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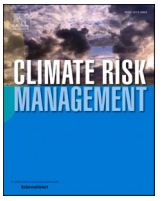

A comparative assessment of accommodation strategies based on elevated buildings for coastal adaptation

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ABSTRACT

Elevating parts or the entirety of the structure of buildings in exposed coastal areas can be an effective way of managing the growing risks associated with climate change and sea level rise. While these accommodation measures are well known, there is little to no research on their role in coastal adaptation policy in Europe or on accommodation taking place at all. A systematic review of grey literature was carried out in metropolitan France, the UK and Ireland to assess the current state of structural accommodation. The analysis shows that although measures such as the raising of floor levels of new developments are common practice as part of property-level resilience and flood risk management on the coasts of the three studied countries, accommodation remains driven by local spatial planning and poorly integrated in overarching adaptation policies. Accommodation is found to be unevenly distributed along the assessed coasts and in many locations is happening in protected or sheltered locations to manage residual risk. Comparisons with the experience from the US – where elevated buildings have been an established strategy for over 50 years – suggest that accommodation could be enhanced by providing guidelines that better account for coastal processes such as the impacts of waves, as well as by promoting financial incentives through subsidies or insurance schemes. National coastal adaptation policies are rapidly evolving in Europe and could benefit from a better understanding of the advantages and limitations of accommodation by elevating buildings.

1. Introduction

Sea level rise (SLR) resulting from climate change represents a major threat to coastal areas and addressing it is a critical societal challenge. While climate mitigation can significantly reduce SLR and its impacts (Nicholls et al., 2018), global-mean sea level is expected to continue to rise beyond the 21st century even under a stable climate (Wong et al., 2014; Oppenheimer et al., 2019; Fox-Kemper et al., 2021). With over one billion people projected to live in exposed low-lying areas below an elevation of 10 m by 2050 (Merkens et al., 2016), there is a growing need for coastal adaptation to flooding that addresses SLR (Cooley et al., 2022). Alongside protect, advance and retreat, accommodation is one of the main adaptation responses available (Dronkers et al., 1990; Oppenheimer et al., 2019).

Several definitions for accommodation exist. The Intergovernmental Panel on Climate Change (IPCC) Special Report on the Ocean

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and Cryosphere in a Changing Climate describes accommodation as "a diverse set of biophysical and institutional responses to mitigate coastal risk and impacts by reducing the vulnerability of coastal residents, human activities, ecosystems and the built environment, thus enabling the habitability of coastal zones despite increasing levels of hazard occurrence" (Oppenheimer et al., 2019). Previous definitions also refer to accommodation as a strategy to increase society's ability to cope with the effects of coastal hazards (Klein et al., 2001), while Nicholls (2018) framed it as an approach where all natural system effects are allowed to occur, and human impacts are minimised by adjusting the human use of the coastal zone. These broad definitions cast a wide net over the types of measures that can be considered as accommodation, including institutional or information options such as early warning systems or insurance schemes (Bongarts Lebbe et al., 2021). In this paper we adopt a more tightly defined definition of accommodation, to distinguish structural measures from information-based strategies, which have received more attention in previous studies (e.g., Hemachandra et al., 2021; Lentini et al., 2023). Here, accommodation refers to methods of reducing the vulnerability of human beings, their livelihoods, and assets (Ara Begum et al., 2022) to coastal flood events by raising the entirety or parts of new or existing buildings.

Elevating houses and structures to vertically avoid coastal flood water is a technique that societies around the world have employed for many centuries/millennia. However, in the modern era, most attention has focused on protect and – to a lesser extent – retreat options (Hino et al., 2017; Nicholls et al., 2019; Lincke and Hinkel, 2021; Sayers et al., 2022). Previous studies in West Africa (Alves et al., 2020; Obi et al., 2021), parts of South-East Asia (Lasage et al., 2014; Prana et al., 2024) and small islands (Magnan et al., 2018) have highlighted that the raising of buildings above coastal floodplains can be carried out by local communities as an informal adaptation strategy, but this generally lacks integration in respective national policies. Accommodation is more widely implemented in the United States, where it is common practice in coastal zones (and in inland floodplains) to elevate buildings above prescribed flood levels (Kennedy et al., 2020; Moeini et al., 2023), using guidelines and building standards from the U.S. Federal Emergency Management Agency (FEMA, 2011). This practise has been institutionalised since the 1970 s as part of the National Flood Insurance Program (NFIP) meaning that there is more than 50 years' experience in carrying out such measures in the U.S.

Structural accommodation measures are also considered in the literature on flood risk mitigation and property-level resilience (e.g., Attems et al., 2020, Fournier et al., 2016). Estimating the costs of different flood mitigation measures, Aerts (2018) found that elevating buildings can be a cost-effective method to reduce flood risk, particularly when implemented during construction. Bailles et al. (2020) found that vulnerability-reducing measures such as elevated buildings on stilts or the suitable position of utilities networks tend to be low regret. Proverbs and Lamond (2017) argued that "avoidance" – which in their definition includes the setting of minimum floor levels for buildings – is generally preferred to other property-level strategies, namely flood resistance (or "water exclusion") and flood resilience (or "water acceptance") and is increasingly recognised as part of a diversified approach to flood risk management in Europe and the United Kingdom. However, structural accommodation – and the elevation of buildings in particular – remains understudied compared to other coastal adaptation strategies with few studies assessing how it is regulated, at what levels of governance it is administered, and the mechanisms through which it is implemented in practice (Galluccio et al., 2024). This research gap is particularly large in Europe with most analysis of accommodation standards, policy and implementation coming from the U.S. (e.g., de Ruig et al., 2020; Erdman et al., 2018). While Haer et al. (2020) considered the role of building elevation in modelling property-level risk and adaptation in Europe, this work was limited to fluvial floods. A complementary review of current coastal practice could contribute to similar modelling efforts of risk and adaptation in coastal settings.

The aim of this study is to provide a current assessment for accommodation in Europe. The primary objective is to improve our understanding of the role of structural accommodation in coastal adaptation strategies, taking France, the United Kingdom (comprising the separate administrations of England, Scotland, Northern Ireland and Wales) and Ireland as case studies. The following key research questions are addressed:

(1) What is the role of structural accommodation in national coastal adaptation strategies?
(2) What measures, if any, are prescribed and at which levels of governance?
(3) How are coastal flood hazards and SLR considered in accommodation policies?

The remainder of this article consists of four sections. The research methods are described in Section 2, followed by findings in each assessed country in Section 3. The analysis of accommodation policy in France, the UK and Ireland is discussed in Section 4, using the experience of the United States as a frame of reference. Finally, the study's wider implications are presented in concluding remarks.

2. Material and methods

With little to no peer reviewed literature existing on structural accommodation policy in Europe, this research relied on grey literature (e.g., government reports, strategy circulars, technical assessments, planning documents). A systematic review of accommodation policy was carried out by defining a structured search plan of grey literature in several steps. For each country, a preliminary scoping of high-level national policy and strategy on coastal adaptation was conducted. The purpose of this first step was to highlight the role, if any, of accommodation in the country's strategy and to identify key related governance actors and tools, as well as the relevant level at which such policies are set.

