—	—
Trade/Commerce	-0,32 (0,504)	-0,67	0,02 (0,504)	-0,01 (0,504)	-0,01 (0,505)
Employee/Civil servant	-0,18 (0,727)	-0,35	0,01 (0,727)	-0,01 (0,727)	-0,01 (0,728)
Craftsman/Worker/Transport	0,69 (0,122)	1,54	-0,06 (0,128)	0,00 (0,935)	0,06 (0,118)
Unemployed/Other	-1,31 (0,052)	-1,95	0,11 (0,067)	-0,05 (0,127)	-0,06 (0,057)
Monthly household income					
< 50,000 FCFA (Ref.)	—	—	—	—	—

50,000–100,000 FCFA	1,28 (<0,001)	3,75	-0,12 (<0,001)	0,01 (0,910)	0,12 (<0,001)
> 100,000 FCFA	1,23 (0,091)	1,69	-0,11 (0,102)	0,01 (0,871)	0,11 (0,090)
Duration of residence					
≤ 5 years (Ref.)	—	—	—	—	—
6–10 years	-0,42 (0,394)	-0,85	0,03 (0,399)	-0,02 (0,401)	-0,01 (0,408)
11–20 years	-0,51 (0,356)	-0,92	0,04 (0,365)	-0,02 (0,367)	-0,02 (0,372)
> 20 years	0,67 (0,174)	1,36	-0,06 (0,177)	0,00 (0,920)	0,06 (0,172)
Perception of locality as flood risk area					
No (Ref.)	—	—	—	—	—
Yes	-0,87 (0,310)	-1,01	0,07 (0,332)	-0,03 (0,429)	-0,04 (0,337)
Household affected by floods					
No (Ref.)	—	—	—	—	—
Yes	0,94 (0,052)	1,94	-0,09 (0,062)	0,00 (0,944)	0,08 (0,050)
Type of housing construction					
Precarious materials (reed, wood) (Ref.)	—	—	—	—	—
Intermediate materials (mud brick, sheet metal)	2,01 (0,011)	2,56	-0,18 (0,016)	0,01 (0,849)	0,17 (0,010)
Durable materials (concrete, multi-storey)	0,73 (0,342)	0,95	-0,07 (0,347)	0,00 (0,912)	0,06 (0,339)
Distance to watercourse					
Close (< 1 km) (Ref.)	—	—	—	—	—
Moderately distant (1–5 km)	-0,69 (0,091)	-1,69	0,05 (0,095)	-0,02 (0,098)	-0,03 (0,107)
Distant (> 5 km)	-1,54 (0,012)	-2,51	0,11 (0,019)	-0,06 (0,025)	-0,05 (0,039)
No watercourse	-0,95 (0,047)	-1,99	0,08 (0,055)	-0,04 (0,068)	-0,04 (0,081)
Unknown	1,16 (0,103)	1,63	-0,11 (0,116)	0,01 (0,864)	0,10 (0,101)
Reception of flood warning messages					
No (Ref.)	—	—	—	—	—

Yes	1,24 (0,001)	3,45	-0,12 (0,001)	0,01 (0,904)	0,11 (0,001)
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NB: β coefficients are from the ordered probit model. Marginal effects (dy/dx) represent probability changes of belonging to each anticipatory effectiveness category associated with a unit change in explanatory variables. Reference categories (Ref.) correspond to the comparison modalities used in the model. Values of $p < 0.05$ were considered statistically significant.

