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High water, high stakes: A global review of flood risk and housing price effects

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ABSTRACT

Flooding is becoming more frequent and severe in urban areas under climate change, with profound implications for the real estate markets. Understanding how flood risk is priced in housing markets—particularly how public hazard information influences buyer behavior—is essential for hazard risk management and has therefore gained increasing attention. This review synthesizes the global empirical research to conceptualize flood risk pricing dynamics. We identify five key risk signals affecting property values, distinguishing between institutional signals (e.g., regulatory maps, insurance premiums) and societal signals (e.g., past flood events, perceived security from protective measures, and fears linked to sea-level rise). While existing studies generally agree on the price effects of these risk signals, variations exist due to varying regulatory and market contexts across locations. These risk signals are also typically considered in isolation; however, we argue that these signals function as an interconnected system, where shifts in one can dynamically influence others and, in turn, market behavior. This review underscores the need to move beyond analyzing individual risk signals and instead consider their interplay within a systems-based approach, offering new insights into how institutional and societal signals can be leveraged for more effective flood risk management.

1. Introduction

Flooding is among the most frequent and costliest global natural hazards. While it is caused by a natural phenomenon that plays an essential role in the Earth's hydrological cycle, flooding occurs in undesirable places and unexpected ways, causing damage to assets and disturbance to human societies. Despite efforts to manage floods, the economic losses from flood events keep escalating [1]. A recent report from Munich Re (2024), states that flood and storm surge-related losses in the last five years averaged USD 320 billion, of which roughly USD 56 billion was insured.

Apart from climate change leading to more frequent and intense flooding and cyclone-associated storm surge [2], a key reason for increased damage is the ongoing need for new residential housing, some of which may either be located in risky areas or, via the cumulative effects of urbanisation, contributing to a growing risk elsewhere [3–5]. While there are formal regulatory tools available to lessen the risk from new development, such as flood hazard zoning, in many countries, there are also calls for planning deregulation and faster or permissive planning processes to help stimulate economic growth and investment [6,7].

Post-development flood risk is transferred not only to insurance companies or homeowners [8]; but, given the scale of many events

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and the need for state assistance or buyouts, there are also potential economic liabilities for governments and current and future taxpayers. While traditional views often focus on whether risk is capitalized into property markets, this paper emphasizes that capitalization critically depends on whether and how risk is communicated with both regulatory and non-regulatory processes, rather than simply on its existence. It is because imperfect flood risk information will lead to misguided risk management behaviour, market failures, and inappropriate development in flood-prone places. Therefore, this paper explores not just the presence of hazard risk, but the role of information, occurrence of hazard and experience of hazard, all of which shape market responses and exposure. To better understand risk in residential housing, academic attention is broadening beyond a focus on traditional regulatory processes to also consider the wider variety of signals and mechanisms that can affect prices and shape markets [9,10]. More formal risk signals include regulatory flood maps, mandated flood insurance, and other official property- or location-specific flood risk information embedded

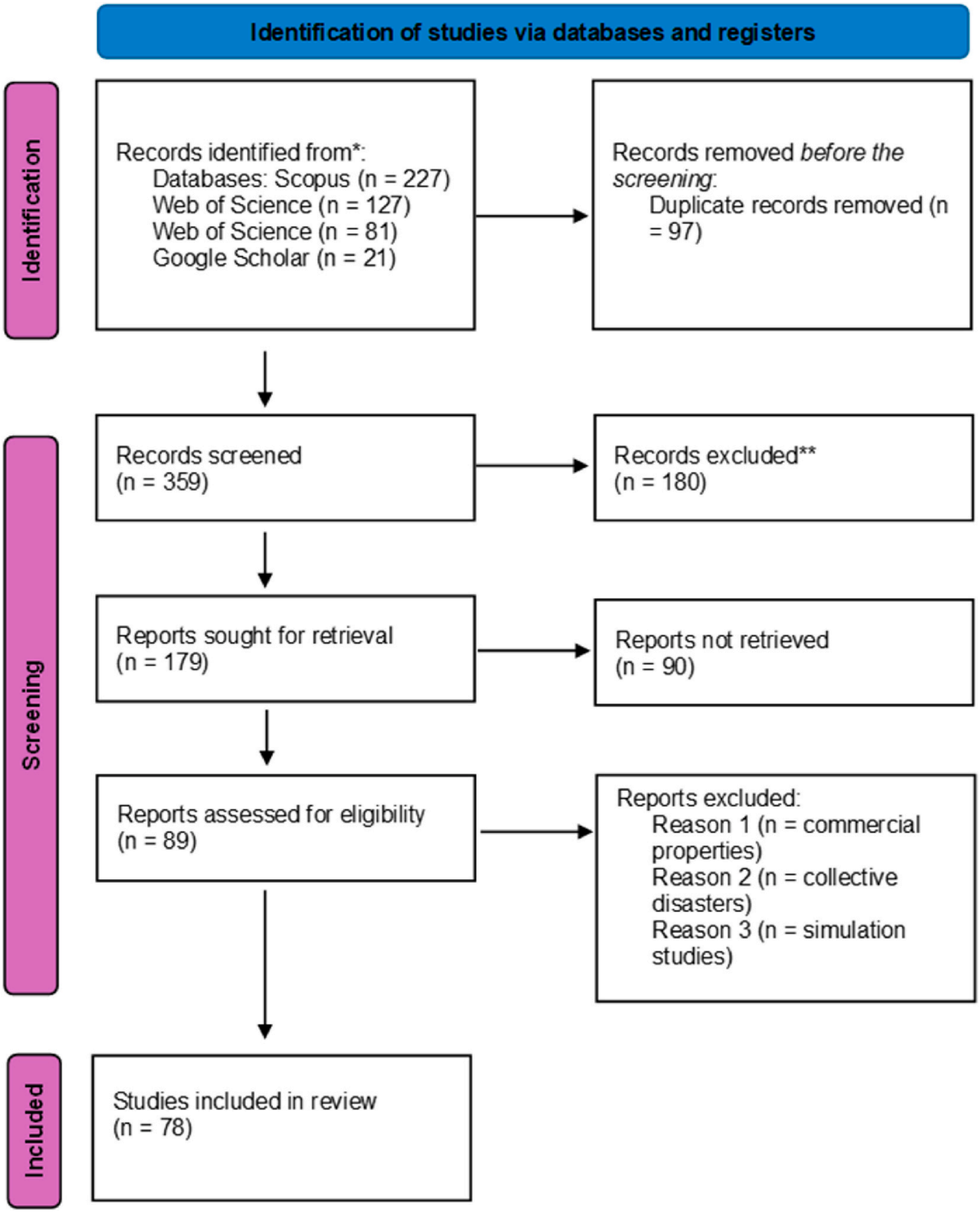

Fig. 1. Selection of Studies Using the PRISMA Method: A systematic approach to identifying, screening, and including relevant studies in literature reviews and meta-analyses.

within institutional flood risk governance. These signals are typically integrated into institutional, policy, or legal frameworks, making them a fundamental part of national flood risk management and land use regulation [11]. Non-institutional risk signals—shaped by societal beliefs and risk perceptions—also influence housing markets. These include past experiences with flood events, belief in climate change, perceived safety due to investments in protective infrastructure, and public risk literacy.

