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It's not just risk—it's responsibility: Changing drivers of home flood protection

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Abstract

Private household adaptation is a critical yet underutilised element of flood resilience. Property-level measures might reduce up to 80% of damage if adopted in a timely manner. However, socio-behavioural factors serve as constraints to adaptation. Among them, a lack of risk awareness is considered a primary barrier. Empirical research typically relies on a single snapshot of data, implicitly assuming these factors are stable over time. Using two nationally representative survey waves from the Netherlands (2020 and 2023), we examine how factors of household intentions to implement six structural home-flood protection measures change. Counterintuitively, despite a major flood in 2021, by 2023, we find lower adaptation intentions (an 11.6 percentage point decline), lower flood worry, and reduced self-efficacy. This coincided with a marked shift in perceived responsibility for flood risk toward the government (12 percentage point increase), while the actual uptake of private adaptation measures remained low (2–5%). Regression analysis reveals a reordering of behavioural drivers: in 2020, prior flood experience, self-efficacy, and flood worry were the most prominent predictors, though perception of responsibility was also consistently significant. By 2023, perception of responsibility emerges as the strongest and most consistent predictor of intention to act (odds ratio 2.4), while the importance of flood experience and worry declines. These results suggest that household drivers for adaptation are volatile, relying not only on a household's experience and capacity to act but also on the understanding of shared responsibility between citizens and the state. "Empowering" households only with information about potential flood risk, while rationally sound, may not result in an intention to protect homes. Climate adaptation policy design that embraces private action must therefore include: clear responsibility framing, support for skills development and the efficacy of measures, targeted

Data availability statement: The data analyzed in this study are available from the SCALAR — Household climate-adaptation and resilience survey (Filatova, Noll, Rijcken, & Wagenaar, 2022), deposited at the DANS Data Station Social Sciences and Humanities: https://doi.org/10.17026/dans-x9h-nj3w. No additional data were used.

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financial incentives, and adaptability to account for evolving public attitudes, even over short timeframes.

Introduction

Recently, the American real estate giant Zillow introduced a climate risk feature on its platform, displaying a property's flood risk directly to potential buyers [1]. This move coincides with a renewed debate among scholars, policymakers, and the public: when a home is at risk, who is responsible for taking action [2]? While such labels are intended to empower homeowners by raising awareness, they typically focus only on correcting one private climate change adaptation constraint: information asymmetry, i.e., the biased perception of flood risks held by homeowners and potential buyers.

The private actions in question often concern structural adaptation measures - tangible steps homeowners can take to make their property safer from floods and mitigate potential damage in the face of accelerating climate risks [3]. These can range from relatively simple modifications, like floodproofing doors or windows, to more significant undertakings, such as elevating an electricity meter or reinforcing a home's foundation [4].

There is a growing consensus that government-led, top-down flood protection initiatives are not sufficient on their own [5], highlighting the importance of private adaptation [6]. While government-led public adaptation measures, such as dikes and seawalls, reduce the *probability* of flooding, private actions *reduce damages* and *recovery time* if a hazard event occurs. Research shows that measures taken at the household level can be remarkably effective, reducing flood-related damages by an estimated 40% to 80%, if taken [4]. However, various socio-behavioural factors may serve as adaptation constraints, preventing people from taking timely action to protect themselves and their homes [7].

To understand the drivers behind a homeowner's decision to implement such property-level measures, researchers frequently turn to surveys. Among different social science theories explaining human decisions under risk [8], Protection Motivation Theory (PMT) stands out as one of the best in explaining private climate change adaptation behaviour [9], at least in the "capitalist societies" [10]. According to PMT, our intention to protect ourselves depends on two stages of decision-making: our threat appraisal (how serious is the risk, and how likely is it to affect me, do I worry about it?) and our coping appraisal (how effective is the protective action, am I capable of performing it, how expensive is it for my case?).

Past studies have successfully used PMT to identify critical factors of private flood adaptations, such as personal experience mediated by worry [11], frequent flood experience and loss of control [12], coping appraisal [13], and responsibility [14], that influence a household's intention to adapt. It was also found that the importance of certain factors, such as flood experience, may diminish over time [12] or lead to a downward spiral of distrust and inaction [15]. Longitudinal studies of private property-level adaptation are scarce and show inconclusive evidence on how individual risk perceptions and intentions to adapt change over time [16,17].

However, what remains unclear is how the key factors of households' adaptation evolve over time, and whether a single survey snapshot delivers a stable value on which policy design can rely. For example, do subjective threat appraisals and perceptions of responsibility - who they believe should lead the charge on flood protection - evolve over time, especially in the wake of a recent flood event? In this context, it is also important to reveal how a sense of responsibility interacts with other motivating factors over time to ultimately shape the decision to adopt or reject various property-level protective measures.

To explore this gap, we draw on two waves of a comprehensive household survey conducted in 2020 and 2023 in the Netherlands, allowing for a comparison of attitudes over time. We first analyse the descriptive statistics to reveal the key trends. Following this, we perform a regression analysis for each survey wave. This allows us to identify the factors associated with the intention to adapt and measure any possible changes in their relative influence, providing a quantitative picture of what motivates or hinders household-level climate action, and whether these socio-behavioural adaptation constraints remain stable over time.

Materials and methods

A high-level overview

Our objective is to understand the relative importance of behavioural factors associated with a household's intention to implement structural home-level flood protection measures over time. Here, our focus is on understanding whether subjective risk perception is a decisive and reliable factor which climate adaptation policies could utilise as an effective policy lever. We estimate this for two independent survey waves: 2020 (N = 1,251) and 2023 (N = 420), and compare patterns across years.

We ground the analysis in an extended PMT framework. In its canonical form, PMT explains adaptive behaviour as dependent on two sets of variables: *threat appraisal* (e.g., perceived hazard probability and worry level) and *coping appraisal* (e.g., perceived outcome efficacy, self-efficacy, and costs). Building on this, we add *flood experience* to stress test the recent findings on its importance for Dutch households and *responsibility perception* to capture the role of perceived personal or shared responsibility in motivating private household action.