4. DISCUSSION

4.1 Perceived effectiveness of anticipatory strategies

The majority of households (91.6%) showed low perceived anticipatory strategy effectiveness. This observation align with the Socio-Ecological Systems (SES) approach, according to which a lack of flexibility or limited access to social capital forces households to adopt reactive rather than adaptive responses [5]. The ranking of perceived effectiveness resulting from this study reflects an adaptation logic, focused on the structural preservation of the habitat, the material rather than on financial or informational mechanisms. The proactive securing of household goods (TES = 382) and the use of sandbags (TES = 369) dominate this ranking, while early warning systems (TES = 120) and preventive savings (TES = 105) bring up the rear. This finding largely aligns with the observations made in the Zio basin [24]. This primacy of structural strategies over other strategies is also documented by [10] in Namibia and Zambia. Another important point to highlight is the gap between the frequency of adoption and the perceived effectiveness of the strategies. Already observed by [24], this distinction is found in our sample. The adjustment of the agricultural calendar and the construction of drainage channels are frequently implemented without dominating the effectiveness ranking. These proactive strategies reflect the concept of transformative adaptation, a resilience theory through which households seek to reduce their flood exposure while strengthening their adaptive capacity [46]. However, their low perceived effectiveness in our results can be attributed to the fact that these adjustments rely on traditional knowledge rather than precise meteorological data, making households particularly vulnerable to increasing climate irregularities. This also suggests that the adoption of a strategy often responds more to its immediate feasibility (low cost, locally available materials) than to a rigorous evaluation of its actual effectiveness [39], [40], [47].

The low score attributed to early warning systems in our study is concerning, in a context where only 45.2% of households report receiving alert messages and where this rate drops to 36.9% in Togblékopé. [19] following its assessment revealed an insufficiency of early warning systems at the national level in Togo. Comparable findings were reported [48] in the Manafwa River Basin in Uganda, where recurrent flooding continued to catch households unprepared despite the existence of warning systems. According to the authors, this reflects either inadequacies in the warning

system itself or limited understanding of the information disseminated. This interpretation is consistent with our findings, in which receiving flood warning messages emerged as one of the strongest predictors of high anticipatory effectiveness (see Section 5.2). Our results suggest that the main challenge lies not in the usefulness of early warning systems, but rather in their limited coverage and effectiveness in reaching vulnerable populations.

4.2 Determinants of anticipatory effectiveness: convergences and specificities

Although female-headed households represent a minority of the sample (23.6%) were associated with a higher probability of achieving a high level of anticipatory effectiveness ($\beta = 1.35$; $p = 0.002$). Although this finding contrasts with most of the existing literature [5], [10], [48], [49], it is consistent with the observations of [15], [50], who reported that female-headed households tend to rely more on informal adaptation strategies. In the present study, these informal strategies ranked among the most effective according to households' perceptions. This finding therefore suggests not necessarily a greater adaptive capacity among women, but rather a better alignment with the strategies perceived as being the most effective.

Monthly household income emerged as a strong determinant of anticipatory effectiveness. Households earning between 50,000 and 100,000 FCFA were significantly more likely to achieve a high level of anticipatory effectiveness ($\beta = 1.28$; $p < 0.001$) than those with lower incomes. This finding is consistent with previous studies identifying household income as one of the main drivers of ex ante adaptation strategies [9], [39]

Housing quality also played an important role. Households living in dwellings constructed with intermediate materials (sheets and wood) were significantly more likely to report high anticipatory effectiveness than those living in more precarious housing ($\beta = 2.01$; $p = 0.011$). Semi-durable housing provides a stronger physical basis upon which households can invest in anticipatory measures, whereas highly fragile dwellings are systematically affected by flooding (Têtou-Houyo et al., 2025). This may explain why the most vulnerable households in our study appeared less likely to invest in anticipatory actions.

Receiving flood early warning messages remained one of the strongest predictors of anticipatory effectiveness ($\beta = 1.24$; $p = 0.001$), reinforcing the central role of early warning information previously highlighted by [14] in Ethiopia, where access to household early warning systems increased preparedness by more than fivefold. In the present study, this factor is particularly important given the marked spatial disparities in warning message coverage, ranging from 100% in Avegbo and 95% in Koufiekou to 67.1% in Guérin-Kouka, 46.7% in Ogou-Kolidé, and only 36.9% in Togblékopé.

Conversely, living more than 5 km away from a river was associated with a higher probability of low anticipatory effectiveness ($\beta = -1.54$; $p = 0.012$). Although this result appears counterintuitive, it may be explained by lower perceived flood risk among households located farther from watercourses, leading them to invest less in

anticipatory measures. A similar mechanism of risk underestimation among non-riparian households has been documented by [21] in the Lower Mono Basin.

In contrast, several variables reported as significant determinants of adaptation in previous studies including age, education, and previous flood experience [5], [14], [15] were not statistically significant in our model. This discrepancy may be explained by the nature of the outcome variable used in the present study. Unlike previous research that focused primarily on the adoption of adaptation measures, our dependent variable captures the perceived effectiveness of the strategies actually implemented. Consequently, an older, more educated, or more experienced household head may adopt an adaptation strategy without necessarily perceiving it as effective.