Urban development planning and flood risk management documents were subsequently targeted in local administrations along the coast of each country. In the UK and Ireland, local authority districts were sampled based on their exposure to coastal and tidal flooding. This was done by selecting districts that either had a coastal boundary or whose administrative boundary intersected with a layer representing the extended coastal floodplain. The extended floodplain is defined as the 100-year floodplain, plus a 2 m allowance for SLR (Fig. 1). The floodplain is computed using extreme sea level from Dullaart et al. (2021) with the Copernicus European Digital

Elevation Model (EU-DEM) version 1.1. Hence this area extends beyond today's floodplain but could be realised by 2100 if high-end SLR scenarios occur (Fox-Kemper et al., 2021, Le Cozannet et al., 2023). The water level heights are derived from the Global Tide and Surge Reanalysis (Muis et al., 2016). Strategic Flood Risk Assessments (SFRA), or equivalent, and Local Development Plans in the UK and Ireland were collected online from Local Planning Authorities and reviewed. In metropolitan France, municipalities with a risk prevention plan were used as an initial subset to assess accommodation measures. Plans on the coast and extended coastal floodplain, which did not specifically consider coastal flooding were discarded, leaving coastal risk prevention plans ("*Plan de Prevention des Risques Littoraux*" – PPRL), which cover flood, erosion and dune migration hazards. The plans and associated documentation were collected from official local government websites. Note that these plans are prescribed to municipalities where flood risks are considered significant, other municipalities located in the floodplain being covered by other regulatory mechanisms such as the Floods Directive. The other tool identified in France for implementing coastal adaptation measures were flood prevention action programs ("*Programme d'Actions de Prévention des Inondations",* PAPI). PAPIs can cover different sources of flooding and were sampled based on the extended coastal floodplain boundary, with technical documents obtained from the European Centre for Flood Risk Prevention and Management (https://cepri.net/rechercher-un-papi). This study is limited to mainland France (and Corsica) and does not consider overseas regions and territories. Previous studies have shown accommodation to be promoted on atolls in French Polynesia for example (Magnan et al., 2022). The reviewed local planning documents in each country are listed in Table 1 and are described in the following sections.

As shown in Table 1, qualitative information was extracted from local planning documents using a set of search terms related to different structural accommodation measures. In cases where the search led to positive results the following data were gathered: the year of publication or approval of the plan or policy, the description of the measure (i.e., the type of measure, the required standard, if it applied to new or existing buildings), and how SLR was considered. An approximate estimation of population affected by local planning regulations on accommodation was determined using 2020 Gridded Population of the World data (CIESIN, 2016). Population below an elevation of 5 m (3 m on the Mediterranean coast) was considered as a rough representation of regional minimum floor level guidelines. In a final step, the collected information was included in a geodatabase (attribute table is available at: https://data.mendeley.com/datasets/svb8nc9b7y/1).

3. Results

Structural accommodation in France, the UK and Ireland is largely driven by the consideration of flood risk and coastal change in spatial planning. In the three countries, for new developments avoidance is the preferred strategy with national policies set to limit development in floodplains. While the priority is to steer new developments away from high flood risk areas, avoidance is also recognised as being possible to achieve vertically. A summary of structural accommodation measures found in local planning documents is shown in Table 2.

When new developments do occur in areas at risk of coastal flooding, guidelines are provided to raise the finished floor levels of

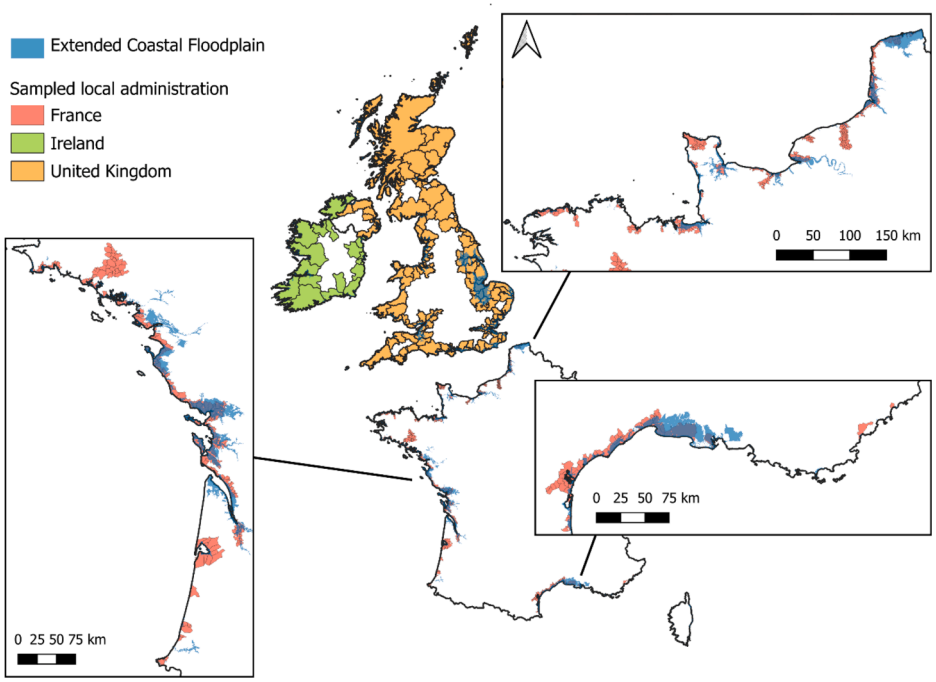

Fig. 1. Selected coastal local administrative boundaries in France (municipalities), the UK (planning authorities) and Ireland (counties).

Table 1
Search terms used to review and assess existing grey literature in France, the UK and Ireland.

Country	Search terms	Document
France (metropolitan only)	• *«Cote/hauteur de plancher»*; *«cote de référence»*; *«niveau des premiers planchers»*; *«bâtiment surélevé »*; *«rehaussement»* • *«espace/zone/étage refuge»*; *«pièce de survie»* • *«mise hors d'eau»*; *«Equipements électriques/sensibles»*	Coastal Risk Prevention Plan (PPRL); Flood Prevention Action Programs (PAPI)
United Kingdom (England, Wales, Scotland, Northern Ireland)	• "Finished floor level"; "raised/elevated floor"; "freeboard"; "voids"; "stilts" • "refuge/shelter area/zone/floor" • "property flood resilience"; "raised electrical equipment/ appliances/ systems"	Strategic Flood Risk Assessment (SFRA); Strategic Flood Consequence Assessment (SFCA); Local Development Plan
Ireland	Same as the UK	Strategic Flood Risk Assessment; Local Development Plan

buildings. A minimum elevation is commonly made up of the combination of a baseline probabilistic extreme sea level, a climate change allowance to account for SLR, and a chosen margin (or "freeboard") for uncertainties. The standard at which each component is defined varies between countries (Fig. 2), including how SLR is represented (Table 3). France and Ireland provide a SLR allowance for 2100 that is applicable nationally, while the UK applies regional SLR targets.

While national guidelines for building elevation are provided by the State (France) and government bodies responsible for managing flood risk or setting national planning policies (UK and Ireland), their application is unevenly distributed within each country and relies on preferences set by urban development plans at the local level. Fig. 3 shows local-level boundaries where urban planning documents (i.e., PPRLs in France, SFRAs or Local Development Plans in the UK and Ireland) provide floor levels to respect. In all three countries, elevating buildings is considered as part of the design of new construction and is not deemed feasible for existing developments. Due to the high costs associated with elevating buildings, property-level flood resilience measures are generally preferred in existing structures, such as moving sensitive equipment to upper floors. Another structural accommodation measure aiming to reduce impacts to inhabitants as opposed to the property is the addition of a refuge area. This approach plays a greater role in coastal risk prevention in France. Specific differences in the prescription of accommodation measures and the interpretation of national policies at the local level are presented for each country in the following subsections.