Theoretically, in an efficient housing market that incorporates knowledge of flood risk, property values in riskier areas should reflect the potential to flood and be less attractive for developers or home buyers compared to other areas, resulting in associated pricing discounts. However, the extent to which this occurs is unclear. For example, the market often reflects a trade-off between coastal amenities and flood risk, which is not an anomaly given the high demand for waterfront properties and may even indicate that the market is functioning as expected. However, even when risk information is available, its influence may be limited if the perceived benefits of coastal living outweigh concerns about long-term risk [12–15]. This suggests that the market may not fully respond to or internalize risk information and could even overvalue property prices, raising equity concerns [16,17]. Given this context, the aim of this research is threefold. First, to capture and categorise the complex mix of institutional and societal mechanisms that have been identified as influencing residential house prices. Second, to benchmark and compare existing empirical evidence on the effects of each mechanism. Third, to identify key messages for policymakers and researchers to consider.

2. Methods

We conducted a systematic review to identify and synthesise the information within the research area. Our first step entailed an exhaustive search of the literature using specified search terms. An initial search in the Scopus database using "price effects" OR "real estate" OR "market dynamics" AND "flood" OR "sea level rise" was conducted, which yielded 227 results. Subsequently, a second search was performed in the Web of Science database using the terms "flood," "real estate," and "price," producing 127 outputs. To broaden the search results, a third search was conducted on the Web of Science using "flood," "property," and "sale." Furthermore, a selection of articles was included from Google Scholar.

The PRISMA method [18,19] in Fig. 1 was employed to further select and streamline the studies to be included in the review. Once collated, the second step entailed removing duplicates, before titles, abstracts, and author information were extracted. The first author initially screened 359 records. The general criteria for this screening were studies on floods and housing market dynamics. To provide a clear focus, studies were excluded for several reasons. First, technical studies that focused on modelling flood risks/sea-level rise or simulations. Second, studies that examined how water bodies, such as lakes, affect property values from an amenity perspective. We also excluded articles on adaptation and risk mitigation strategies, such as managed retreats or response to floods.

If a criterion was not met directly, but the study was in a similar context, the abstract was set aside for further evaluation. After the

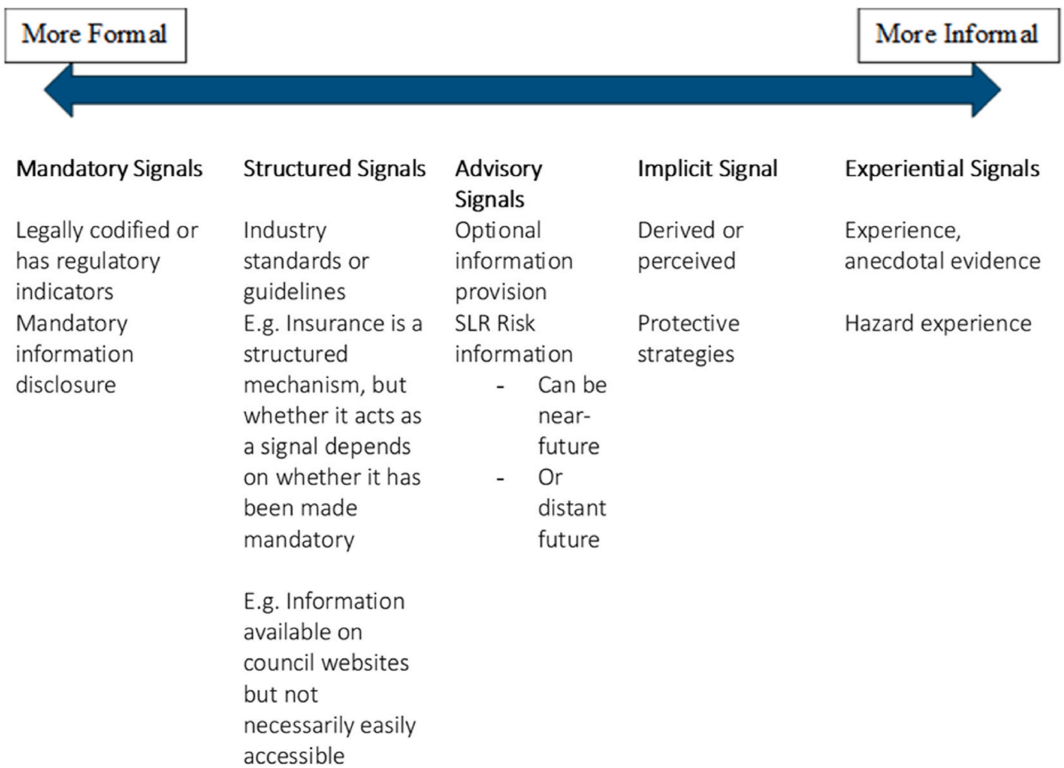

Fig. 2. The spectrum of Housing Price Risk Signals from Formal to Informal Indicators.

initial screening, 180 records were excluded, leaving 179 records for preliminary assessment. Articles that discussed risk from the perspectives of lenders, developers, or politicians—such as climate model risk assessments, bankruptcy filings due to hazard events and tax increment financing—were excluded, as they did not directly evaluate the impacts on residential housing prices. Additionally, articles regarding the effects of climate change on developers, overall real estate markets, or economic crises were excluded. After this step, 90 further reports were omitted, and the remaining 89 were retrieved with full text extracted.