Within this framework, we examine intentions to adopt six structural measures aimed at reducing flood impacts at the property level: strengthening foundations, reinforcing walls/floors, raising the electricity meter, installing anti-backflow valves, installing pumps/drainage, and fixing water barriers. As the primary analysis method, we perform logistic regression for each wave and measure separately.

Data

We use the SCALAR household climate-adaptation and resilience survey [18], focusing on two samples collected in 2020 (N = 1,251) and 2023 (N = 420) in the Netherlands. The sample sizes differ between the two waves; however, this is a standard feature of longitudinal surveys. Although our 2023 sample is smaller and sufficient for the analysis, it may miss detecting small effects. Therefore, some predictors may appear "less important" because their confidence intervals widen. Further, two waves studied opinions in the same geographical areas, specifically the south-west of the country, and they comprised different respondents. Most importantly, both waves were designed to be nationally representative with respect to key socio-demographics (e.g., gender, age, education, income, and savings; see Fig 1).

Statistical analysis

We employ two primary methods: descriptive statistics, including frequency tables and Likert plots, and regression analysis, specifically the Logit model, which has been demonstrated to be effective in similar tasks [19]. We utilise an implementation of the Logit model in the statsmodels Python package [20].

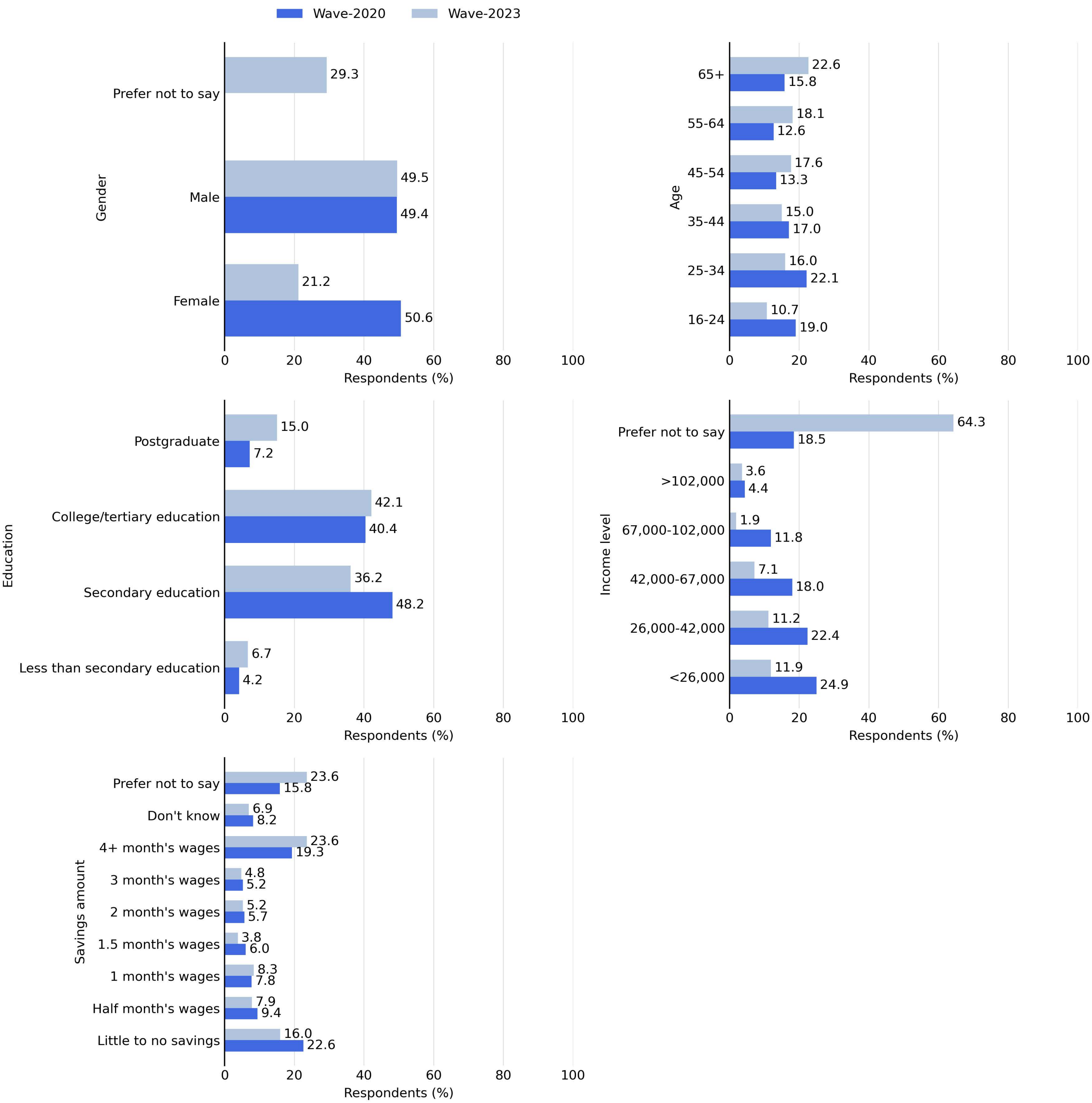

Fig 1. Sample composition by wave (2020 vs 2023). Distributions of gender, age, education, income, and savings for Wave-2020 (*N*=1,251; royal blue) and Wave-2023 (*N*=420; light steel blue). The samples are comparable across demographics and were designed to be nationally representative. Bars show the percentage of respondents in each category and sum to 100% within panel and wave.

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As the dependent variable, we use the answers to the question: "*Please indicate if you have already implemented any of these structural measures or if you intend to do so in the future*," for each of the six structural measures, resulting in six regression models. In the survey, respondents had the opportunity to indicate whether they had already implemented each measure, plan to implement it within a specific time horizon (within 6 or 12 months, a year, two years, or after two years), or do not plan to implement it. For our analysis, we combine all intentions to implement a specific measure, regardless of near-future timing (in 1 year, 2 years, or more), into a single, measure-specific overall intention to adapt. For each structural measure, we analyse respondents' intention to implement it among those who had not yet done so. Acknowledging that the behavioural drivers of *planning* can differ from the drivers of *completed* action, we follow the standard that is common in the survey literature to treat *intention to implement a measure* as the main outcome variable. This standard emerged from accumulated evidence that some predictors, such as risk perception, can change after implementation [13,17,21]. Mixing adopters and non-adopters without explicitly modelling the adoption stage may lead to conflating determinants of intention with post-adoption feedback effects. Moreover, adoption prevalence for individual measures is low in our sample (2–5%; Table 3), limiting reliable multivariable modelling of adoption with a large predictor set.