4.3 Spatial Heterogeneity: Urban, Semi-Urban, and Rural Areas

Every locality might have some established or traditional coping strategies, but the type of response adopted by people and its effectiveness may vary over time [51]

The perceived effectiveness of anticipatory adaptation strategies did not follow a simple urban-peri-urban-rural gradient. Although Togblékopé is an urban locality, it recorded the lowest mean anticipatory effectiveness score (4.84 ± 4.32) and the highest proportion of households with low effectiveness levels (97.1%). In contrast, Guérin-Kouka, which is also classified as urban, achieved the highest mean score, alongside Koufiekou (12.66 ± 12.22 and 12.40 ± 12.78 , respectively, for the peri-urban setting). This finding is consistent with the observations of (Têtou-Houyo et al., 2025) in the Zio River Basin, where the study area was predominantly urban and peri-urban. Their results suggest that the effectiveness of adaptation strategies is influenced less by the administrative classification of settlements than by factors such as the quality of drainage infrastructure, flood intensity, and the extent of unplanned urbanization. These factors are particularly pronounced in Togblékopé and may explain its comparatively low effectiveness levels.

Post-hoc comparisons further confirmed the robustness of this spatial heterogeneity. Togblékopé differed significantly from both Guérin-Kouka ($Z = 6.07$, adjusted $p < 0.001$) and Koufiekou ($Z = 3.13$, adjusted $p = 0.017$). By contrast, no significant differences were observed between the two rural localities (Avegbo and Ogou-Kolidé) and the other study sites. The absence of a clear contrast between rural and urban settings is in line with the findings of [10], who, in a comparative study of Namibia and Zambia, showed that the determinants of adaptation tend to operate in a broadly similar manner regardless of the administrative classification of the area of residence.

5. CONCLUSION AND POLICY IMPLICATIONS

In light of these findings, the study highlighted the perceived effectiveness of anticipation strategies by households and the factors influencing it based on administrative status. At the end of this study, we can conclude that in most Togolese localities, the endogenous strategies implemented by the households themselves remain one of the main pillars of proactivity against floods. Their apparent low

effectiveness (91.6%) is based on several determining factors that it would be advisable for the leaders to take into consideration. This situation reinforces the weakness in disaster response, contribute to the spread of diseases, thus causing the same damage as the recent floods in June 2026 on the coast (Togo, Ghana, Côte-d'Ivoire). It is therefore important to correct this vulnerability. The institutions responsible for disaster risk management in Togo should act on levers such as :

- Development of a sufficiently robust early warning system, and training residents to correctly interpret the messages.
- Identify, analyse, and formally finance at the community level the strengthening of endogenous practices that have proven their effectiveness in action.

Authors' Contribution

Nahara Tchagodomou and Nadège I.P Dossoumou designed the study. The scientific relevance and methodology were reviewed and validated by Cyprien Aholou. The data collection, analysis, and processing work was carried out by Nahara Tchagodomou. Nahara Tchagodomou was assisted in data collection by Adnane Kpekpasi and in analysis by Samad Tchakondo. Nahara Tchagodomou wrote the entire article. Cyprien Aholou and Franziska Wolf reviewed the manuscript. Komi Agboka and Komi Begehou secure funding acquisition. All authors have read and agreed to the published version of the manuscript.

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Availability of data

The data is available upon request from the corresponding author.

Declarations

Ethical Approval and accordance

The study protocol was reviewed and approved by the Ethics Committee of the Faculty of Health Sciences of the University of Lomé (CE-FSS), under reference number N°581/2026/CE-FSS/19/01. The research was conducted in accordance with the ethical principles and guidelines of the CE-FSS, as well as applicable Togolese

legislation and institutional requirements. The study did not involve any procedures that could negatively affect the participants sensibilities.

Consent to Participate

Verbal informed consent was obtained from all participants prior to their participation. Each participant was informed about the purpose of the study and voluntarily agreed to take part.

Clinical Trial Number : not applicable

Consent to Publish declaration : not applicable

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