

BUILDING A CLIMATE SHELTERS SYSTEM TO PROMOTE CLIMATE- RESPONSIVE CITIES

The Case of Bonfim Parish in Porto

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To my parents, Daniele and Mozart.

Cities are not problems. They are solutions.

Jamie Lerner

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RESUMO

As alterações climáticas afetam as cidades de forma desigual, evidenciando vulnerabilidades socio-territoriais. Esta disparidade suscita preocupações éticas, contribuindo para o surgimento do debate sobre a justiça climática que acompanha as discussões subjacentes às estratégias de adaptação às alterações climáticas, onde vulnerabilidades, resiliência das comunidades e capital social são conceitos centrais. Desta perspectiva resulta uma maior evidência da importância do envolvimento do público no processo de planeamento e da utilização de elementos urbanos para promover a interação entre e dentro das comunidades. A ação climática pode, deste ponto de vista, e numa abordagem interventiva e transformadora, tirar partido da infraestrutura social para criar abrigos climáticos, que não só protegem as pessoas de fenómenos climáticos extremos, como também promovem a coesão social.

Neste sentido, o principal objetivo deste trabalho é desenvolver um sistema de abrigos, (também designados de refúgios) climáticos no município do Porto, nomeadamente na freguesia do Bonfim, como uma estratégia de adaptação às alterações climáticas. Com esta proposta procura-se fortalecer a capacidade de adaptação e a resiliência das comunidades no território, que passarão a dispor destes espaços, cujo uso potenciará uma maior integração social, para além de constituírem uma resposta aos impactos de eventos climáticos extremos.

Assim, desenvolveu-se uma metodologia em duas fases: na primeira fase, realizar-se-á uma preparação para a proposta, com a identificação de critérios para seleção de abrigos climáticos, realizada através dos estudos de casos de referência, seleção de fontes de informação, recolha e análise dos dados e definição do grupo de indivíduos a ser entrevistado na fase seguinte; na segunda fase ocorrerão as etapas práticas, como a identificação de potenciais locais para abrigos climáticos e seu refinamento, através de entrevistas com o público e observações dos locais para a seleção e proposta final dos abrigos.

Esta metodologia foi desenvolvida com a preocupação de englobar abordagens “top-down” e “bottom-up” e de forma a que possa ser replicada em qualquer processo de planeamento urbano, quer seja noutras freguesias do município do Porto, quer seja no contexto de outras cidades.

A freguesia do Bonfim, no Porto, foi escolhida devido à sua localização numa área central do município, que congrega diferentes tipos de vulnerabilidades e riscos climáticos, permitindo um estudo mais abrangente e uma proposta mais completa de abrigos climáticos. O estudo preparatório permitiu concluir que os eventos climáticos mais expectáveis de vir a ocorrer na cidade são as ondas de calor, as ondas de frio e as chuvas fortes/inundações. Neste contexto, os abrigos propostos visam a proteção da população, com foco nos grupos vulneráveis existentes no território, tais como pessoas em privação socioeconómica e os idosos, para a criação do sistema de abrigos climáticos na freguesia.

A proposta final traduz-se num sistema de abrigos que resultaram da aplicação da metodologia ao território e num conjunto de recomendações relacionadas com a sua implementação futura, nomeadamente questões relacionadas com a sua manutenção, monitorização, governança mas também questões relacionadas com literacia climática.

A tese conclui que o sistema de abrigos climáticos serve para além da adaptação climática, por se apropriar de infraestruturas sociais que tem a capacidade de aumentar a resiliência das comunidades. Deve pressupor assim um objetivo de promoção da qualidade de vida da população em geral, através dos métodos participativos e de uma governança que garanta a eficácia do seu funcionamento.

PALAVRAS-CHAVE: abrigos climáticos, alterações climáticas, adaptação climática, infraestrutura social, resiliência das comunidades.

ABSTRACT

Climate change impacts cities unevenly, revealing territorial vulnerabilities. This disparity gives rise to ethical concerns, which in turn has led to the emergence of the debate on climate justice, which is closely linked to the discussions underlying climate change adaptation strategies. In these discussions, the concepts of vulnerability, community resilience and social capital play a central role. From this perspective, there is growing evidence of the importance of public involvement in the planning process and the use of urban elements to promote interaction between and within communities. From this perspective, climate action can be implemented in an interventionist and transformative manner, utilising social infrastructure to create climate shelters. These shelters not only protect individuals from extreme weather events but also foster social cohesion.