As a result, our dependent variable becomes binary with 0 corresponding to the respondent's response "Do not plan to implement a measure" - no intention to adapt, and 1 corresponding to the respondent's response "Planning to implement a measure" — intention to pursue one of the six property-level adaptation measures (Table 1).

As for the independent variable, we start the analysis of our six measure-specific variables grounded in extended PMT (Table 2). To avoid unstable models, we screen for multicollinearity using the Variance Inflation Factor (VIF > 5) and pairwise correlations. We find that response efficacy and perceived costs are collinear with self-efficacy and have high VIF across measures and waves. We therefore excluded them from the final models. The final predictor set consists of perceived flood frequency, flood worry, flood experience, self-efficacy (measure-specific), and responsibility perception.

Responsibility perception was measured differently in the 2020 and 2023 waves. In Wave-2020, respondents indicated who should be responsible for flood protection on a 5-point ordinal scale ranging from "completely government" (1) to "completely individual" (5). In Wave-2023, respondents allocated 100 percentage points across eight actors: citizens, businesses, local NGOs, international NGOs, local government, national government, water authorities, and others.

To derive a comparable ordinal measure for Wave-2023, we first computed a *government share* by summing allocations to local government, national government, and water authorities. We computed an *individual share* by summing allocations to citizens and businesses. NGO allocations were excluded from both totals, as they do not map cleanly onto either pole of the government-individual continuum. We then classified respondents into five categories aligned with the 2020 scale:

1. **Completely government**: government share = 100%
2. **Mostly government**: 50% < government share < 100%
3. **Equal responsibility**: neither government nor individual share exceeds 50%
4. **Mostly individual**: 50% < individual share < 100%
5. **Completely individual**: individual share = 100%

To assess the validity of this harmonisation, we computed mean government responsibility shares for both waves using a continuous scale (mapping the 2020 ordinal categories to 100, 75, 50, 25, and 0, respectively). The mean government share was 66.6% in Wave-2020 and 65.5% in Wave-2023, suggesting comparable distributions of responsibility attribution across waves.

We estimate separate logistic regressions (logit link, binomial family) for each wave × measure combination (6 measures in 2020 and 2023; 12 models total) using `statsmodels` and report robust (HC0) standard errors. Because each

Table 1. Surveyed property-level flood adaptation measures. Short names and descriptions of the six structural measures included in the survey and used to construct the dependent variable in the regression models.

Short name	Description
Strengthen foundations	Strengthening the housing foundations to withstand water pressures
Reinforce walls/floor	Reconstructing or reinforcing the walls and/or the ground floor with water-resistant materials
Raise electricity meter	Raising the electricity meter above the most likely flood level or on an upper floor
Install anti-backflow valves	Installing anti-backflow valves on pipes
Install pump/drainage	Installing a pump and/or one or more system(s) to drain flood water
Fix water barriers	Fixing water barriers (e.g., water-proof basement windows)

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Table 2. Independent variables based on extended PMT (waves 2020 and 2023). Operationalisation of threat appraisal (worry, perceived frequency), coping appraisal (self-efficacy, response efficacy, perceived costs), and PMT extensions (experienced flood, responsibility perception). Responsibility differs by wave (2020: 5-point scale; 2023: 100-point allocation).

Group	Short name	Question	Type	Values (summary)
Threat appraisal	Flood worry	How worried are you about flooding at home?	Likert 1–5	1 not at all … 5 very worried
Threat appraisal	Perceived flood frequency	How often do you think flooding occurs at your property?	Ordinal 1–10	Categories from “completely safe” to “> annual”; “don‘t know”; see Note A
Coping appraisal	Self-efficacy	Do you have the ability to undertake the measure (DIY or by paying a professional)?	Likert 1–5	1 unable … 5 very able
Coping appraisal	Response efficacy	How effective would this measure be in reducing flood damage?	Likert 1–5	1 extremely ineffective … 5 extremely effective
Coping appraisal	Perceived costs	Considering your finances, would implementing this measure be cheap or expensive?	Likert 1–5	1 very cheap … 5 very expensive
PMT extension	Experienced flood	Have you personally experienced a flood?	Binary	Yes / No
PMT extension	Responsibility (2020)	In your opinion, whose responsibility is it to deal with floods?	Likert 1–5	1 completely government … 5 completely individual
PMT extension	Responsibility (2023)	Allocate responsibility for dealing with floods across actors (sum to 100).	Allocation 0–100	8 actors; see Note B

Table notes: **A**: Full category wording for perceived flood frequency: 1 completely safe; 2 <1/500y; 3 1/500y (0.2%); 4 1/200y (0.5%); 5 1/100y (1%); 6 1/50y (2%); 7 1/10y (10%); 8 annual; 9 > annual; 10 don‘t know.

B: Actors in 2023 allocation: citizens; private companies/businesses; local NGOs; international NGOs/UN bodies; local/regional/state government; national/federal government; water authorities; other.

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wave includes many coefficient tests across the six measures, we control the False Discovery Rate (FDR) within each wave using the Benjamini–Hochberg (BH) procedure [22]. The family is defined as *all* coefficient tests across predictors and measures in that wave. We report q-values (BH-adjusted p-values) and consider an effect statistically reliable when $q < 0.05$. To keep tables readable, we show the odds ratio (OR) cells in the cross-measure summary only when $q < 0.05$. Confidence intervals are 95% unadjusted CIs (i.e., CIs are not multiplicity-adjusted), which is standard when FDR is used for inference. Significance markers (stars) reflect q-values; effects with OR< 1 are marked with a dagger to indicate a protective association. For each model, we report pseudo-R^2, ORs with 95% CIs, and FDR-adjusted significance. We also provide VIF summaries by measure and wave in the Supporting Information to document the absence of collinearity.