3.1. France

France's national adaptation plan – which is in its second iteration, with a third version currently in preparation – covers a wide range of impacts of climate change, including shoreline retreat and increasing flood risk, proposing strategies to promote economic resilience (MTES, 2015). France's national integrated strategy for shoreline management encourages local and regional authorities to define coastal adaptation strategies and plans (MEEM, 2017). While this recognises that protection cannot be the only response to better cope with natural hazards within a changing climate, the objectives of the resulting regional plans remain vague on the topic of coastal adaptation and therefore accommodation (Le Cozannet and Cazenave, 2024). The strategy is now supported by recent regulation such as the 2021 law on resilience and climate, which fosters a softer approach toward coastal management. It remains too early to assess the impact of this new legislation. While one of the key principles of this non-binding strategy and resulting plans is to control urban development in coastal areas, for example by ensuring that new developments do not increase vulnerability to coastal risks, the strategy provides greater consideration for other types of coastal adaptation (i.e., protect and retreat).

In parallel, an enforceable regulation on coastal risks that considers adaptation to SLR, including accommodation, has been developed. One of the main objectives of France's national flood risk management strategy is to increase the security of exposed populations (MEDDE, 2014). The flood risk strategy claims that while avoiding developments in flood risk areas is to be prioritised, new construction should be adapted when they are allowed. Structural accommodation measures can contribute to achieving avoidance, prior to the consideration of flood resistance and resilience measures (Fig. 4). At present, the main regulatory tools used by the national government to translate its risk management policy at the local level are natural risk prevention plans ("*Plan de Prévention*

Table 2
The occurrence of recommended or mandatory structural accommodation measures for residential buildings in high flood risk areas in local planning documents.

Country	Number of documents assessed	Structural accommodation measure			
		Raised floor levels	Sacrificial or less vulnerable ground floor	Refuge area	Raised vulnerable systems
France	451	375 (83 %)	0	369 (81 %)	361 (80 %)
England	140	102 (73 %)	59 (42 %)	51 (36 %)	71 (51 %)
Wales	15	6 (40 %)	6 (40 %)	5 (33 %)	7 (47 %)
Scotland	26	12 (46 %)	0	0	1 (4 %)
Northern Ireland	7	3 (43 %)	0	0	1 (14 %)
Ireland	18	16 (89 %)	11 (61 %)	0	9 (50 %)

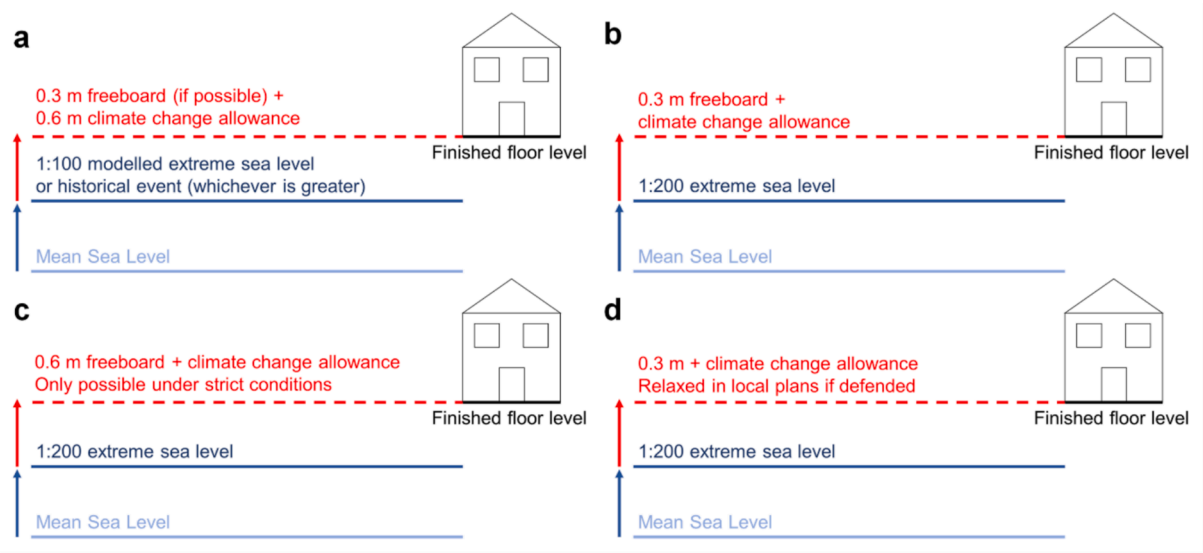

Fig. 2. Guidelines for minimum finished floor levels for structural accommodation in (a) France, (b) England, (c) Scotland, (d) Ireland. A minimum floor level is defined as the combination of an extreme sea level, a climate change allowance and a freeboard, or margin of error. Climate change allowances differ between countries and are detailed in Table 3. Northern Ireland lacks a national standard to accommodate for future coastal flooding by raising floor levels. Wales's planning policy only recommends that residential developments be designed to remain flood free during a 200-year tidal flood.

Table 3
Summary of SLR allowances in France, England Scotland and Ireland, which also apply to accommodation. SLR allowances are provided by river basin district in England and Scotland and a progressive SLR allowance (by "epochs" of approximately 30 years) is provided in England. In Ireland, two SLR scenarios are provided and apply to different development categories based on their vulnerability.

Country	Geographic scale	Timing of SLR (targeted year)	SLR range (m)
France	National	2100	0.6
England	Regional	Progressive, cumulative rise from 2000 to 2125	1.01 to 1.62
Wales	Regional	2100 or 2120	0.76 to 1.33
Scotland	Regional	2100	0.85 to 1.02
Ireland	National	2100	0.50 or 1.00

des Risques Naturels" – PPRN) (Le Cozannet and Cazenave, 2024).

Since 1995, these binding, State-led, municipality-level ("communes") natural risk prevention plans must be included in land use and urban planning documents, with the overarching aim being to reduce the vulnerability of people and assets in areas affected by natural hazards. Specific guidelines for coastal flooding were developed in 1997 leading to the adoption of coastal risk prevention plans (PPRL). The 2014 update of these guidelines provided methods for coastal flood modelling and consideration of SLR (DGPR, 2014). PPRLs are attached to local urban planning documents and must be approved following a technical study of risk and a consultation process with local officials. PPRLs are used to consider coastal flooding risk in urban planning policies by providing hazard and zoning maps, as well as defining rules for constructability in at-risk areas. Mandatory measures can be prescribed to existing buildings in addition to recommendations to increase overall property resilience.

A total of 451 municipalities with PPRLs were assessed in this study, 56 of which had a prescribed plan (Fig. 5). While PPRNs can adopt a multi-hazard approach addressing different sources of flooding, many municipalities on the French coast do not consider coastal flooding and do not have a PPRL. This can correspond to steep areas where coastal flooding risks are limited and the main concerns are erosion and landslides. Other areas however, such as the French Riviera (South-East France), still lack a PPRL and have not been highlighted as priority areas despite the current knowledge of coastal hazards and risks (Cazaux et al., 2019).