In this context, the primary objective of this study is to develop a system of climate shelters in the municipality of Porto, specifically in the parish of Bonfim, as a strategy for adapting to climate change. The objective of this proposal is to enhance the adaptive capacity and community resilience in the area, through utilisation of spaces that facilitate greater social integration, as well as being a response to the impacts of extreme weather events.

A two-phase methodology was therefore developed. The first phase involves preparing the proposal by identifying criteria for selecting climate shelters through reference case studies, selecting sources of information, collecting and analysing data, and defining the interview group for the next phase. The second phase includes practical steps such as identifying potential climate shelters, refining the selection through interviews with the public and observations on each space condition, and finalising the selection and proposal of final official shelters. This approach integrates both top-down and bottom-up approaches, making it replicable for planning processes in other parishes of Porto and other cities.

Bonfim parish was chosen due to its central location in the municipality of Porto and its diverse climate vulnerabilities and risks, allowing for a comprehensive study and complete proposal for climate shelters. The preparatory study concluded that the climate events most likely to occur in the city are heat waves, cold waves and heavy rainfall/flooding. In this context, the proposed shelters aim to protect the population by focusing on vulnerable groups in the area, such as socio-economically deprived people and the elderly, in order to create a system of climate shelters in the parish.

The final proposal translates into a system of shelters that resulted from the application of the methodology to the territory and a set of recommendations related to their future implementation. These recommendations address issues related to the maintenance, monitoring, governance, and climate literacy of the shelters.

The thesis concludes that the climate shelter system goes beyond climate adaptation, as it appropriates social infrastructure that has the capacity to increase community resilience. It must therefore aim to promote the quality of life of the population in general, through participatory methods and governance that guarantee the effectiveness of its operation.

KEYWORDS: climate shelter, climate change, climate adaptation, social infrastructure, community resilience.

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1

INTRODUCTION

The impacts of climate change in urban areas exacerbate existing inequalities and vulnerabilities. Cities both contribute significantly to climate change and suffer acutely from its consequences. Despite occupying only around 3% of the Earth's surface, urban areas are responsible for 71% of carbon dioxide emissions (Ray & Shaw, 2018). By the year 2023, nearly half of the global population—about 3.3 to 3.6 billion people—lived in situations of high susceptibility to the adverse effects of climate change (IPCC, 2023b). In vulnerable regions, the death rate from extreme weather events in the last decade was 15 times higher than in less vulnerable areas. Within urban areas, vulnerabilities arise from various factors, including economic hardships, poor health, social isolation, language barriers for immigrants, and precarious housing situations (Breil et al., 2018).

Since the 1980s, climate change has been receiving increased attention in scientific and political arenas, with a primary focus on mitigating its effects by reducing greenhouse gas emissions. Recently, there has been a significant rise in the importance of climate adaptation and the consideration of vulnerabilities (Bulkeley et al., 2014; Bulkeley & Tuts, 2013).

Given the challenges climate change imposes on urban areas, cities are increasingly engaged in climate adaptation strategies to become more climate-responsive. These strategies involve plans and legislation at different governance levels and specific interventions such as the implementation of blue and green infrastructures. Furthermore, climate adaptation must be developed with consideration of the vulnerable groups within the territory.

Concepts such as climate justice, community resilience, and social capital have emerged in this context. A resilient community with high social capital can respond more quickly and effectively to extreme events, making them less dependent on institutions. These concepts provide a framework for spatial planning to offer effective climate action. Involving the population in the decision-making process increases acceptance of new interventions, and considering vulnerable groups and their specific needs results in better-oriented projects for cities and fosters community resilience.

The city of Porto has experienced extreme climate events, such as heat waves, cold waves, and heavy rains/flooding. These events can significantly impact public health, particularly among vulnerable groups such as the elderly, children, and low-income populations. By analysing how these groups are dispersed throughout the territory and correlating this information with climate risks, effective strategies can be developed.