Our models treat responsibility perception as an exogenous predictor. However, it is plausible that responsibility and adaptation intentions mutually influence each other: individuals who already intend to take measures may retrospectively attribute more responsibility to homeowners, and vice versa. With cross-sectional data and no instruments, we cannot disentangle these pathways. The odds ratios we report should therefore be interpreted as associations, not as causal effects of responsibility on intention.

Results

Household intentions to adapt declined substantially between 2020 and 2023

Our analysis begins by examining the changes in private household flood adaptations between the 2020 and 2023 waves. The actual adoption rates of structural measures remain consistently low in both years, ranging from 2% to 5% depending on the specific measure, with no significant change detected between the survey waves (Table 3).

However, a striking and substantial shift occurred in households' intention to adopt these measures. As shown in Table 3, the proportion of respondents planning to implement a measure dropped across all six actions. In general, the intention to adapt decreased by 11.6 percentage points, from 25.4% on average across six measures in Wave-2020 to 13.8% in Wave-2023. The largest declines (≈ 13 percentage points) were observed for intentions to "Raise the electricity meter," "Install a pump/drainage system," and "Fix water barriers."

Shift in behavioural drivers: Decreased worry and self-efficacy, and greater reliance on government

To understand this decline in intention, we examine shifts in the key drivers of protective behaviours. While we began our analysis with a full set of six predictors, after carefully examining correlations and VIF, we conclude that only three factors remained robust across all measures and waves. These factors, which most strongly influence a household's intention to pursue property-level adaptation, are flood worry, self-efficacy, and perceived responsibility.

Surprisingly, despite a major national flood event occurring between the survey waves in July 2021 [23], the overall level of flood worry decreased among our respondents from 2020 to 2023 (Fig 2). Although the 2021 event impacted another part of the country, a flood in the Netherlands is an extremely rare event and has been extensively discussed in society, on policy forums, and in the media. 2021 was also an unprecedented event, exceeding the expected probability, intensity and timing [24]. Despite this, we observe a decrease in worry among our respondents in Wave-2023 compared to respondents in Wave-2020, with the most notable change being a 16 percentage point increase in respondents reporting they were "Not at all worried," with corresponding decreases in higher worry categories.

In general, between 40–60% of households - depending on the measure and survey waves - feel they are absolutely unable to implement a property-level flood protective measure, compared to only 4%-9% of households who report very high self-efficacy (Fig 3). Over time, alongside a diminished sense of worry, we observe a significant decline in

Table 3. Intentions to adopt property-level flood measures Wave-2020 and Wave-2023. Shares of respondents reporting no intention, planning to implement, or already adopted each measure in Wave-2020 and Wave-2023. The proportion planning to implement fell on average by 11.6 percentage points (from 25.4% to 13.8%), with the largest declines (≈ 13 percentage points) for raising the electricity meter, installing a pump/drainage system, and fixing water barriers.

Measure	Wave-2020			Wave-2023		
	No intention	Planned	Adopted	No intention	Planned	Adopted
Raise electricity meter	68%	28%	4%	81%	15%	4%
Install anti-backflow valves	70%	26%	3%	81%	15%	4%
Install pump/drainage	70%	27%	3%	83%	14%	4%
Fix water barriers	71%	26%	3%	83%	13%	4%
Strengthen foundations	74%	24%	2%	85%	13%	2%
Reinforce walls/floor	72%	25%	3%	85%	13%	2%

Table notes: Values are percentages of respondents within each wave for a given measure. Rows sum to 100% per wave (subject to rounding).

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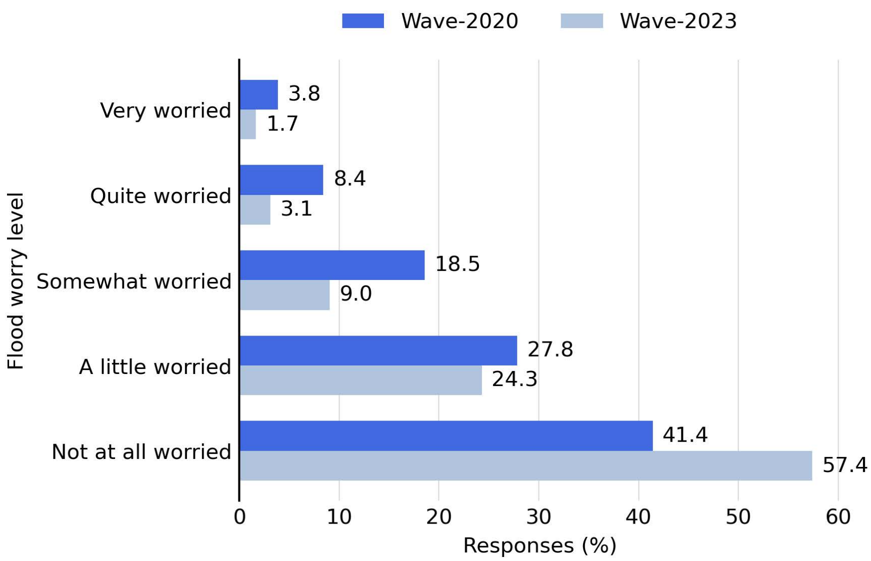

Fig 2. Flood-worry levels declined between 2020 and 2023. Horizontal bars compare worry about flooding in Wave-2020 (royal blue) and Wave-2023 (light steel blue). Despite a major flood occurring nationally in 2021, overall worry is lower in 2023: the share "Not at all worried" rises by about 16 percentage points (41% → 57%), with corresponding declines in higher-worry categories. Percentages label respondent shares and sum to 100% within wave.

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respondents' perceived self-efficacy - their subjective belief in their own ability to implement protective measures. As detailed in Panel A) and Panel B) of Fig 3, more respondents in 2023 felt they were "somewhat unable" or "unable" to implement these measures, with an average increase of 7.2 percentage points in these categories compared to 2020. This erosion of confidence was most pronounced for "Fix water barriers" (an 11.1 percentage point increase in feeling unable) and least so for "Install anti-backflow valves" (a 3.4 percentage point increase).