Once approved, the main impact of PPRLs is to define areas where flood hazard is high and building is not allowed. PPRLs also include accommodation measures for new and existing buildings. The plans set a reference hazard level – relative to sea level – above which the ground floor of new buildings must be built. The reference level is based on a modelled 100-year event (or a historical event, if higher) to which a SLR allowance is added. An additional 0.3 m uncertainty margin is only recommended in national guidelines and unevenly applied in PPRLs across France (Fig. 2a). In the wake of the Cyclone Xynthia in 2010, which led to 47 deaths in France and significant flooding in several departments along the Atlantic coast (Lumbroso and Vinet, 2011), the State issued a legal decree calling for a revision of PPRLs and for the integration of climate change into planning. This included a margin of 0.60 m to consider SLR for all of France, representing a projected rise for 2100 (MEDDTL, 2011). New guidelines for PPRLs were published in 2014 incorporating

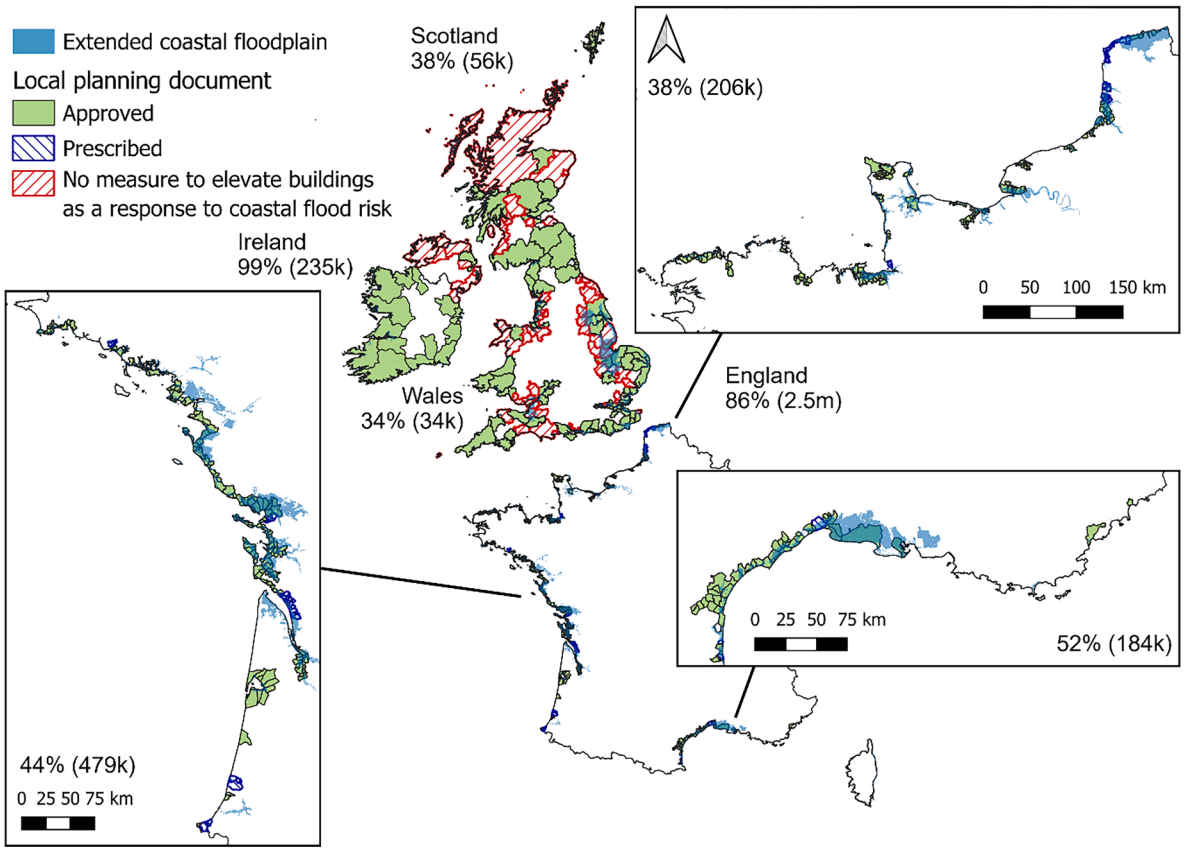

Fig. 3. Local planning documents containing structural accommodation measures across France, the UK and Ireland (as of March 2024). Each country or region is annotated with the percentage of the extended coastal floodplain with a document containing structural accommodation measures and the estimated population concerned (in parentheses). Only 8 % of the extended floodplain is covered in Northern Ireland, representing less than 10 k people. France.

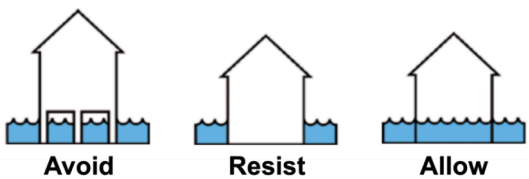

Fig. 4. Building-level flood hazard mitigation strategies in France in order of preference (adapted from MEDDE and METL, 2012).

these changes. PPRLs prescribed before this date and that have not been renewed tend to disregard SLR as part of the rules on finished floor levels (Fig. 3). This is the case in 19 out of 49 and 18 out of 173 municipalities on the Mediterranean and North coasts, respectively. On the Atlantic Coast, PPRLs covering a total of 10 municipalities in North Gironde and the Noirmoutier island were approved in 2022 and 2015, respectively, but prescribed before 2011 and do not follow the State guidelines on climate change. Instead of the 0.60 m national requirement, the North Gironde PPRL ("Embouchure et North Gironde") uses a 0.20 m margin to represent SLR.

Cyclone Xynthia played a pivotal role in the development of flood risk management and coastal adaptation in France and has influenced the definition of structural accommodation in planning. Municipalities on the Atlantic coast in areas affected by Xynthia (dotted rectangle in Fig. 5b) commonly use the sea levels observed during the event as the reference level on which to base finished floor levels. With most fatalities during Xynthia having occurred in single-storey houses (Creach et al., 2020), local plans have increasingly prioritised the addition of refuge areas (Fig. 6a). While refuge zones are a feature in all selected PPRLs, the rules overseeing their implementation vary between different plans. The inclusion of a refuge area in buildings in high flood risk areas is either presented as a recommended measure, a required alternative to minimum floor levels or a mandatory action to take within five years of the approval of the PPRL. This obligation applies to communes affected by Xynthia, such as in Vendée (Fig. 6a) on the Atlantic coast, but also in parts of the North and Mediterranean coasts and is also commonly associated with other flood resilience measures, such as raising vulnerable electrical systems. France's guiding principle remains that future-proofing new constructions will be less expensive