The articles were then scrutinised for eligibility from the full text. One of the main inclusion criteria was that the studies should focus on the residential housing market; therefore, studies focusing on commercial real estate were excluded. The second eligibility criterion focused on identifying empirical studies rather than theoretical or simulation-based approaches. And thirdly, we focussed on studies based on floods and storm surges associated with cyclones. Therefore, studies that looked at collective disasters, such as fires, wind, and floods, or those that looked at other disasters, such as land liquefaction, were excluded. All authors agreed with the 78 studies to be included in the final review.

3. Results

3.1. Categorisation and context

The analysis involved identifying, categorising and analysing the range of mechanisms by which researchers identify how flood risk information can influence house pricing. To provide clarity between research themes, we have categorised these into five risk signals, as shown in Fig. 2, depicted on a notional continuum from formal (institutional) to informal (societal). It should be noted that these are not hard and fast lines but more a way to conceptualize research to date and structure the following data. In the context of flood risk in the residential sector, mandatory signals pertain to those that are mandated or legally codified. This could be a legal obligation to disclose flood risk information before house sales. Structured signals pertain to those enforced by an institution that meets industry guidelines but is not necessarily fully mandated or required by law. Examples include insurance signals or information on council websites or zoning regulations. Advisory signals, while structured and somewhat formal are not strictly enforced and are only used for informational purposes such as information pertaining to SLR. Implicit signals are those derived by the people themselves, these should be large protective structures and resilient strategies. Experiential Signals, similar to implicit signals, result after a direct experience or through anecdotal evidence. The experience of a hazard event can lead to discounts of up to 20 % or more on the informal side of the spectrum. In contrast, on the formal and semi-formal side, zoning information typically yields discounts ranging from 5 % to 15 %, while changes in insurance premiums can cause a discount of about 5 %. Additionally, discounts associated with sea level rise-related information are generally low and, in some instances, are not even capitalized even though they lie on the formal side of the spectrum. Protective strategies, especially larger scales, tend to create a sense of safety and generate a price appreciation of around 10 %. Importantly, even though a signal may be formalized, it does not generate the largest discounts; rather, those are predominantly derived from firsthand experience of a disaster, which may be considered informal in nature or the perceived sense of safety due to

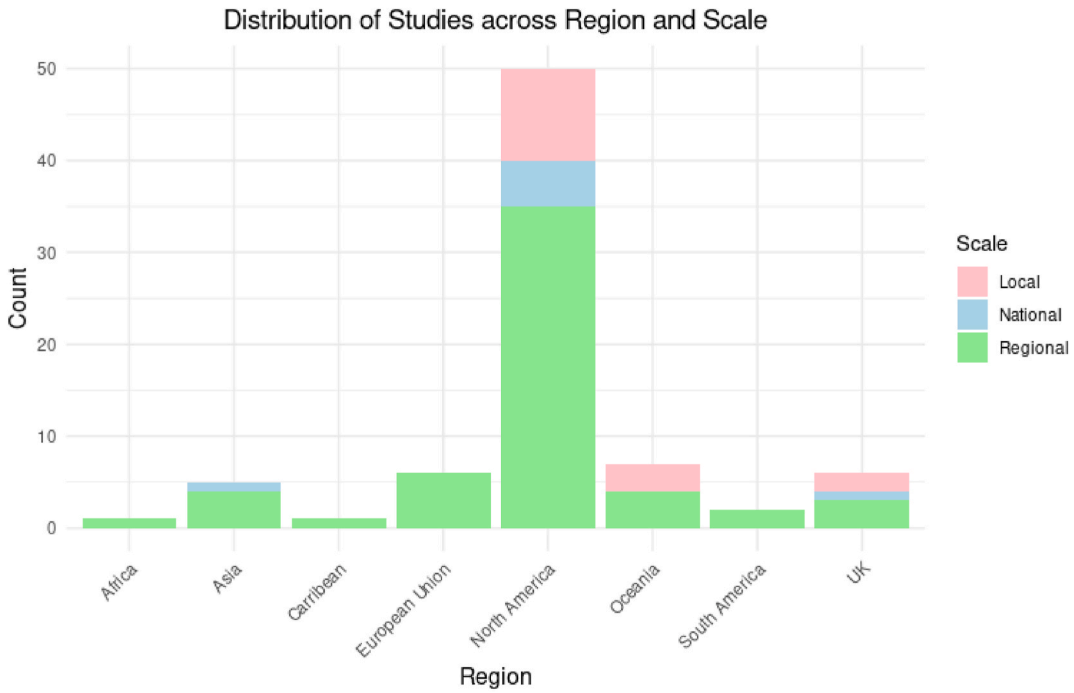

Fig. 3. Global study Distribution on Flood risk and housing prices.

large structures. This indicates that human consumer behaviour and how they perceive risk is extremely important in understanding price changes.

Most of the studies in our sample are based in the US, with fewer than ten studies each from other regions of the world (Fig. 3). These studies were conducted at varying geographical scales, with the majority (~69 %) focusing on regional scales (Ortega & Taşpınar, 2018; [20]) as well as local levels, such as studies by Blackwell et al. [21]; MONTZ [22]. Some studies reflected research which was conducted at a nationwide scale [23,24].

A large majority of the studies employed an econometric framework, specifically a hedonic price model, to understand the effects of flood risk and information on price dynamics in the housing sector. Researchers commonly utilised three main analytical approaches within this framework: cross-sectional analysis, difference-in-difference (DID), and repeat-sales models. Among these methodologies, nearly 38 % of the studies employed the DID approach [20,25,26], while a noteworthy 42 % opted for cross-sectional analysis [27,28], and select few used the repeat-sales or panel estimate method [29,30]. The methods were designed to understand the specific nuances and address any biases that might have arisen due to spatial variations, temporal changes, and the age of the properties examined. Next, we summarise the findings according to the five main risk signals that researchers have analysed.

3.2. Synthesized findings based on risk signals

3.2.1. Zoning and mandatory property risk disclosure

Under this risk signal, we reviewed studies that investigated house prices based on mandatory regulation, typically zoning or property level disclosure, including some boundary effects, i.e. (flood zone versus nearby non-flood zone). The idea of boundary effects or zones is established through regulatory maps that provide information on flood risk, administered by the government, local councils, or paid websites within the private sector. Among the reviewed studies, the most commonly studied flood risk category is the 1-in-100-year flood event, or 1 % annual exceedance probability (AEP), with a few studies focusing on rarer events, such as the 1-in-500-year [31] or 1-in-1000-year flood events [20].