The final behavioural factor we discuss in detail here, perception of responsibility, revealed a decisive shift away from the individual and toward the government (Fig 4). In 2020, nearly half of the respondents (47%) believed responsibility was shared equally. By 2023, this figure had fallen to 35%. Conversely, the proportion of respondents believing that flood protection is primarily the government's responsibility increased substantially, from 20% in 2020 to 32% in 2023.

Perception of responsibility becomes the dominant driver of adaptation intention in 2023

To formally identify the factors associated with the intention to adapt in each wave, we conduct a series of six logistic regression analyses. The binary outcome variable is reported intention to pursue a specific measure in the coming years (coded as 1) versus no intention to adapt (coded as 0). After assessing a full set of six potential predictors from PMT (see Table 2) and checking for multicollinearity (VIF > 5), we keep five key predictors for the final models: perceived flood frequency, flood worry, flood experience, self-efficacy, and responsibility perception.

The results, summarised in Tables 4 and 5, reveal a changing landscape of the influence of these behavioural factors of private adaptation actions. In Wave-2020, four factors: self-efficacy, responsibility perception, flood worry, and flood experience, were statistically reliable for all six adaptation measures after controlling for the FDR with the wave (BH; $q < .05$). Experienced flood had the largest average effect sizes (e.g., ORs ~3–5), while responsibility and self-efficacy were positive and consistent (responsibility ORs ~1.3–1.4).

Most critically, the relative importance of these two core predictors "inverted" between the two waves. By 2023, the influence of flood worry had become selective (significant for four of six measures), and flood experience had largely dropped out (significant for only one measure). In contrast, responsibility perception and self-efficacy remained robust

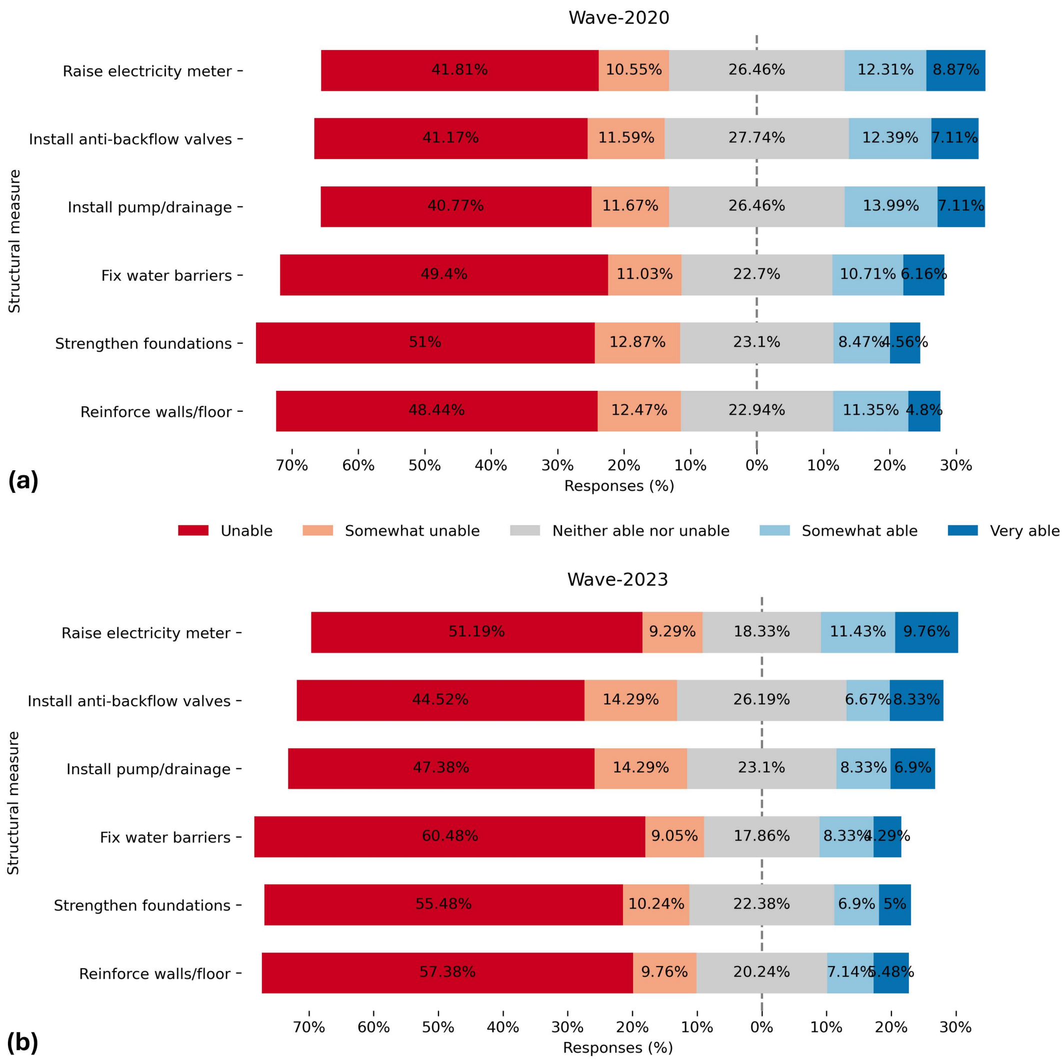

Fig 3. Self-efficacy or perceived ability to carry out structural household flood-protection measures (2020 vs 2023). Panels display diverging stacked bars for six structural measures, with “unable” responses to the left and “able” to the right; the vertical dashed line indicates the neutral point (0%). *Panel a:* Wave-2020. *Panel b:* Wave-2023. Across measures, many households feel unable to implement these actions, and the unable categories increased on average by about 7.2 percentage points from 2020 to 2023 (largest for “Fix water barriers,” smallest for “Install anti-backflow valves”). Percentages are respondent shares; bars sum to 100% per measure.

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across all six measures and grew in relative importance. Responsibility now shows ORs around 2–3 (e.g., up to 2.69 for Reinforce walls/floor), making it the most consistent and strongest driver of intention in 2023. Perceived flood frequency is generally null and appears protective (OR< 1) only for Reinforce walls/floor in 2023.