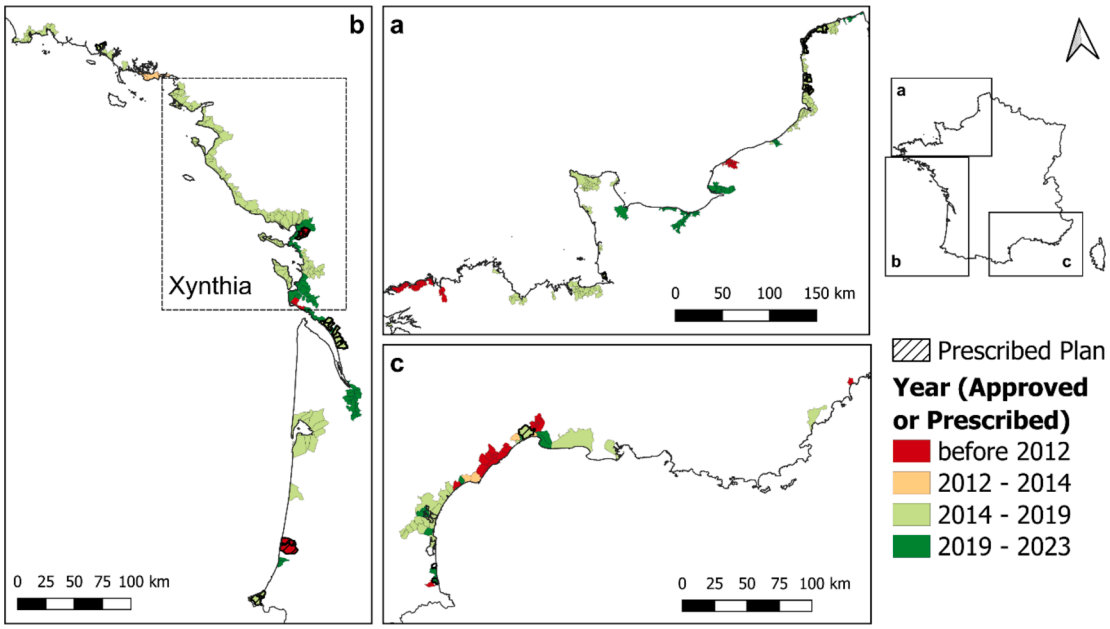

Fig. 5. Flood risk prevention plans along the French coast. Plans that did not refer specifically to coastal flooding are shown in dashed red. PPRLs are regionalised into (a) the North, (b) the Atlantic, and (c) the Mediterranean coasts. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

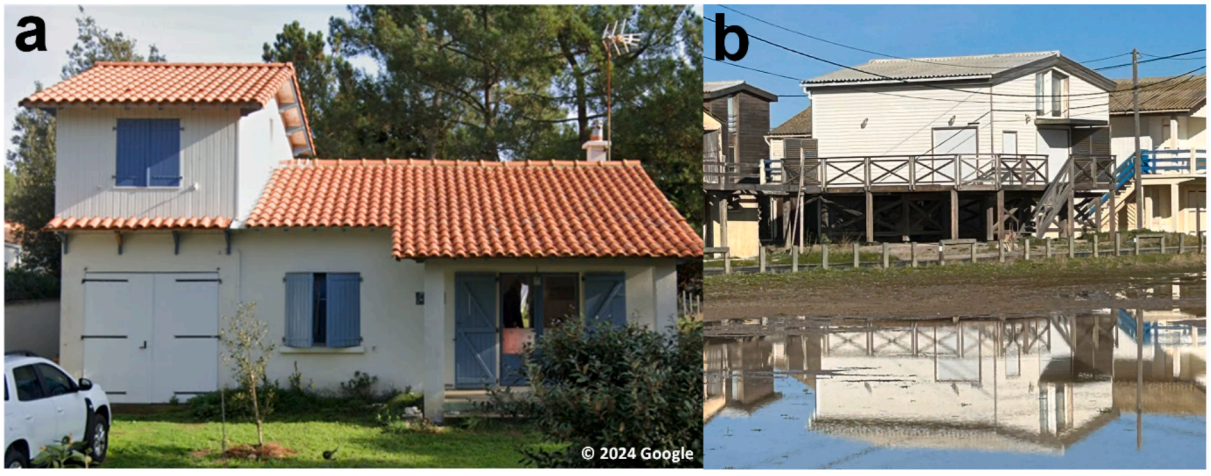

Fig. 6. Examples of structural accommodation measures in France. (a) Refuge added to a coastal single-storey house in Vendée, an area that was affected by Xynthia on the Atlantic coast. (b) The seaside neighbourhood of the "*Plage des Chalets*" on the Mediterranean coast comprises over 1,000 holiday houses elevated on stilts. Although the first elevated houses date back to the 19th century, most were destroyed during World War II and rebuilt in the 1950 s. A small dike between the houses and the sea also protects the neighbourhood. This is an example of informal accommodation developed to avoid coastal flood hazards before national guidelines existed.

than adapting existing buildings (DGPR, 2014). Examples of informal accommodation exist in France, such as elevated bungalows on stilts in Gruissan on the Mediterranean coast (Fig. 6b).

Whether it is raising floor levels, or adding a refuge area, structural accommodation measures in France address residual risks and are considered complementary rather than a substitute for protection. Argued in the 2011 decree, the French government's position is that areas protected by coastal flood defences remain exposed to flooding and that no defence is infallible. A subsequent 2019 decree on PPRs related to coastal flooding emphasised that reference hazards should be determined based on failure scenarios of defences, which can either refer to breach scenarios or a complete failure. The 2019 decree moreover changed rules for new constructions, allowing for urban renewal projects in high flood risk areas that are designed to reduce vulnerability, providing new opportunities for

accommodation.

Another driver for structural accommodation in France is the flood prevention action program (PAPI). The PAPI serves as the main operational tool for local authorities to implement local flood risk management strategies, based on the objectives of France's national strategy, at the scale of risk basins. These 6-year programs cover a comprehensive spectrum of cross-cutting measures in the risk cycle including prevision, prevention, and protection. Two of the programs' main strategic objectives are to (1) improve the consideration of flood risk in urban planning and (2) to reduce the vulnerability of people and property. While most measures and funds are dedicated to hard protection schemes, accommodation is therefore also relevant to PAPIs (Jacquet et al., 2016). Out of the 27 programs sampled between 2011 and 2022, 23 address accommodation. PAPIs can identify and recommend property-level measures to reduce vulnerability to coastal flooding. The programs also synergise with PPRLs, supporting the implementation of prescribed measures – or the development of a plan if it does not already exist – through vulnerability assessments, awareness raising as well as providing guidance on accessing available funding.

Areas covered by a PPRL or a PAPI are eligible to subsidies from the "*Fonds de Prévention des Risques Naturels Majeurs*" (FPRNM, previously called "*fonds Barnier*"). Available to private individuals and small businesses, this fund can contribute to the costs of measures prescribed in risk prevention plans or identified as part of vulnerability assessments in a PAPI. In 2021, the State released a list of measures that can be carried out to reduce vulnerability to flooding within a PAPI and that are eligible to the FPRNM. Elevating floor levels, the creation of a refuge area and the raising of vulnerable equipment all feature in this list (MTE, 2021).

3.2. England

The United Kingdom comprises England and the devolved administrations of Scotland, Wales, and Northern Ireland, who are each responsible for coastal adaptation. In England, the Department for Environment, Food and Rural Affairs (Defra) is the policy lead for flood risk management, including publishing the guidance on flood risk and coastal change as part of the National Planning Policy Framework (NPPF). As in France, avoidance is the prioritised strategy in the flood management hierarchy as part of a risk-based sequential test approach to promote development away from areas at risk. Measures to avoid flood risk vertically, by locating the most vulnerable uses on upper stories, and by raising finished floor levels, are also listed possible strategies in plan-making (DLUHC, 2014). The NPFF replaced Planning Policy Statements such as the Planning Policy Statement 25 (PPS25) on Development and Flood Risk, which previously dedicated a section on raising floor levels as a "possible option to manage flood risk to new developments" (DCLG, 2009).