This dissertation focuses on the development of a climate shelters system as a climate adaptation strategy. Climate shelters are spaces within the social infrastructure category that can serve as refuges during extreme climate events, such as heat waves, cold waves, and heavy rain/floods. Social infrastructures are crucial elements in building resilience because they provide spaces for interaction among residents, thereby increasing social cohesion. By utilising these infrastructures as climate

shelters, the population can seek refuge in familiar spaces during extreme events, enhancing both their safety and sense of community.

1.1. OBJECTIVES

The main objective of this Master's Thesis is to propose a climate shelters system in Bonfim parish, as a central component of a climate adaptation strategy. This system aims to build the population's adaptive capacity and increase community resilience. To ensure the efficiency of this proposal, this research is divided into the following specific objectives:

1. Carry out a **literature review**, analysing the challenges imposed by climate change in the urban environment, how it generates and intensifies vulnerabilities, worsening its risks, and how urban adaptation planning can respond to these issues. Also, it is important to understand how community resilience can be achieved by building a climate-responsive city through the use of social infrastructures and, ultimately, a climate shelters system;
2. **Investigate how other cities implemented climate shelters** as an adaptation strategy and gather insights and lessons learned from these implementations;
3. Develop a **methodology** to be applied in this research but also to be replicable in other locations;
4. **Establish an area** in the municipality of Porto for the implementation of the strategy to enable a more detailed and localised proposal;
5. **Test and validate** of the proposed methodology in the parish of Bonfim;
6. Elaborate a set of **recommendations** to be applied in conjunction with the climate shelter proposal to enhance its effectiveness and integration into broader climate adaptation efforts.

1.2. GENERAL STRUCTURE

The literature review (Chapter 2) was conducted in two parts, evolving organically throughout the research process. The search was made via keywords in academic articles and books on platforms such as ScienceDirect and Google Scholar. Initially, the focus was on studying relevant concepts to achieve climate justice in planning. It was essential to trace a process from the challenges of climate change in territories and how these challenges generate and intensify vulnerabilities. This included analysing the risks, identifying vulnerable groups, and understanding the impacts they suffer due to these changes. Finally, the review outlined how the planning process can and should involve these groups to achieve justice. This section, therefore, examines the problem, its consequences in urban areas, and potential resolutions.

The second part of the literature review aimed to better focus on the dissertation's final objective: how climate shelters, as instruments of climate adaptation, can achieve community resilience. Social infrastructures were then discussed as tools for achieving community resilience, culminating in how these infrastructures can be transformed into climate shelters.

Following the literature review, a research study was conducted on cities where climate shelter strategies have already been implemented (Chapter 3) to understand the processes in each location. Five cities were chosen, four of them in Europe, based on the literature and to align with the context of Porto, where similar strategies will be implemented. The analysis revealed that some cities have specific short-term shelter strategies for one type of risk, while others are developing networks of shelters for multiple climate risks, typically heat and cold waves.

The methodology (Chapter 4) was developed based on the literature review and reference cases to provide a comprehensive approach to implementing the proposal. The methodology was divided into two phases: the first phase focused on data collection and analysis for characterising the territory and its needs, and the second phase involved the proposal's development.

Chapter 5 characterised the case of study, starting with an initial analysis of the municipality and a more detailed analysis of the parish of Bonfim, where the proposal was implemented. The proposal (Chapter 6) included identifying all potential shelters and refining the selection through space observations and interviews, leading to the final proposal. The results were then discussed, and additional recommendations were made regarding the proposal.

Finally, chapter 7 provides final conclusions on this dissertation, offering insights into how this work complemented existing literature, its limitations and directions for further research.

2

LITERATURE REVIEW

Climate change has far-reaching impacts on urban areas, exacerbating existing inequalities and vulnerabilities. These vulnerabilities stem from various factors, including economic hardships, physical conditions such as poor health or living alone, and social conditions such as language barriers for immigrants or precarious housing situations (Breil et al., 2018; IPCC, 2023b).