We must note one cautionary point, however. Because responsibility is measured with different items in 2020 and 2023 and rescaled within each wave, the odds ratios are not strictly comparable in absolute magnitude across waves. We therefore interpret responsibility‘s effect size primarily within each wave, where in 2023 it is consistently larger than that of other predictors and remains the most robust correlate of intention.

Given the different measurement approaches for responsibility perception across waves, we conducted sensitivity analyses to assess whether our findings depend on the specific harmonisation method. For Wave-2023, we tested

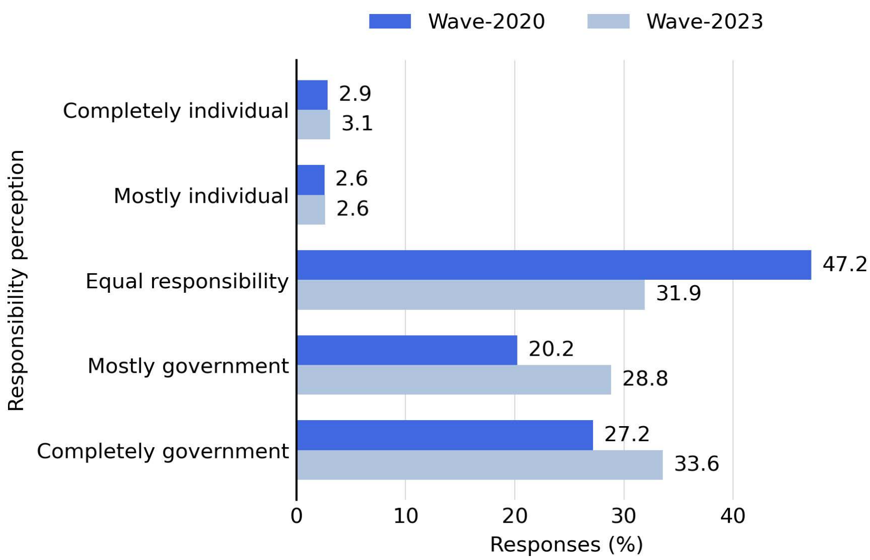

Fig 4. Perceived responsibility for flood risk management shifted toward government (2020→2023). Horizontal bars show how respondents distribute responsibility between individuals and government in Wave-2020 (royal blue) and Wave-2023 (light steel blue). Views move away from "Equal responsibility" (about 47% → 35%) toward greater government responsibility ("Mostly government" increases from about 20% to 32%; "Completely government" remains near 27–28%). For visual comparability, the 2020 item is a five-point scale, while the 2023 allocation task (100 points across actors) is summarised to the same five categories. Bars show percentages and sum to 100% within the wave.

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four alternative operationalisations: (1) the default categorical measure described; (2) a binary measure distinguishing government-dominant from individual-dominant respondents; (3) a continuous measure using the raw government percentage (0–100); and (4) models excluding responsibility perception entirely.

A table summarising the stability of key predictor effects across these specifications can be found in the Supporting information. Self-efficacy and flood worry remained significant predictors across all structural measures and all operationalisations. The pattern of significant effects was consistent regardless of whether responsibility perception was measured categorically, continuously, or excluded from the model entirely. This suggests that our substantive conclusions regarding predictors are robust to the harmonisation approach used for responsibility perception.

The pseudo-R^2 values (≈0.21-0.34 across models) indicate that the behavioural predictors explain a substantive but not exhaustive portion of variation in intentions. This is typical for models of individual protective behaviour, where many unobserved factors (e.g., geographical location [25], social networks [26]) may also play a role.

Discussion

Our findings reveal an unexpected and consequential shift in the drivers of household flood adaptation in the Netherlands between 2020 and 2023. Between these two survey waves, the Netherlands experienced a major flood in 2021 that drew nationwide attention and public debate, despite occurring outside our survey region. In that context, one might have expected heightened risk awareness and stronger motivation to act. Yet, our data show the opposite: adaptation intentions declined by 11.6 percentage points, alongside lower flood worry and lower self-efficacy. Most importantly, our analysis indicates a reordering in the relative importance of behavioural drivers. While prior flood experience appears to be a dominant correlate of intention in 2020, by 2023, perceived responsibility emerges as the most powerful and consistent predictor of a household's intention to protect its home.

These results both confirm and challenge existing literature. The strong association between prior flood experience and intention in our 2020 data aligns with prior work describing experience as a potential "window of opportunity" for

Table 4. Determinants of adaptation intention in 2020. Measure-specific odds ratios (OR; 95% CI) from logistic regressions (logit; HC0 SEs). Cells appear only when the Benjamini–Hochberg FDR-adjusted $q < .05$ *within wave*; em dashes (—) indicate non-significant effects (q≥.05). Stars reflect *q*-values; daggers would denote protective effects (OR< 1). Across all six measures, self-efficacy, responsibility, flood worry, and prior flood experience are consistently reliable; perceived flood frequency is rarely significant.

Adapt. measure	*Self-efficacy*	*Resp. perception*	*Flood worry*	*Exp. flood*	*Perc. flood freq.*
Raise electricity meter	1.86 (1.67–2.07)***	1.33 (1.13–1.55)***	1.91 (1.67–2.18)***	3.65 (2.38–5.58)***	1.09 (1.02–1.17)*
Install anti-backflow valves	1.82 (1.63–2.03)***	1.33 (1.14–1.56)***	1.71 (1.50–1.96)***	2.94 (1.95–4.43)***	—
Install pump/drainage	1.68 (1.51–1.87)***	1.35 (1.15–1.57)***	1.91 (1.67–2.18)***	3.22 (2.16–4.81)***	—
Fix water barriers	2.04 (1.82–2.29)***	1.32 (1.12–1.55)**	1.94 (1.69–2.23)***	4.05 (2.65–6.19)***	—
Strengthen foundations	2.04 (1.79–2.32)***	1.38 (1.17–1.64)***	1.86 (1.62–2.13)***	2.42 (1.60–3.66)***	—
Reinforce walls/floor	2.29 (2.01–2.61)***	1.27 (1.07–1.50)**	1.95 (1.69–2.25)***	4.59 (3.01–7.00)***	—

Table notes: Cells show OR (95% CI). Entries shown only when FDR-adjusted $q < .05$ (BH within wave). Significance: * $q<.05$, ** $q<.01$, *** $q<.001$. Predictors: *Self-efficacy* (1–5), *Responsibility perception* (resp. perception; 1–5; higher = more homeowner responsibility), *Flood worry* (1–5), *Experienced flood* (exp. flood; 0/1), *Perceived flood frequency* (perc. flood freq.; ordinal). Outcome: intention to adopt the listed *Adaptation measure* (adapt. measure; respondents reporting "already adopted" for that measure are excluded).