The consensus of existing studies is that homes in flood zones experience greater price discounts than those in non-flood zones. The forest plot below summarises the discounts observed in different regions worldwide (Fig. 4). In North America, property discounts

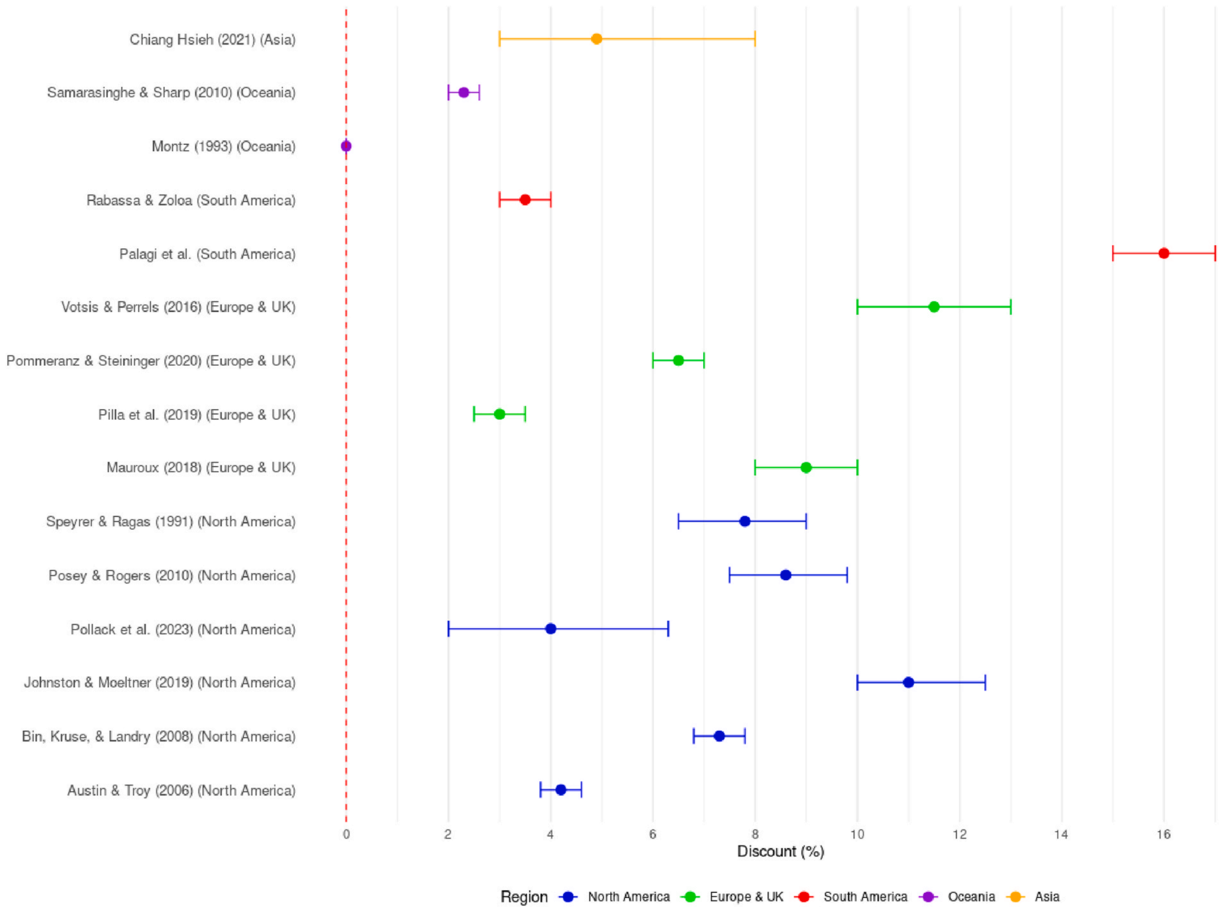

Fig. 4. Forest plot of price effect (discounts) in different regions of the world for 1-in-100-year Flood risk.

range up to 11 %, and in some cases, price appreciation has been reported [32]. The European and UK studies predominantly examine 100-year flood zones, with discounts ranging from 3 % to 13 %. South America reports the most extensive range of discounts varying from 3.5 % to 16 %, likely due to only having a few studies. Asia and Oceania, on the other hand, have reported minimal to moderate discounts, typically below 8 %. Most studies report that as the probability of flooding decreases, so does the price discount relative to the 100-year flood events [20,25,31,33].

In the US, where most of these studies are based, the large variations in discount values attributed to flood risk information are closely tied to differing regulations governing disclosure. While the initial National Flood Insurance Program (NFIP) mandated flood disclosure and insurance for properties located in Special Flood Hazard Areas (SFHAs), varying laws and inconsistent implementation across states and localities have further exacerbated information asymmetry. For example, the impact of California's AB1195 law, which required sellers to disclose relevant information prior to closing the home sale, resulted in more significant discounts compared to the original NFIP program [34]. Pollack et al. [24] also showed that homes in states with mandatory disclosure experience a higher average discount (6.3 %) than those in non-disclosure states (2.4 %). Another nationwide study in the US showed that in states with the most stringent and comprehensive form of disclosure requirements—such as revealing floodplain location, prior flood damage, and flood insurance information—the estimated flood zone discount noted was 4.1 %, which surpassed the nationwide average discount of 2.2 % (Hino & Burke, 2020). Furthermore, other indicators in the US, such as population growth in non-floodplain towns, revealed some risk capitalisation attributed to NFIP and related reforms [35]. These examples indicate how markets can be affected by regulatory weakness and strength, and the interplay between zoning as a blunt instrument and the more specific property level information.

Analysis outside of North America reveals diverse findings regarding the impact of flood risk information on property values in flood-prone areas. For instance, in North Shore City, New Zealand, it was reported that properties in established flood zones sold at a discount; however, disclosure of the flood risk map led to a reduction in the discount, likely due to an adjustment in buyers' risk perception [36]. Other factors, such as house characteristics and the number of days a property remains on the market, are more influential in explaining price differences [37]. Similarly, in Taiwan [38] and France [39], it was observed that if house prices were low to start with, the risk disclosure information did not significantly impact the prices. This brings to light the assumption of perfect information that buyers may have had access to prior to disclosure. However, other likely reasons could be low comprehensibility of the technical information contained or access to this information at a much later stage in the property purchase process [39]. Contrary to common assumptions, Both Montz [37] and Chiang Hsieh [38] emphasised that disclosure does not necessarily disrupt the market's current state.