It is, therefore, imperative for urban planning efforts to address vulnerability comprehensively. In particular, climate adaptation strategies must aim to foster justice throughout the planning process and outcomes. Failure to integrate the needs of vulnerable groups into adaptation processes can exacerbate existing inequalities and further marginalise these communities (Breil et al., 2018). Thus, attention must be paid to ensuring that adaptation strategies are inclusive and equitable, effectively safeguarding all members of society against the impacts of climate change.

This thesis aims to deepen critical concepts for fostering fairer spatial planning, particularly amidst the pressing challenges posed by climate change, which currently occupy a central position on the global agenda. To that end, this literature review is structured around two main themes. The first theme explores the challenges posed by climate change for urban planning, mainly in terms of adaptation strategies. This encompasses understanding the impacts of climate change, factors contributing to vulnerability among different social groups, and risks associated with urban environments. Additionally, it provides a theoretical framework for climate adaptation planning, highlighting approaches to community participation and engagement, as well as principles of climate justice. The second theme expands concepts of community resilience and social capital, emphasising the significance of social infrastructure in climate adaptation efforts. Specifically, it examines the role of climate shelters as crucial infrastructures for promoting climate adaptation and justice. These shelters, accessible to all members of society, provide safety and security during climate-related disasters. Overall, this research explores how climate shelters, as integral components of social infrastructure, contribute to equitable climate adaptation strategies and enhance community resilience.

2.1. CHALLENGES FOR CLIMATE ADAPTATION

Climate change has garnered increased attention in both scientific and political arenas since the 1980s, primarily focusing on mitigating its effects through greenhouse gas emissions. However, there has been a notable rise in the significance of climate adaptation and the consideration of vulnerabilities in recent times (Bulkeley et al., 2014; Bulkeley & Tuts, 2013). This way, adaptation and mitigation have emerged as the primary responses to climate change (Füssel & Klein, 2006).

The impacts and risks of climate change in urban areas have brought to light current vulnerabilities within cities (Breil et al., 2018). Thus, effective planning must encompass the diverse range of social,

economic, institutional, physical, and environmental vulnerabilities within the community (Breil et al., 2018; Preston et al., 2011). The multitude of vulnerability determinants and varying normatives across locations, regions, or countries pose significant challenges to the climate adaptation planning process (Preston et al., 2011).

At the city level, vulnerabilities not only exacerbate the negative impacts of climate change, especially during extreme events but also magnify post-event consequences (Otto et al., 2017). The lack of knowledge among low-income individuals, for instance, presents barriers to engaging with bureaucratic systems focused on disaster reduction, such as accessing assistance from institutions providing housing, medicine, or food (SAMHSA, 2017). In Bangladesh, for example, post-disaster, families often prioritise individual problem-solving over seeking community support, leading to diminished social cohesion. Additionally, tensions within communities emerge regarding employment opportunities and access to water, further compounding vulnerabilities, including the risk of violence (Otto et al., 2017).

Furthermore, the lack of understanding regarding the societal impacts of climate change and its links with vulnerabilities hampers the promotion of adaptation strategies (Breil et al., 2018; Mastrandrea et al., 2010). The social and economic impacts of climate change are particularly challenging to assess due to practical knowledge gaps and insufficient interdepartmental communication (Breil et al., 2018).

Typically, adaptation planning tends to favour wealthier city zones, often excluding vulnerable populations from decision-making processes, potentially leading to increased displacement and exposure to climate change-induced disasters (Chu & Cannon, 2021; Mohtat & Khirfan, 2021). Thus, understanding how inadequate planning exacerbates injustices within the territory is crucial, and applying principles of justice can help mitigate or reverse these issues (Chu & Cannon, 2021).

Social, environmental, and climatic vulnerabilities are further entrenched in cities during natural disasters. Moreover, planning skewed towards affluent areas of cities exacerbates territorial injustices. Therefore, addressing vulnerabilities and risks is essential in climate adaptation planning, necessitating recognition of at-risk groups and their circumstances. Climate justice principles offer valuable guidance in ensuring fairness in planning processes by incorporating vulnerable groups into strategies, policies, and decision-making procedures.