Model diagnostics (by measure, in row order): Raise electricity meter: N=1, 207, pseudo-R^2=0.250; Install anti-backflow valves: N=1, 212, 0.213; Install pump/drainage: N=1, 214, 0.215; Fix water barriers: N=1, 217, 0.280; Strengthen foundations: N=1, 220, 0.259; Reinforce walls/floor: N=1, 215, 0.320.

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Table 5. Determinants of adaptation intention in 2023. Measure-specific odds ratios (OR; 95% CI) from logistic regressions (logit; HC0 SEs). Cells appear only when the Benjamini–Hochberg FDR-adjusted $q < .05$ *within wave*; em dashes (—) indicate non-significant effects (q≥.05). In 2023, responsibility perception shows the largest and most consistent associations across measures, with self-efficacy remaining robust; flood worry is selective; prior flood experience is largely non-significant; perceived frequency is generally null and protective for one measure.

Adapt. measure	*Self-efficacy*	*Resp. perception*	*Flood worry*	*Exp. flood*	*Perc. flood freq.*
Raise electricity meter	1.67 (1.36–2.04)***	2.12 (1.53–2.94)***	—	—	—
Install anti-backflow valves	1.36 (1.12–1.67)**	2.45 (1.74–3.47)***	1.58 (1.18–2.12)**	3.98 (1.53–10.36)**	—
Install pump/drainage	1.84 (1.47–2.30)***	2.14 (1.48–3.09)***	1.68 (1.24–2.28)**	—	—
Fix water barriers	2.26 (1.71–2.98)***	2.35 (1.54–3.58)***	1.68 (1.19–2.37)**	—	—
Strengthen foundations	2.06 (1.60–2.64)***	2.34 (1.63–3.35)***	—	—	—
Reinforce walls/floor	1.97 (1.52–2.55)***	2.69 (1.82–3.99)***	1.46 (1.04–2.05)*	—	0.74 (0.57–0.96)†

Table notes: Cells show OR (95% CI). Entries shown only when FDR-adjusted $q < .05$ (BH within wave). Significance: * $q<.05$, ** $q<.01$, *** $q<.001$. † OR < 1 (protective association). Predictors and outcome as in Wave-2020.

Model diagnostics (by measure, in row order): Raise electricity meter: N=404, pseudo-R^2=0.226; Install anti-backflow valves: N=404, 0.219; Install pump/drainage: N=405, 0.251; Fix water barriers: N=402, 0.343; Strengthen foundations: N=411, 0.289; Reinforce walls/floor: N=412, 0.309.

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encouraging protective action [11,12]. However, the reduced overall importance of experience in Wave-2023, together with the observed decline in worry, suggests that this window may close faster than anticipated, or that experience alone is not sufficient to sustain private motivation over time.

Several mechanisms could plausibly contribute to the observed pattern, and our data do not allow us to distinguish between them. First, a widely discussed possibility is that large disasters can sometimes trigger psychological responses that do not translate into sustained engagement due to their scale, such as helplessness, denial, or cognitive dissonance. Second, the governmental response to the 2021 flood may have unintentionally shaped expectations about who should bear responsibility for private losses. Following the 2021 event, the Dutch government declared a state of "disaster" [24], which made private individuals and businesses eligible for compensation for uninsured losses. While this support was clearly needed, extensive international evidence suggests that public compensation can, under some conditions, reduce incentives for private risk reduction when it reinforces expectations of future state support [15,27,28]. Third, more structural constraints may have played a role: rising construction costs, labour shortages, limited contractor availability, and competing household investment priorities (including energy-related renovations) can lower perceived feasibility and reduce self-efficacy, even if perceived risk remains unchanged [29–31]. Because we do not measure perceived state support, compensation expectations, or perceived renovation feasibility in sufficient detail, we treat these explanations as plausible but untested and encourage future work to include explicit items on compensation expectations, trust in government protection, perceived fairness/adequacy of recovery support, and perceived affordability and feasibility of renovation.

The rise of responsibility perception as the dominant correlate of intention across all studied property-level measures is striking, especially given that this shift occurred over just three years. Earlier studies have highlighted the role of perceived responsibility in shaping private adaptation, including in the Dutch context [14]. Our longitudinal comparison underscores how dynamic and consequential this factor can be: in Wave-2023, a homeowner‘s beliefs about who should act appear more influential than their flood experience, their worry, or even their perceived ability to act (self-efficacy), factors commonly reported as central drivers of private adaptation [9]. This suggests that decisions to protect one‘s home are shaped not only by perceived risk and costs, but also by institutional arrangements and an implicit social contract that define the roles of citizens and the state in ensuring safety. While strong institutions are vital for climate adaptation [6,7], institutional setups and informal norms that performed well under historically lower risk may become restrictive in a rapidly changing risk landscape. In the Netherlands, extensive public flood protection has contributed to a highly developed protection regime, but it may also have fostered a strong norm of reliance on public protection. Yet, even the world‘s most advanced flood defence systems cannot guarantee a zero probability of flooding. As risk regimes change, it becomes increasingly important to communicate that private choices, including property-level adaptations, can meaningfully shape the damages households suffer when floods occur.