Furthermore, while studies highlight and report discounts associated with properties located in flood zones [25,40], others have emphasised that boundary conditions in relation to flood risk are blurry. For example, the common notion is that being inside a flood zone is risky while being out of the flood zone is not. Zhang and Leonard [41], find that properties just outside the floodplain may still be perceived as having some flood risk, leading to more minor price differences compared to properties within the floodplain. In contrast, properties farther away (1000–1500 feet) are considered safer, resulting in larger price premiums due to declining risk perceptions and increasing distance from the hazard zone. In Germany, the presence of discounts not directly in flood zones but in the neighbouring locations also alludes to the imperfect nature of the boundary conditions and risk salience outside of zones [42]. Although considered a risk, properties situated closer to the shore despite being located in the flood zone frequently experience an increase in value due to high amenities [24,26,32,42,43]. This suggests that flood risk should not be perceived as a firm boundary condition but as a more nuanced distance gradient based on other local geography, including amenity provision.

Table 1
Global Perspectives on Insurance Policy Offerings: Analysing how insurance products and coverage vary across regions, reflecting local risk profiles and regulatory environments.

Country	Flood Insurance Offering	Details
United States	National	- Required if financed by a mortgage provided by the federal government [51].
Jamaica	Private	- Requirement of mortgage institutions [75].
United Kingdom	Private but since 2007 has been offered through National scheme (not compulsory)	- Part of general property insurance (Lamond, 2007); - Since 2007, Flood Re, a subsidised government initiative, was created (Penning-Rowsell, 2015) - Some mortgage lenders may need comprehensive insurance [29]
Japan	Private	- No national flood insurance program - Bundled with fire insurance and required by landlords and banks. - Risk-based pricing started from 2024 (Wolf & Takeuchi, 2022)
Germany	Private (voluntary)	- Bundled with other disaster coverage [42]
Canada	Private (Voluntary)	- Overland insurance availability began in 2015 [44] - Has limited availability
Australia	Private (Voluntary)	- National Flood Insurance Database exists but is not publicly accessible - Coverage varies widely among states ([58]; Lamond et al., 2019). - Rainwater runoff and storm surge may be excluded without flood cover
New Zealand	Private (Voluntary)	- Basic coverage with other hazards [28]
Argentina	Limited or no availability	- Flood insurance is generally unavailable (Rabassa & Zoloa, 2016)
Taiwan	Limited or no availability	- Flood insurance is generally unavailable [38]
Brazil	Limited	- Insurance in some areas does not cover flood effects or rehabilitation costs (Stumpf et al., 2014)

As such, the cross-sectional approach used for disentangling price effects and comparing property in and out of flood zones homogenously, is often criticised. The repeat-sales approach entails tracking the same property over time, while the DID approach aims to capture the impact before and after an event. A comparison conducted in the US indicated that the repeat panel estimate reveals a −2.1 % floodplain discount, while the Difference-in-Difference estimate shows a −1.4 % discount, and the cross-sectional estimate indicates a +1.7 % increase (Hino & Burke, 2020). Therefore, studies focusing on the risk at a gradient distance from flood zones are deemed more suitable [43].

Furthermore, in terms of data requirements, we find that studies have used a combination of listing price data, while some have used the data post-completion of sales. If the data analysed are based on asking prices rather than final contract prices, this shows a discrepancy in "willingness to demand" rather than "willingness to pay" [43]. Contrastingly, one study reported that discounts are larger for the 'sold' than the 'for sale' sample, which indicates that homebuyers are aware of high-risk flood areas [44].

3.2.2. Insurance signals

Seventeen studies were analysed under the insurance premium risk signal in our sample. It should be noted that it is difficult to integrate or compare international data as the structure of the insurance sector and markets relating to hazard zoning and hazard events vary significantly across regions and countries. Table 1 below provides summaries of insurance offerings in selected countries to help contextualise our discussions of results and comparisons between countries in the reviewed articles.

In the US, studies identified the key role of the insurance sector in addressing flood risks [45], emphasising the importance of insurance premiums in signalling risk and influencing buyer behaviour. For instance, it has been noted that insurance policy take-up increases for disaster-affected properties even if they are not located in flood zones [46]. Stable participation in the National Flood Insurance Program provides a buffer against sharp declines in property values, likely due to better risk management and an increase in public confidence [47].

Updating flood maps to accurately reflect current and actual risks in an efficiently operating market should have price effects on insurance. However, updating the risks could have implications for the insurance sector through changes in the floodplain boundaries and insurance premiums. For example, properties reclassified from out to in the zone may have higher insurance premiums, while those classified from in to out of the zone may see an increase in housing price due to lower perceived risks [48].

Reforms could also lead to higher insurance premiums and create issues of accessibility and affordability and increased excess or under insurance. For instance in insurance reforms led to a 14.3 % relative increase in the price of flood insurance, an 8.2 % decrease in insurance demand, a 4.2 % decrease in property prices and a 2.3 % decrease in property transaction volumes [49]. A drop in insurance coverage will leave many vulnerable to the financial burdens of flooding and become counterproductive [49]. Government intervention to subsidise the premiums can result in market imbalances and give home buyers a distorted picture of risk [50–52]. Conversely, if the government does not intervene, the high risks and insurance premiums will be reflected in decreased house prices [51,53]. The Biggert Water Act in the US removed subsidies, which increased insurance premiums and, in turn, discounted house prices [45]. While a discount is achieved, the discount is often less than the cost of future flood insurance premiums [54]. Interestingly, there are also instances where insurance policies come with financial coverage for repairs, and the resulting repairs improve the house, thus increasing its value (Nyce, 2015).

Findings from other international contexts reveal that insurance coverage is generally limited, is not mandatory, and is sometimes not well standardised. Therefore, in these countries, insurance may not serve as a suitable mechanism for signalling risks to buyers. For

Table 2
Findings of studies to account for future SLR-related flooding.