2.1.1. CLIMATE CHANGE AND EXTREME EVENTS

The Anthropocene is the current geological era, where human, or anthropological actions, influence the geological history of planet Earth (Ellis, 2019). Human interventions, spanning trade, financialisation, migration, urbanisation, technological advancements, and communication, have introduced novel forms of risk. These human-induced processes reshape the planet's biosphere, impacting biodiversity, ecosystem functionality, water cycles, and climate patterns (Stockholm Resilience Centre & Stockholm University, n.d.). Notably, climate changes are evident through parameters such as air and surface temperatures, as well as sea-level rise (Ellis, 2019).

Climate change encompasses long-term shifts in temperature and climatic patterns, which can arise naturally or be exacerbated by human activities. The burning of fossil fuels and oils, and the emission of greenhouse gases (GHGs) such as carbon dioxide and methane intensify these changes. Consequently, climate change leads to global warming and a surge in extreme weather events, affecting ecosystems, agriculture, health, and infrastructure (Liu et al., 2023). Events such as heatwaves, heavy rainfall, and droughts trigger a chain of impacts like flooding and wildfires (IPCC, 2023b), with concerns mounting over their increasing intensity, frequency, and unpredictability (World Adaptation Science Programme, 2021).

Despite urban areas occupying only around 3% of the Earth's surface, they contribute to 71% of carbon dioxide emissions (Ray & Shaw, 2018). This heightened emission rate is attributed to the complex nature of urban systems, characterised by high fossil fuel consumption through the generation of energy for construction activities, building climate control mechanisms (e.g., air conditioning), transportation, industrial operations, and waste (Un-Habitat, 2011).

Rising temperatures will disrupt climate zones, impacting regional fauna and flora distributions, reducing biodiversity, and fostering the proliferation of pests and invasive species, leading to increased disease burdens. Water evaporation due to heat exacerbates droughts, further threatening agriculture and livestock, and exacerbating food shortages. Some countries already struggle with drought-related challenges, including forest fires, which are projected to worsen with rising temperatures. For instance, in 2023 “long-term drought persisted in North-western Africa and parts of the Iberian Peninsula, as well as in parts of Central and South-West Asia, and intensified in many parts of Central America, northern South America and the southern United States” (World Meteorological Organization, 2024, p. 25), and wildfires extensively affected countries such as Canada and United States (World Meteorological Organization, 2024). Increased rainfall in some areas augments flood risks, compounding existing natural flood occurrences, particularly in Europe. Rising river and ocean levels pose threats to coastal infrastructure and ecosystems (European Commission, n.d.). Elevated temperatures contribute to glacier melt, potentially jeopardising freshwater sources. Moreover, altered precipitation patterns may trigger extreme weather events like hurricanes, floods, and droughts (Roser & Seidel, 2017).

The latest IPCC Report (2023) underscores that climate change impacts surpass previous estimations, disproportionately affecting vulnerable groups. Even if the 1.5°C target above industrial levels is met, adverse effects on health, food security, water availability, and economic prosperity are imminent. Exceeding this threshold could lead to widespread ecosystem devastation, increased disease prevalence, biodiversity loss, famine, and flood-related damages (IPCC, 2023b; Roser & Seidel, 2017). The IPCC predicts that a 4°C rise could lead to the extinction of approximately 50% of tropical marine species (IPCC, 2023b).

Climate change impacts manifest cascading effects across spatial, temporal, and systemic scales. Understanding the shocks and stresses induced by climate change is pivotal in bridging the gap between risk mitigation and adaptation efforts (World Adaptation Science Programme, 2021). Shocks, characterised by sudden and extreme events, alongside long-term stresses, exert significant pressure on economies, environments, and social structures, influencing vulnerability to future shocks (Williams-Eynon, 2023). This way, it is imperative to analyse the risks of climate change in the territory, predict their possible impacts on the population and understand how they might enhance vulnerabilities.

2.1.2. RISKS, IMPACTS AND VULNERABILITIES

Climate change exerts various impacts on cities and the environment, posing risks to people, animals, and ecosystems. With increasing exposure, vulnerability, and occurrence of extreme events, the negative impacts escalate. For instance, climate change can exacerbate poverty, making adaptation processes even more challenging and heightening vulnerability among affected populations (Breil et al., 2018; Thomas et al., 2019). In urban settings, climate risks intertwine with non-climatic issues like social, economic, and environmental factors, compounding vulnerability to risks (Bulkeley & Tuts, 2013).