The Environment Agency (EA) is the regulatory authority with a strategic oversight of all sources of flooding and is responsible for developing and applying England's National Flood and Coastal Erosion Risk Management (FCERM) Strategy. Adopted by the government in 2020, the strategy refers to the NPPF on development in the floodplain: "requiring developers to take suitable mitigation measures such as raising floor levels to improve the resilience of properties to flooding" (EA, 2020) (Fig. 7). The EA's standing advice for new developments is that finished floor levels should be 0.30 m above whichever is higher between the 200-year tidal flood level plus an allowance for climate change, the average ground level of the site or the adjacent road level to the building (Fig. 2b). As opposed to France, climate change allowances defined by the EA are variable across England by river basin district considering vertical land movement and the projected acceleration of SLR by epoch up to 2125 (Table 2) (EA, 2016).

Coastal adaptation policy in England and Wales is shaped by Shoreline Management Plans (SMPs), which support the FCERM providing a high level framework to plan for long-term coastal change (Nicholls et al., 2013; Sayers et al., 2022). SMPs apply a management approach for sections of the coast (management units) through this century, namely "hold the line", "no active intervention", "managed realignment" and "advance the line". As Nicholls and Klein (2005) argued, while it is possible to map these options to the "protect, "retreat" and "advance" coastal adaptation strategies, accommodation is not considered in the SMP framework. This is

Fig. 7. Examples of structural accommodation measures on the Isle of Wight, south coast of England. A void area is located below finished floor levels. Over half the buildings in this floodplain have been rebuilt and raised from grade in the last 20 years.

perhaps because accommodation does not represent a standalone strategy for dealing with SLR in the UK and is used to manage residual risk at the property level which is smaller than the SMP management unit.

The NPPF requires Local Planning Authorities (LPA), typically boroughs, districts, or unitary councils, to complete a Strategic Flood Risk Assessment (SFRA) to assess flood risk from all sources in their area and to support and inform local planning and decision making. The SFRAs serve to assess flood risks as well as to identify opportunities to reduces the impacts of flooding and are used by developers to produce site-specific flood risk assessments for new development proposals. LPAs are responsible for building regulations and have a legal duty to include policies in their spatial plans on climate adaptation, therefore playing a key role for accommodation.

The main structural accommodation measure described in SFRAs is the raising of floor levels in new developments. The EA's guidance shown in Fig. 2b is generally used as a minimum reference, however some LPAs require a greater standard (a 0.60 m freeboard instead of 0.30 m) where detailed modelling is lacking, or for sleeping areas (e.g., Dartford or Medway on the Thames Estuary). In areas benefitting from defences, floor levels are required to be raised above the maximum water levels caused by a defence breach during a 1 in 200 event plus climate change. This is the case on the east (e.g., Ipswich) and south coasts (e.g., Torbay, Plymouth) as well as some LPAs behind the Thames Barrier (e.g., Westminster, Hammersmith and Fulham, Richmond upon Thames).

National guidelines do not recommend specific methods to elevate buildings, or in what circumstances they might be effective. Although NPPF's guidance on flood risk and coastal change recognises that stilts and voids can be an appropriate approach to mitigate flood risk, LPAs commenting on such options tend to not consider them as acceptable strategies for new developments (e.g., East Suffolk, Southwark). A more common approach for elevating buildings in SFRAs is to design flood-compatible uses (i.e., parking or storage) at ground level while living and sleeping areas are placed above predicted flood levels. These measures can jeopardise access to buildings, which can be a barrier for accommodation. The guarantee of safe access and egress is indeed a priority policy for spatial planning in the UK. In contrast to the approach in France, refuge areas are rarely recommended. Overall, decision-making on structural accommodation is carried out on a case-by-case basis in local planning. The EA recommends the inclusion of flood resistance and resilience measures when the raising of floor levels to minimum standard is not considered possible. Guidance is provided in the CIRIA Property Flood Resilience Code of Practice and includes permanently raising electrical appliances and sockets (Kelly et al., 2020).

3.3. Wales

As the rest of the UK, Wales follows a risk-based approach to reduce the number of people living in high flood risk areas, setting tests to allow resilient developments into lower-risk areas. However, where England's FCERM strategy highlights the raising of floor levels as a requirement for developers in the floodplain, the National Strategy for Flood and Coastal Erosion Risk Management in Wales focuses on property flood resistance (e.g., demountable flood barriers) and resilience measures (as described in the CIRIA code of practice). Other than the raising of electrical systems, which falls under flood resilience, there is little consideration of structural accommodation.

Wales' national planning policy is supported by the Technical Advice Note (TAN) 15 (Welsh Government, 2004). TAN15 provides advice regarding development on floodplains, including the consideration of flood risk from all sources. For highly vulnerable developments (e.g., residential), developers are required to demonstrate that a site is designed to be flood free for a 200-year event in the case of coastal flooding, including an allowance for climate change. In more extreme events, the TAN15 guidance expects flooding to occur within properties and recommends a maximum tolerable depth of flooding on 0.60 m in residential developments, with maximum velocities of 0.15 m/sec. These standards are not prescriptive and suggest that indoor property resilience measures are preferred to a freeboard as a strategy to manage residual risk.

The Welsh Government is due to implement a revised TAN15 and a draft version was published in 2021. While its implementation has since been suspended due to concerns expressed from Local Authorities, the TAN15 required local planning authorities to produce Strategic Flood Consequences Assessments (SFCAs) to inform Local Development Plans not only on potential sources of flooding, but also on ways to manage and reduce flood risk. Analogous to SFRAs in England, SFCAs also are used to inform more detailed site-specific assessments. Three SFCAs, covering 6 of the 15 sampled planning authority districts on Wales' coast recommended raising floor levels for new developments in high flood risk areas.

3.4. Scotland

Adopted in 2023, Scotland's national spatial planning strategy is set out in the National Planning Framework 4. Policy 22 on flood risk and water management states that new developments in flood risk areas must demonstrate that adaptations are made to accommodate for climate change (Scottish Government, 2023b). The development of elevated buildings remains restricted to sites that were previously used in a built-up area and is therefore not possible in greenfield sites. The Scottish Environment Protection Agency (SEPA) provides specific guidelines for raising finished floor levels in new developments. SEPA expects a minimum of 0.60 m difference between the design flood level (200-year event) and the finished floor levels of a development (Fig. 2c). This freeboard is independent and additional to sea level rise allowances, which are provided by SEPA as a cumulative rise in each river basin from 2017 to 2100 based on the UK Climate Projections 2018 (SEPA, 2023).

In accordance with Policy 22, SEPA released in 2020 a position statement on elevated buildings in flood risk areas as a flood mitigation and climate adaptation strategy (SEPA, 2022). SEPA stated that while avoiding development in flood risk areas was still the preferred approach, it would not oppose elevated buildings in clearly defined circumstances and in cases where they are structurally safe and capable of being maintained for their lifetime. The conditions are that (1) the underside of the building is above the height of the design flood level, plus the allowance for freeboard, (2) the development does not reduce floodplain capacity, (3) the proposal does

not create an island of development and must be connected to developed areas outside the flood risk area, and (4) that safe, flood free pedestrian access and egress is secured.