Author and Year	Region	SLR Projection and Horizon	SLR Priced
[60]	Africa	2100	Yes/marginal
[23]	North America	2100 Low Scenario: 30 cm Intermediate Scenario: 1 m Extreme Scenario: 2.5 m	No
[56]	North America	2100: Below 2 ft 2 – 3 ft Above 3 ft	Yes
[57]	North America	2100	Yes
	North America	2100: 1–6 ft	Yes
(Bernstein et al., 2019)	North America	78–122 years: One foot of SLR: 78 years. 2–3 feet of SLR: Within 80 years. 4–5 feet of SLR: After 101 years. Six feet of SLR: After 122 years.	Mixed
[58]	Oceania	2030–0.08–0.17 m (under RCP 8.5) 2050–0.25 – 0.54 m (under RCP 8.5) 2090–0.45–0.82 m (under RCP 8.5) 2100–0.61–1.1 m (under RCP 8.5)	No
[59]	Oceania	50 year 100 year	No

instance, in the UK and Canada, studies have shown that separating the effect of actual flood damages or updated risk information from changes in insurance premiums is not enough for market participants to accurately assess flood risk and the expected losses [44]. In some cases, the cost of offering full risk-based flood insurance, which provides complete coverage for replacing a median-priced house, is so high that insurers find it impractical and instead only offer partial coverage. When insurance coverage is limited, homeowners often rely on government relief programs. This reliance on relief provided by the government may lead buyers and sellers to overlook flood insurance and risk information in property transactions [42,44]. In countries where the discount is noted concerning insurance, yet with the different insurance options and discount rates, it is difficult to determine if the average house discount truly represents the insurance cost and associated damage if it were to occur [28]. Importantly, even if insurance were to become an indicator of risks further down the track, in high-risk areas, it may simply become unaffordable and not easily accessible.

3.2.3. *Future flooding associated with sea-level rise*

In our sample study, eight studies have attempted to explore the impacts of long-term climate-related sea level rise (SLR) and flooding. Most of these relatively recent studies were published in the early 2020s. The SLR horizon period ranged from 2030 to 2100. The horizon period gives insight into whether the risks are for near-future or distant-future events. There is a lack of conclusive evidence regarding whether and to what extent future sea level rise and climate change are being considered in the housing market (Table 2).

Studies from various US regions, including South Florida, Georgia, and Hawaii, demonstrated that coastal property values generally reflected risks associated with future SLR, though the degree of price discount varies by inundation level [55–57]. Several studies identified distance and elevation as key variables in their analysis ([56,58]; Bernstein et al., 2019; [57]). Conversely, Murfin and Spiegel [23] separated the sensitivity of housing to rising seas from other confounding characteristics, such as elevation differences. They focused on vertical land motion and found no price discount. In other international contexts, such as Australia and New Zealand, SLR risks are generally not reflected in property prices [58,59]. Similarly, coastal properties near environmental amenities (e.g., ocean views) in Lagos, Nigeria, retain premium value despite SLR exposure [60]. One of the reasons attributed to discounts and cases of non-discounts is due to buyer or investor sophistication influencing the market, with non-owner-occupied homes reflecting discounts in the absence of clear and comprehensive information about sea level rise available to home purchasers. Seasonal residents might value proximity to the ocean but not necessarily oceanfront properties, a topic requiring further research [61]. Secondly, most homeowners see SLR as a distant future problem as, on average, buyers spend 6 years in a house. Buyers perceive the lack of immediate, visible impacts as less risky [60]. Therefore, how SLR information is communicated to the public, particularly the projection horizon, may impact how well this information is reflected in house prices. Some studies have attempt to measure the effect of current or future flood risk on property values without taking into account whether properties are inside an SFHA (which already influences prices), therefore, their estimates for SLR related price effects may be biased [24]. Additionally, most studies have focused on complete inundation scenarios based on sea-level rise projections. However, one study (Tarui et al., 2023) has highlighted the issue of seasonal flooding due to high wave action. This study found that while the risk associated with chronic sea-level rise (SLR) is reflected in housing markets, the risks from seasonal or tidal flooding are not necessarily accounted for. This indicates a significant research gap. Firstly, there is an overemphasis on instances of complete inundation, which are less likely to occur in the near term and have a lower probability. In contrast, the likelihood of tidal-related flooding, especially when considering relative sea-level rise, elevation and vertical land movement, is more imminent. Despite this, the risks associated with tidal flooding are not adequately considered, nor are they factored into housing prices.

3.2.4. *Protective infrastructure or resilience strategies*

We analysed eleven papers on the protective strategy risk signal. We defined protective strategies as those that involve any form of construction or building alteration designed to mitigate the effects of floods. These measures can be divided into large-scale and small-scale constructions. Large-scale constructions refer to significant hard structures or green infrastructure for flood defence. All studies examining large-scale structures report price appreciation ranging from 9 % to 20 % (Kim, 2020; Wolf & Takeuchi, 2018; [62]), except for one study that noted discounts despite the presence of protective measures [27]. Large-scale structures, such as dams, act as a collective defence strategy and can enhance safety perceptions among homebuyers, leading to price increases (Kim, 2020; Wolf & Takeuchi, 2022). A single large project can protect multiple properties and create positive spillover effects. However, there are potential downsides, such as climate gentrification, which may displace low-income residents to less protected areas [62]. The benefits of these projects also tend to decrease with distance from the structure and as time progresses [30,62].

Small-scale constructions involve changes or considerations in the built structure, such as considering building height, floor height, or elevation. The government can often formalise these, such as implementing minimum floor heights or building codes in areas prone to flood risk. Small-scale construction, such as building elevation, flood resistance, or resilience technology, is a more individualistic protective strategy against flooding, but its effectiveness is uncertain [63]. The results for this cohort are somewhat mixed, depending on how the studies are interpreted. For instance, properties at an elevation are positively correlated with price appreciation [64]. However, introducing base building elevation levels [65] or reinforcing minimum floor level requirements (Nguyen, 2022), which create specific zoning or boundary effects similar to flood zones versus non-flood zones, can lead to price discounts. This sheds light on the importance of distinguishing homes by elevation or considering the flood risk information in a multi-dimensional way instead of the binary thinking of mere categorisation in flood zones or out of non-flood zones. Homes distinguished by elevation reveal that buyers may be willing to pay more for elevated properties, regardless of their location in flood zones [66]. This also challenges the assumption that all properties in a flood zone face identical risks. However, this may not hold true, at least momentarily, in the aftermath of a disaster; for example, Blackwell et al. [21] found that homes elevated above flood levels often experience price discounts equal to or greater than those of non-elevated homes following a flood.

3.2.5. Hazard experience

This risk signal pertains to the occurrence of a flood or cyclonic event and its impact on the housing market. This is complex, however. Numerous studies have attempted to understand whether the price effects are due to risk information disclosures or the occurrence of actual hazard events, such as floods or storm surges associated with cyclones/hurricanes. Additionally, some research has focused on the exclusive effect of a hazard event on house prices without necessarily looking at the impacts of information disclosure.