Additionally, the power disparity between developed and developing nations fuels arguments that more developed countries may use their influence to maintain advantageous positions. However, it is precisely due to this influence that they bear responsibility for the repercussions of their actions on developing

countries (Okereke, 2010). Within the same rationale, vulnerable groups, aside from enduring the brunt of climate change consequences and injustice, possess lower adaptive capacities and lack resources to shield themselves from ensuing risks (Mohtat & Khirfan, 2021).

Climate change affects people differently, according to their socio-economic status, age, and gender (Climate Just, n.d.-c). Moreover, climate change engenders these vulnerabilities, which are further compounded by factors such as food security, health, displacement, and migration (Otto et al., 2017). From this point of view, vulnerabilities can be analysed from two angles: adaptive capacity and sensitivity. Adaptive capacity focuses on a group's ability to respond to climate change impacts and prepare to mitigate them, while sensitivity pertains to the degree of exposure to danger and susceptibility to the adverse effects of climate variation and extreme events (Breil et al., 2018; Kim et al., 2016). In other words, vulnerability can be understood both as the result of an event and as a starting point (Birkmann et al., 2022).

For a comprehensive grasp of climate adaptation planning, certain concepts merit attention, as depicted in Table 1 below. These concepts facilitate understanding of how climate change impacts the urban environment, amplifying vulnerabilities and requiring more robust planning to ensure climate justice in adaptive strategies.

Table 1 - Concepts related to climate change. Source: adapted from IPCC (2023b).

Concepts	Description
Hazard	“The potential occurrence of a natural or human-induced physical event or trend that may cause loss of life, injury or other health impacts, as well as damage and loss to property, infrastructure, livelihoods, service provision, ecosystems and environmental resources” (p. 125). This includes extreme weather events.
Risk	The interaction between hazard, exposure, and vulnerability. It relates the potential adverse consequences of impacts and a community's capacity to respond to climate change.
Impact	The consequences of a risk when it occurs. It refers to the consequences of an event, which can be positive or negative. Concerning climate change, it relates to the repercussions that a hazard has on livelihoods, the economy, health, the ecosystem, services, or infrastructure.
Exposure	The presence of elements that could be affected by a hazard, such as people, species, services and resources, infrastructure, and ecosystems, among others.
Vulnerability	“The propensity or predisposition to be adversely affected.” (p. 130)

The IPCC Report (2023) underscores the intricate interplay of three intertwined factors — climate hazards, vulnerability, and exposure — that shape risk dynamics. Additionally, Fig. 1 illustrates the interconnectedness of climate, ecosystems, biodiversity, and human societies. Risk, as defined by the IPCC, “provides a framework for understanding the increasingly severe, interconnected and often irreversible impacts of climate change on ecosystems, biodiversity, and human systems” (IPCC, 2023a, p. 5).

The degradation and depletion of ecosystems due to human activities heighten people's vulnerability. Climate change exerts impacts on both human and natural ecosystems, while human society also impacts natural ecosystems. Consequently, concerted efforts are required to curb greenhouse gas emissions to mitigate climate change and to conserve and restore natural ecosystems, ensuring their continued provision of livelihoods for people.