Structural accommodation as a strategy is an evolving topic in Scotland that is cautiously framed at the national level and unevenly represented locally. The Scottish Government released in 2023 a guidance document to support the development of Coastal Change Adaptation Plans enabling local authorities to plan for future climate at the coast and promote long term adaptation and resilience (Scottish Government, 2023a). The guidance document shows that while Scotland recognises the need for coastal adaptation, its focus is on a mixture of protection (natural or artificial) and long-term managed re-alignment (i.e., retreat), with a limited role for accommodation. This is also evident in Flood Risk Management Plans, which highlight the main strategies to reduce the effects of flooding in Scotland's 14 Local Plan Districts and which do not address structural accommodation measures. Accommodation appears at the more localised level in policy and technical guidance documents relating to spatial planning. As in England, Local Development Plans and SFRAs are the most relevant documents for structural accommodation, with 13 out of the 26 selected planning authorities providing guidance on raising floor levels for new developments.

3.5. Northern Ireland

In Northern Ireland, the Department of Agriculture, Environment and Rural Affairs (DAERA) provided in 2019 an overview of the government's adaptation strategy in the second Northern Ireland Climate Change Adaptation Programme (NICCAP). This includes a commitment to develop local strategies to increase the resilience of the built environment and to implement strategies to manage flood risk. To achieve this objective, Northern Ireland's Strategic Planning Policy Statement (SPPS) is used in the preparation of Local Development Plans (DOE, 2015). The main approach to manage future coastal flood risk in the SPPS is to prevent new developments in areas within the 200-year coastal floodplain plus the latest climate change predictions (i.e., SLR up to the 2080 s epoch under medium emissions). While the SPPS lists land raising as a potential adaptation strategy, there is no mention of structural accommodation. Belfast is the only planning authority with specific guidelines in its Local Development Plan (LDP), recommending the raising of finished floor levels as a possible flood mitigation measure. The Belfast LDP goes further in stating that for new developments in flood risk areas permanent solutions such as elevated buildings are preferred to temporary measures such as demountable defences. The recommended freeboard is 0.60 m above the 200-year design flood level with SLR.

3.6. Ireland

The policy framework to define rules for the raising of floor levels in Ireland follows a similar approach to England, where SFRAs are produced at the city and county level to help support local development plans. Accommodation features in Ireland's national planning documents as a flood risk management strategy. Published by the Department of the Environment, Heritage and Local Government (DHLGH, 2009), the Planning System and Flood Risk Management guidelines for planning authorities state that new developments should respect a minimum floor level above the 200-year coastal flood level, with an allowance for climate change and uncertainties (Fig. 2d). The Office of Public Works is the lead agency for flood risk management and has defined two scenarios to represent the impacts of climate change and SLR. A "Mid-Range Future Scenario" and a "High End Future Scenario", each anticipating a SLR of 0.50 m and 1.00 m respectively by 2100. Guidelines for spatial planning and development management are considered in the Sectoral Adaptation Plan for Flood Risk Management, prepared under the National Adaptation Framework, which sets Ireland's national strategy to reduce the vulnerability of the country to the impacts of climate change (OPW, 2019). The strategy also emphasises the role of local authorities in planning for adaptation.

Local Development Plans in Ireland have recently entered a new 6-year cycle with the large majority being updated after 2021 and providing rules for raising floor levels in new developments in Strategic Flood Risk Assessments. Of the 18 counties selected in this study, only two showed no evidence of accommodation policy, namely Louth County and Donegal County, located in the north of Ireland. A freeboard of 0.30 m is generally recommended in Ireland. The plans for Cork (southern coast), Limerick and Clare (eastern coast) require an additional 0.20 m of freeboard in areas where wave overtopping is identified as contributing to flood risk. While the national planning strategy states that flood defences carry a residual risk that should be considered in designing finished floor levels within protected areas, this approach is not well represented at the local level. Ten SFRAs as part of local development plans provide separate guidance for defended and undefended areas. In these plans, a climate change allowance is not required in elevating buildings, provided SLR is included in the defence height for the scheme protecting the proposed development. Similarly, the Fingal Development Plan (north of Dublin) states that freeboard requirements can be relaxed in sites benefiting from flood defences, if justified in planning applications. As in the UK, assigning a less vulnerable use to the ground floor is a commonly recommended alternative accommodation measure for new developments.

4. Discussion

4.1. The role of accommodation in national and local coastal adaptation strategies

While measures relevant to structural accommodation were found in France, the UK and Ireland, they tend to feature as part of flood risk management strategies in spatial planning rather than as a coastal adaptation policy. Protect and – to a lesser extent – retreat remain the dominant strategies. Elevating new buildings (all or parts of the structure) follows national guidelines and is considered to contribute to the avoidance strategy when new developments cannot be steered away from high flood risk areas. However, national

standards not only differ between the studied countries, but their translation at the local level within countries is also uneven.

France's coastal adaptation strategy was highly influenced by the high loss of life and damage in Cyclone Xynthia in 2010, which accelerated the approval of coastal risk prevention plans and the spread of accommodation measures with national guidelines to consider SLR (Rouhaud and Vanderlinden, 2022). While these measures can be binding, as part of France's risk prevention policy, accommodation has faced significant hurdles due to competing interests and clashes between national and local authorities (Mineo-Kleiner et al., 2021). Enforceable plans can be the cause of social conflict over the limitation of constructability (Le Cozannet and Cazenave, 2024), which jeopardises the implementation of structural accommodation measures. Additionally, Cazaux et al., (2019) and Robert and Schleyer-Lindenmann (2021) found that some areas, such as in southern France, neglected coastal risks in their adaptation plans or avoid implementing risk prevention plans.

As shown in Fig. 3 by the coverage of plans and the affected population, structural accommodation is more highly prioritised both at the national and local level in England than the rest of the UK, featuring as part of the EA's national FCERM strategy. Despite national guidelines and building standards, responsibility ultimately falls onto local planning authorities and decision-making is taken on a case-by-case basis with the recognition that elevating buildings will not always be possible, particularly if it comes in conflict with other priority interests such as ensuring safe access and egress. Scotland adopts a more constrained approach to using structural accommodation with strict planning rules limiting elevated buildings to exceptional circumstances. Few local plans were found to mention accommodation in Wales and Northern Ireland. Burns et al. (2022) argued that while coastal flooding and SLR were identified as key issues, local authorities in Northern Ireland were not involved in climate change adaptation planning until recently and a long-term coastal management plan was therefore lacking.

Ireland follows a similar approach to England with a national spatial policy recommending elevated floor levels as a method of addressing residual risk. Discrepancies were found in several local plans in Ireland, where freeboard requirements could be relaxed in the presence of coastal flood defences, further highlighting potential conflicts between local and national interests. In the three studied countries, accommodation occurs in protected or sheltered locations and is not considered a standalone strategy to address SLR and coastal change. This is a point of divergence from the US where elevated buildings are widely located in undefended areas (Erdman et al., 2018).