Many studies reviewed concentrated on the impact of flood hazards on house prices. These studies often highlight a significant discrepancy between pre-flood risk perceptions and the reality of risk following a flood event. Substantial declines in property prices have been recorded after such events [67–69]. Similar results have been reported in studies investigating the effects of hurricanes. For instance, research on storm surge associated with hurricanes indicates that properties tend to sell at a premium either before a hurricane [50] or during a period of inactivity [70]; however, following hurricanes, properties often experience a discount ranging from 5 % to 15 % [71].

Comparative studies on whether the informational disclosure drives the price change or the occurrence of hazard events reveal that the impact of information disclosure can often be minimal or even insignificant in some cases [27] and can vary between low and high-risk areas [40]. However, the occurrence of an actual flood or hurricane event tends to drive the most considerable price discounts [41,48,72,73]. This indicates that buyers associate the occurrence of a hazard as an actual risk, and risk associated with the information (hazard zone) is considered a 'perceived risk'. There are exceptions noted in developing countries. For example, in Thailand, no significant impact of flooding on residential land prices was observed [74]. Similarly, apartment sale prices in Jamaica decreased due to hurricanes but increased in response to excessive rain. Nonetheless, residential land prices remained unaffected by both events [75]. Market inefficiencies can significantly influence real estate prices in some countries. In Jamaica, increased apartment prices after extreme rainfall were attributed to reduced housing availability, which gave sellers leverage as adverse conditions deter buyer negotiations. In Thailand, residential land prices remain stable despite flood damage due to limited liquidity and transactional difficulties that prevent immediate price adjustments.

Most studies indicate a high degree of variation in results due to temporal, spatial and hazard-specific factors. In terms of temporal variation, several studies have indicated that the discounts observed are highest immediately after the disaster, and this is often temporary and demonstrates a decaying effect (Atreya et al., 2013; [70]; Lamond et al., 2010; Saginor, 2016). However, different resurgence times have been reported, between 2 and 9 years ([76]; Atreya et al., 2013; [28]). The recovery of price is also affected by the socio-economic fabrics within the economy. Beltran et al., 2019 reports that while properties at both high and low sale price points incur discounts, properties in the highest price range recover much more quickly. Similarly, higher-income areas displayed faster recovery, whereas lower-income neighbourhoods faced prolonged declines [77].

The duration of the sales data used in the analysis is crucial for the temporal variation associated with hazard events. Most studies (58 %) have utilised less than 10 years of data, while nearly 36 % examine around 20 years. Only a small fraction, 6 %, of studies leverage more than 20 years of data. As such, the temporal impact associated with discount and the time to resurgence may not be fully captured with a shorter data period.

The results also show that nuances are related to spatial and contextual factors. For instance, the price discount varies based on whether the properties were inundated or not, irrespective of the flood zone designations (Yi & Choi, 2019); in some cases, differences can be attributed to whether the flood was an inland, coastal or a river flood whereby lower discounts in properties subjected to inland flood versus coastal flood are observed [41,58]. Additionally, even if properties may get flooded, if they are situated in coastal property areas, they recover more quickly than their non-flooded inland property counterparts, likely due to the coastline acting as an amenity [29]. These findings underscore the complex interplay of risks and the space-related factors that affect property prices.

The characteristics related to hazard event, such as frequency and intensity, have a noted price effect, leading to varying findings among studies. Economic recovery varies in relation to flood depth across the floodplain [22,78–80]. In relation to the frequency of hazards, an initial shock flood event may register the highest decrease in property values [61]. However, subsequent floods might have minimal effect on prices once initial discounts have been recorded. In contrast, other research points to a relationship between repeated consecutive floods resulting in consistent price discounts, which tend to remain low ([31]; Lamond et al., 2010; Leonard & Zhang, 2018; [68]).Some papers also allude that it is not just a mere occurrence of hazards, but the visual property damage is increasingly recognised as a significant indicator of market impact [40,46,75,81]. However, the persistence of price declines outside flood zones and in instances of non-destructive indirect events suggests that new risk information, rather than just physical damage, influences market corrections [77,82]

4. Discussion and concluding remarks

This review highlights the complex and multifaceted nature of flood risk pricing in the global housing market. Our findings indicate that globally, flood risk is generally capitalized in residential house markets, yet to widely varying degrees. The mechanisms by which flood risk signals are priced in these markets also vary, occurring through five distinct yet interconnected pathways: risk disclosure, hazard event experience, insurance premium signals, protective strategies, and future flooding associated with sea-level rise. From our analysis, we observed that boundary effects—established through the guidelines provided by regulatory flood maps (i.e., inside or outside of flood zone)—paired with individuals' direct experiences of hazard events — emerged as having the most critical impact on housing prices and serving as an essential risk signal. Furthermore, the fluctuations in insurance premiums also represent a significant risk signal that impacts prospective home buyer decisions. In addition to these signals, protective structures and structural adjustments also influence the public's perception of risk, affecting how risk is priced in the market. Only a handful of studies have specifically focused on the explicit understanding of risk by the general public and the broader impacts of climate change as early indicators of escalating flood risks in the future.

The results are highly heterogeneous, suggesting that the relationship between flood risk and residential house prices is not uniform across different contexts. This underscores the importance of adopting systems thinking and employing a structured lens to examine the nuanced ways in which flood risks cascade through residential property markets. In the following, we elaborate on these key findings and derive their implications for policymaking and future research directions.

4.1. Varying contexts and risk management frameworks

The synthesis of empirical studies highlights the differing contexts and frameworks in which various flood risk signals operate within the housing markets. For example, regulatory flood risk signals are most effective in markets with robust regulatory risk management frameworks, as seen in North America and parts of Europe, while showing limited or no effectiveness in less robust markets such as Oceania and Asia. Similarly, flood insurance acts as a more compelling price signal in countries with robust regulatory frameworks, such as the United States, where flood insurance is regulated by the federal government and mandatory for properties located in the designated flood zones and financed through federally backed mortgages. Conversely, insurance can fail to function effectively as a risk signal, leaving markets vulnerable to under-pricing of flood risk in countries with limited or voluntary insurance coverage, such as Brazil and Argentina. Other price signals, such as direct hazard experience, public risk perception of sea-level rise, and proximity to protective structures, can further complicate the community's perception of flood risk. They, therefore, can significantly alter or amplify the effects of regulatory risk signals.