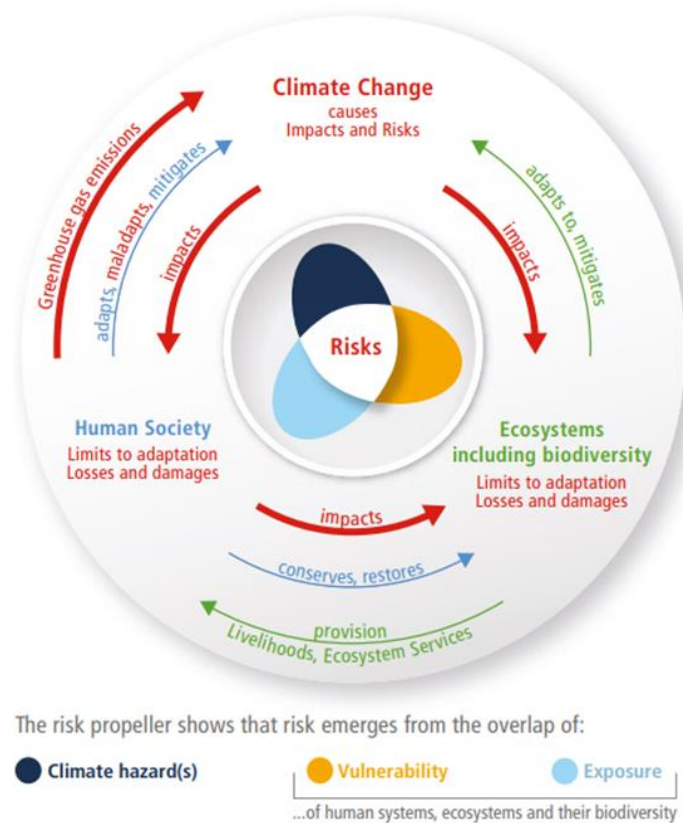


Fig. 1 - Relations between Exposure, Vulnerability and Climate Hazard to create Risks. Source: IPCC, 2023a.

Given the impacts of climate change and their exacerbation of vulnerabilities in the territory, understanding who is most susceptible to these impacts becomes paramount in adaptation planning. Consequently, various tools can be employed to identify these groups, map their locations, and discern which events they are particularly vulnerable to.

In the scope of this thesis, the UK's Climate Just website seemed to be a valuable and foundational tool for planning adaptation to climate change by mapping vulnerable groups and the risks they face. It distinguishes between various types of hazards and vulnerabilities while presenting strategies and policies for a fairer response to climate change. This example underscores the significance of identifying vulnerable groups within a territory, which may encompass factors such as age, gender, health, economic capacity, crime, mobility, and immigration (Climate Just, n.d.-c).

For instance, children are susceptible to health issues and diseases resulting from flooding and heat waves, with traumas potentially leading to behavioural difficulties. Conversely, the elderly are significantly impacted by extreme events like heat waves and flooding due to physiological factors (Amorim-Maia, Anguelovski, Chu, et al., 2023; Breil et al., 2018; Climate Just, n.d.-c; Otto et al., 2017).

Gender disparities also compound vulnerability for women, who often face lower incomes, legal and political disadvantages, and physical and biological differences compared to men. Limited access to resources and justice, limited mobility, and voice (Breil et al., 2018), and lack of entitlements further exacerbate their vulnerability (Thomas et al., 2019). Additionally, females tend to exhibit higher biological vulnerability to elevated temperatures, resulting in increased heat-related mortality (Otto et al., 2017).

Similarly, individuals in poor health are at greater risk of heat-related mortality, with extreme events like flooding potentially disrupting access to medication or life support equipment (Breil et al., 2018). These people have more physical impairments, which makes it more difficult for them to act (Climate Just, n.d.-c).

Lower-income populations struggle to prepare for and recover from extreme events, often residing in informal settlements or high-risk areas (Breil et al., 2018), which hampers their capacity to respond, adapt, and recover (Thomas et al., 2019). Furthermore, inadequate education among lower-income populations complicates the understanding of climate hazard information and appropriate responses. Language barriers, such as those faced by immigrants and refugees, exacerbate the challenge, as does residing in high-crime areas, which may deter evacuation during extreme events (Breil et al., 2018).

Poor social networks further compound vulnerability, impacting access to information and assistance, particularly among older individuals, those with disabilities, ethnic minorities, the homeless, substance abusers, and rural residents (Breil et al., 2018). Limited mobility, whether due to disability or accessibility issues, reduces autonomy and delays access to aid during hazards (Climate Just, n.d.-c).

Finally, tenants face restrictions in making housing adaptations to climate change and may lack adequate insurance or knowledge about past local hazards (Breil et al., 2018; Climate Just, n.d.-c). Factors such as inadequate green infrastructure and building construction can amplify the impacts of climate hazards, for instance, buildings with basements that are more vulnerable to flooding, or higher buildings which can be more susceptible to heat during heat waves (Climate Just, n.d.-c).