These results have profound policy implications. If climate risks continue to intensify, shared responsibility for physical risk becomes unavoidable: governments can reduce flood probabilities (e.g., via dikes) and steer exposure through spatial planning, while citizens can reduce damages through property-level measures (e.g., dry- or wet-proofing) and limit exposure by factoring risk into housing decisions. Institutions then need to evolve to support these shifting roles, including through financial incentives that make climate-smart investments feasible. Our findings may also inform the design of specific policy instruments, such as climate risk labels for homes [2,32]. Labels may increase awareness, but our results suggest that information provision alone is unlikely to be sufficient, and may even be counterproductive, if households interpret risk disclosure as confirmation that the government should solve the problem. Effective policy, therefore, needs to integrate physical risk information with behavioural insights and institutional design. In practice, this means moving beyond information provision to:

1. Clearly frame responsibility: Communicate explicitly that flood risk management is a shared duty between the state (reducing hazard probability and steering exposure) and households (reducing damages and making risk-informed choices that affect exposure).
2. Enable private action: Pair risk communication with tangible support (e.g., subsidies, technical guidance, trusted contractors, and practical workshops) to increase perceived feasibility and self-efficacy.
3. Build an adaptive policy process: Recognise that attitudes and perceived responsibility are not static. Policies should include feedback loops to monitor and adapt to evolving public sentiment, even over short timeframes.

The generalisability of our findings likely depends on the institutional context. The Netherlands is characterised by comparatively strong flood protection and well-developed water governance, which can shape public expectations regarding who “should” manage flood risk. In settings with weaker flood protection institutions or less reliable compensation, households may, by default, place greater responsibility on themselves, and structural constraints (e.g., housing quality, access to finance, and limited technical support) may dominate intention formation. At the same time, the central role of coping appraisal, particularly self-efficacy, may generalise across contexts, as perceived ability to act is a common prerequisite for private adaptation. Comparative studies across governance and protection regimes would be valuable to test whether the observed shift toward responsibility perception as a key correlate of intention is context-specific or part of a broader pattern.

This study has several limitations that open avenues for future research. First, as is common in the literature on private flood protection [9,10,13,33], we focus on adaptation intention rather than action. The well-documented intention-action gap means that observed intentions may overstate future implementation [17]. Future work should track households over time to identify what converts intentions into action and to model adoption and intention as distinct stages. Second, the 2021 flood was nationally salient but occurred outside the survey region, which may have reduced its perceived personal relevance and weakened any "learning effect"; this "psychological distance" could help explain why worry and intentions did not increase in Wave-2023. Third, while we document a shift in behavioural correlates, we cannot establish causal reasons for the change, whether related to the 2021 event, its policy response, broader societal stressors such as the COVID-19 period [31], or changes in perceived feasibility (e.g., material and labour constraints) [30]. Fourth, Wave-2023 has a smaller sample (N = 420) than Wave-2020 (N = 1,251). While the effects for responsibility and self-efficacy remain large and precisely estimated in 2023, the reduced sample size lowers the power to detect weaker associations. We encourage future work to strive for comparable sample sizes across waves [34]. Accordingly, wave-to-wave comparisons should be interpreted cautiously, emphasising effect directions, magnitudes, and patterns that are consistent across multiple measures. Finally, because the two waves capture different respondents from the same region rather than the same individuals, future research could use panel data, qualitative interviews, behavioural experiments, or structural equation modelling to test specific mechanisms and to examine how key predictors evolve after implementation.

Conclusion

In the urgent quest for climate resilience, household-level adaptation remains a critical but stubbornly difficult goal. This study aspires to understand if and how the drivers of homeowners' intentions to implement flood protection measures on their homes change over time. Our analysis of two household surveys conducted in the Netherlands, just three years apart, reveals an unexpected and critical insight: citizens' motivation to adapt is not a stable function of risk perception, but rather is volatile and largely shaped by people's perceptions of personal responsibility. Between our survey waves in 2020 and 2023, the psychological landscape shifted from one where private intention to adapt is driven by personal experience, worry, and self-efficacy to one where private adaptation is predominantly determined by the perception of who is fundamentally responsible for protection - the individual or the government.

The primary contribution of this work is the demonstration that the social contract can outweigh individual risk calculations and behavioural factors that traditionally explain private adaptation, such as risk perceptions and self-efficacy. Notably, a shocking hazard event occurred in the country in July 2021, between our two survey waves. Although our dataset does not permit us to establish causality, the descriptive evidence is clear: respondents in Wave 2023 are less worried, feel less responsible, and are less capable of taking private flood protection measures compared to respondents in Wave 2020. One implication of this pattern is that policies aiming to "empower" households with risk information alone are built on a fragile assumption. Without a clear and compelling narrative of shared responsibility, such policies may fail to stimulate private action. Ultimately, building a climate-resilient society requires more than just raising citizens' awareness of the risks they face; it necessitates forging a clear and collaborative partnership between citizens and the government to confront those risks together.

Supporting information

S1 Table. Model diagnostics by wave and measure. Sample sizes and pseudo-R^2 for each fitted model.
(XLSX)

S2 Table. Full logistic regression results (Wave 2020). Log-odds coefficients (Coef), robust SE (HC0), raw *p*, Benjamini–Hochberg FDR-adjusted *q* (computed within wave across all predictors × measures), and odds ratios (OR) with 95% CIs for each predictor and adaptation measure. Significance markers appended to OR use *q*: * $q < .05$, ** $q < .01$, *** $q < .001$. † indicates OR< 1 (protective association). Households reporting "already adopted" are excluded. VIF checks indicated no multicollinearity concerns (all VIF < 5).
(XLSX)

S3 Table. Full logistic regression results (Wave 2023). Columns as in S2 Table. Stars reflect FDR significance within 2023; † marks protective associations (OR< 1).
(XLSX)

S4 Table. Robustness of key predictor effects to responsibility perception operationalisation (Wave-2023). Cell values show the number of structural measures (out of 6) for which each predictor was significant ($q < .05$). Consistency across columns indicates robustness to the harmonisation method. Default = 5-category ordinal (50% threshold); Binary = government-dominant vs. individual-dominant; Continuous = raw government share (0–100%); Excluded = responsibility omitted from model. Self-efficacy and flood worry show consistent significance across all operationalisations, confirming that core PMT findings are robust to the responsibility harmonisation approach.
(XLSX)

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