4.2. *Preferred types of structural accommodation measures and their financing*

The main structural accommodation measure is the elevation of new developments. Elevating existing buildings is deemed economically unfeasible and is not considered in either France, the UK or Ireland. This finding aligns with previous studies on the cost-benefit of flood mitigation (Poussin et al., 2015). In the United States, where wood framed construction is more common, FEMA provides specific guidelines on how to retrofit houses above a flood protection level by lifting it and extending foundations below (FEMA, 2014). The preferred options for existing buildings in policies assessed in this study is to create a refuge area (in France), or to move sleeping areas above the design flood level with a margin for uncertainty and an allowance for SLR. While it is only a recommended measure in most areas, regions in France – notably the ones affected by Xynthia – have made it mandatory for homeowners in high flood risk zones to install a refuge area. Acceptability remains another challenge for this type of prescribed structural accommodation, particularly without appropriate funding schemes (Creach et al., 2020).

Accommodation measures are generally defined via building standards and the homeowner, or developer, bears the costs in the planning applications and construction. In France, national subsidies are made available through the FPRNM and can be used to cover parts of the costs of elevating buildings, creating refuge areas, or raising vulnerable electrical systems. The French ministers in charge of economy and environment recently requested an assessment on insurability in the context of climate change (Langreney et al., 2023). One of the main recommendations was to increase funding on accommodation through a new national fund of €180 million per year to prevent the increase of damages costs due to flooding and other climate hazards. Another report by France's national audit institution argued financing and costs were barriers to property-level resilience for adaptation, as well as fears of impacts on the appearance of dwellings, a potential loss of comfort, or the perception that collective protection is a requirement and the responsibility of the State (Cour des Comptes, 2024). Barriers to the implementation of accommodation measures remain, such as a lack of awareness on both flood hazard and its potential impacts, as well as difficulties for individuals to take private action when public disaster relief programmes are well established (Champonnois and Erdlenbruch, 2021).

In the US, FEMA leverages its NFIP to promote and incentivise more community-level flood control practices. For federal flood insurance to be available to residents, new homes are required to adopt certain practices, including stricter building codes and rules about building elevation in high-risk areas (Leatherman, 2018). In the UK, Flood Re – the joint initiative between the government and the insurance sector – has submitted proposals to promote the uptake of property flood resilience measures by offering lower premiums for properties that have been made more resilient (Flood Re, 2019). While these efforts could provide a financial incentive for accommodation, existing schemes in the UK such as Build Back Better (Flood Re, 2024) focus on properties that have been flooded and typically involve measures such as using flood resistant materials or installing flood barriers rather than elevating buildings.

4.3. *Integrating coastal processes in the prescription of building elevation*

In France, the UK and Ireland, elevating buildings is also used to manage other sources of flooding (e.g., fluvial, pluvial). Accommodation policies in these countries provide little consideration of the specific characteristics and mechanisms of coastal flooding. In the UK and Ireland, a 100-year and a 200-year design flood level serve to define finished floor levels in areas at risk of fluvial flooding and coastal flooding, respectively. The impacts of waves and associated high velocity flows – which are likely conditions

during coastal storms, especially on open coasts – on the structural integrity of elevated buildings can be key factors to assess the feasibility of accommodation (Moeini et al., 2023). Waves may also cause erosion undermining buildings and their foundations. However, these issues are either addressed with buffer zones (France) or increased freeboard (Ireland) and not by building standards as part of accommodation. France, the UK, and Ireland offer little to no guidance on the types of construction methods that are permitted. Structural accommodation can be achieved through a wide range of methods. In the US, while FEMA maps do not consider SLR, construction rules recognise different hazard zones in coastal areas (FEMA, 2009). The V-Zone represents coastal floodplains where wave action and fast-moving waters can cause extensive damage and erosion. Closed foundations are not permitted in the V-Zone, and concrete column and grade beams are not recommended. In France, while a surf zone is designated in some PPRLs and velocity is used to characterise coastal flood hazards, these are primarily used to determine constructability. Existing buildings in the highest risk areas may still require to be elevated if redeveloped (e.g. replacement dwellings) with little consideration for the structural impact of waves and high velocity. Comprehensive guidelines for elevating buildings in Europe in areas subject to wave action and high velocities should be considered and are consistent with the stated desire for structural safety. Property-level flood management measures should also be fitted to local conditions to ensure cost-effectiveness, as concluded by Poussin et al. (2015). Such considerations will be critical criteria to ensure the success of accommodation in Europe and could impact many people on the coast (Fig. 3).

Although this assessment of planning and policy is a first step in the evaluation of the state of accommodation in France, the UK and Ireland, it cannot provide a full picture of how these measures are carried out in practice. Discrepancies may exist between policy recommendations and their implementation. Guidelines may not be fully respected, and informal accommodation, such as through cultural norms or historical legacies (Fig. 6b), can occur without it being represented in policy. Further research into local policies and practise should look to bridge this gap, which was outside of the scope of this study.

5. Conclusions

A systematic review of structural accommodation in national strategies and local planning documents was carried out for France, the UK and Ireland. The comparative assessment of measures within and across countries highlighted the following points:

(1) Accommodation has received far less attention than other adaptation strategies with national coastal adaptation policies focusing on protect and retreat. Despite being promoted by a shift towards a diversified approach to flood risk management in the UK and Ireland, as well as the severe impacts of major recent events such as Cyclone Xynthia in France, accommodation still faces institutional, financial, and technical barriers.
(2) Measures to increase resilience at the property-level, namely elevating new buildings, dedicating less vulnerable ground floor uses, creating refuge areas or raising vulnerable systems were found in each country. Accommodation in France, the UK and Ireland remains strongly driven by local spatial planning and differences were evident in the definition of measures and the standards they must respect, leading to an uneven geographic distribution of accommodation.
(3) Despite national climate change allowances, the integration of SLR is not consistently applied at the local level. Uncertainty margins and freeboard also vary and are the only way coastal-specific hazards, such as waves, are presently considered.

While the US must contend with different socio-economic and geographic considerations, barriers to structural accommodation can be overcome using its 50 + years of experience. One common practice from the US that is not included in the European guidelines is the recognition of the impact that waves may have on raised structures in a high velocity V-Zone. In most locations in Europe accommodation is happening in sheltered locations or behind defences to manage residual risk. However, as accommodation is applied more widely in the future and sea levels rise, it is inevitable that structural accommodation will be proposed in areas where waves are significant. This suggests a need for more focus on such concerns in future revisions of accommodation guidelines – such development could be the definition of prohibited or appropriate building standards. The US experience shows the latter approach is feasible.

Accommodation can be a complementary low-regret option to shoreline management and does not prevent adopting a protect or a retreat strategy in the future. An important step in France, the UK and Ireland will be to better integrate accommodation as part of national coastal adaptation policies. This study constitutes a first step in creating an assessment of structural accommodation in Europe. Reviewing the literature cited in the Europe chapter of the 6th Assessment IPCC report (Bednar-Friedl et al., 2022), we note that France and the UK are overrepresented, suggesting that much of past research on accommodation has been conducted in these countries. The study cases in this paper may not be representative of the rest of Europe, in regions with a potentially lower adaptive capacity, and an important future step will be to expand the geographic scope of this work to other countries.

CRediT authorship contribution statement

Ulysse Pasquier: Writing – review & editing, Writing – original draft, Visualization, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Robert J. Nicholls:** Writing – review & editing, Writing – original draft, Supervision, Methodology, Investigation, Funding acquisition, Formal analysis, Conceptualization. **Gonéri Le Cozannet:** Writing – review & editing, Writing – original draft, Methodology, Investigation, Funding acquisition, Formal analysis. **Paul Sayers:** Writing – review & editing, Writing – original draft, Investigation, Formal analysis, Methodology.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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