A one-size-fits-all approach to flood risk communication and regulation is likely to fail. The effectiveness of such an approach is highly dependent on the broader regulatory and institutional context. Generally, strong and consistent regulatory frameworks enhance the impact of risk signals like zoning and insurance on efficient market behaviours and non-regulatory risk signals, such as past flood experiences, perceived sea-level rise, and proximity to protective structures, can either reinforce or distort formal regulatory signals. This underscores the need for risk managers and policymakers to consider how these informal signals interact when designing risk communication and planning interventions, and to tailor strategies to the specific institutional, cultural, and market contexts of each region to ensure risk is appropriately priced and managed.

4.2. Impact of diverse scales and research designs

Existing studies are difficult to compare for deriving consensus findings and transferable lessons due to differing temporal and geographical scales and varying analytical methodologies. The studies are conducted across various local, regional and national scales. Defining the scale across studies is challenging due to differing administrative boundaries in different regions and countries. Consequently, it is difficult to fully interpret the nature of the price discounts and how well these findings can be extrapolated and compared on a broader scale. In addition to the scales, we also find that different methodologies are employed, undermining the comparison between the resultant empirical findings across studies. A comparative analysis of the three methodological approaches showed that repeat panel and difference-in-difference approaches yield similar estimates of the flood zone discount. In contrast, the cross-sectional estimate detected appreciation in flood zone properties [25]. The repeat-panel method entails temporally tracking the same property and can account for time-invariant characteristics, such as amenities associated with being close to the waterfront. The cross-sectional method controls for housing characteristics and analyses properties inside, and outside flood zones, fails to account for endogeneity and heterogeneity, such as how property prices may influence nearby amenities or vice versa and differentiation between areas within a zone (e.g. urban versus rural) [43]. As such, the cross-sectional is not a rigorous approach to causal analysis, which most existing research uses to explore the relationship between flood risk and housing prices. Using the cross-sectional method can yield different results, undermining the validity of such results, particularly for comparison across studies to develop a deeper insight into risk and housing prices. Future research should conduct comprehensive, multi-scale studies that employ longitudinal data and leverage rigorous methods like difference-in-differences or repeat-sale analysis to better capture temporal variations and causal relationships between risk signals and housing prices. However, an important consideration is that while the repeat-sales method is robust, a lack of data may deter the broader adoption of this approach.

Additionally, while hedonic pricing models can capture non-linear relationships based on the way in which the model is specified, they typically only represent consumer behaviour in a static one-dimensional way, which is through direct changes in the house prices. These models have limitations when it comes to exploring how the property prices would change based on occurrence of a hazard event or given that a protective structure is situated and how some of these dynamic factors influence risk perceptions and people's decisions [83]. Even in the best-case scenario, where flood information is provided and mandatory, the model will not function as expected without considering different levels of public risk literacy.

4.3. The need to consider risk signals as part of a system

It is vital to note that risk signals related to flooding do not operate independently; they interact and collectively influence housing prices. However, most existing studies focus on one price signal in isolation while overlooking the dynamic interplay and cumulative effects of multiple risk signals operating concurrently within the housing market. This suggests a pressing need for a systems-based approach that views the housing market holistically. By integrating multiple risk signals, researchers can gain a comprehensive understanding of how these factors dynamically change and influence the housing sector [84,85]. As such, future research should also consider exploring advanced analytical approaches, such as agent-based modelling to investigate the complex interactions between flood risk signals, market dynamics, and community perceptions. We also would like to highlight several underexplored areas around the five identified risk signals that warrants further investigation to fully understand and implement the systems approach.

Firstly, risks associated with future flooding due to climate change are generally under-researched. While we are cognizant that flood risks pertain to more imminent flooding and that sea-level rise due to climate change is a slow process, market signals must also reflect the long-term risks associated with minimising losses [82,86]. There should be a particular focus on the projection horizon to see the response with anticipated near-future and medium-term events. Secondly, even with the growing availability of flood risk information and disclosure—its limited influence on homebuyers suggests a critical gap in risk communication, belief and response [87]. Factors such as further uncertainty regarding flood zone status (Chang et al., 2010), cultural and political affiliations [88], and other social demographic factors such as education and income [23,76] influence risk understanding and buyer decisions [45]. As the field continues to develop, attention should shift toward understanding what influences the heterogeneous nature of risk perception, information comprehension, and buyer behaviour.

Secondly, a hazard event causes the most significant shock and discounts in the housing market. Sales activity typically declines in the immediate aftermath of floods, but recovery patterns vary based on spatiotemporal and socioeconomic factors. Even though hazards cause the most significant discount, they may also lead to increased vulnerability and widening socioeconomic inequality among marginalised groups [89]. In high-risk areas, these would likely be those without sufficient insurance coverage. Notably, the question remains whether cheaper properties are purchased by people who can afford them and whether it results in the risks being transferred and increasing the problem of inequity. For instance, Ellen and Meltzer [77], find that Hurricane Sandy changed the composition of homebuyers in hard-hit regions outside the flood zone, especially low-income ones who were more likely to be Black or Hispanic, giving them more home ownership options, albeit in flood-risk areas. Therefore, the next inquiry phase should aim to uncover how intersecting factors like race, gender, age, and disability shape vulnerability to hazard events through case studies that highlight the diverse experiences of marginalised groups and may also help to understand the information asymmetry problem better [90].

Building upon the findings, the review emphasised that responding to hazards ultimately results in investments in adaptive and/or protective strategies. However, large-scale interventions, such as managed retreat or the construction of physical defence structures, require significant capital investments, which can be cost prohibitive for governments and may not always be feasible. Additionally, the social implications of these strategies, especially with respect to gentrification and social injustice, remain poorly understood. In light of persistent challenges related to inequity, future work could investigate the unintended consequences of large-scale adaptations, as well as explore how small-scale, community-led resilience strategies may be formalized and implemented at scale.

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Anshuka Anshuka: Writing – original draft, Visualization, Validation, Investigation, Formal analysis, Data curation. **Xinyu Fu:** Writing – original draft, Validation, Supervision, Project administration, Methodology, Funding acquisition, Formal analysis, Conceptualization. **Iain White:** Writing – original draft, Supervision, Funding acquisition, Conceptualization.

Declaration of competing interest

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ijdrr.2025.105452.

Data availability

No data was used for the research described in the article.

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