An insightful perspective on vulnerability, introduced by Amorim-Maia, Anguelovski, Connolly, et al. (2023), emphasises the concept of intersectionality. They argue that climate vulnerability is multifaceted, influenced by historical, socioeconomic, and material conditions, which collectively impact the exposure, sensitivity, and adaptive capacity of vulnerable groups (Amorim-Maia, Anguelovski, Connolly, et al., 2023). This intersectional understanding is crucial for developing targeted and effective climate adaptation strategies that address the diverse needs and challenges faced by different communities.

These factors influence individuals' and groups' sensitivity to climate change and its impacts on well-being. Social and institutional contexts shape social networks, crucial for community response to climate change (Climate Just, n.d.-c). By mapping vulnerable groups across multiple dimensions and assessing their sensitivity, adaptive capacity, and exposure, spatially targeted planning can advance climate justice, recognising diverse community risks and characteristics (Breil et al., 2018).

2.1.3. INTEGRATING CLIMATE JUSTICE INTO CLIMATE ADAPTATION PLANNING

Climate change has evolved into an ethical concern regarding justice, particularly concerning how vulnerable populations are disproportionately impacted and how cities address these challenges (Royal Town Planning Institute, 2020). The effects of climate change vary across locations, highlighting the uneven distribution of vulnerabilities within territories (UN-Habitat, 2014). Therefore, planning efforts aimed at reducing vulnerabilities and implementing climate action are essential for achieving a just

transition to a resilient society (Breil et al., 2018). Spatial planning plays a crucial role in coordinating different sectors and adopting a long-term approach through policy interventions (Royal Town Planning Institute, 2020).

The concept of climate justice has emerged as a guiding principle in the planning process, stemming from environmental justice and applied specifically to climate change. The aftermath of events like Hurricane Katrina in 2005 highlighted issues of injustice, where marginalised communities bore the brunt of the impacts due to inadequate infrastructure, lower living standards, less information, fewer loans, and continued discrimination (WIREs Clim Change, 2014), meaning lack of resilience resources (Mohai et al., 2009), which resulted in lack of capacity for preparing, avoiding, and recovering (Thomas et al., 2019). This led to a re-evaluation of the role of the natural world in conceptions of justice and the emergence of climate justice principles, focusing on reducing CO₂ emissions, transitioning away from fossil fuels, and protecting vulnerable communities through inclusive decision-making processes (WIREs Clim Change, 2014).

The main issue within climate justice is based on the principle of differentiated responsibility (Okereke, 2010). The foundation of climate justice lies in historical disparities between countries and their responsibilities for greenhouse gas emissions, with industrialised nations primarily responsible for emissions that disproportionately affect less developed countries (Porter et al., 2020; WIREs Clim Change, 2014). Climate justice recognises two distinct human groups: those who have benefited from fossil fuel-driven economic development and colonialism, and remain largely unaffected by climate change, and the majority population, which has contributed minimally to climate change but bears the brunt of its adverse effects (Porter et al., 2020).

These injustices, manifesting on both a global and local scale, underscore the imperative of placing justice at the forefront of discussions on climate adaptation. Disparities between developed and developing nations, alongside the disproportionate impact felt by marginalised communities, accentuate the urgency of addressing justice concerns (Okereke, 2010; Porter et al., 2020). The concept of climate justice is deeply rooted in the principles of social justice, drawing upon a wealth of literature on the subject. Consequently, many of the principles underpinning social justice find application in the planning and implementation of climate adaptation strategies (Okereke, 2010). Fundamentally, the pursuit of climate justice revolves around three core principles: recognition, procedural, and distribution (Bulkeley et al., 2014; Chu & Cannon, 2021; Forsyth, 2014; Malloy & Ashcraft, 2020; Mohtat & Khirfan, 2021; Ntiwane & Coetzee, 2018; WIREs Clim Change, 2014). These principles serve as guiding frameworks for ensuring fairness and equity in the face of climate-related challenges. Moreover, scholars often highlight the concept of intergenerational justice, emphasising the ethical responsibility of present generations towards future ones. This notion underscores the reality that the consequences of decisions made today will be borne by future generations, necessitating sacrifices from the current population to secure the well-being of those yet to come (Bulkeley et al., 2014; Chu & Cannon, 2021; Okereke, 2010; Porter et al., 2020; WIREs Clim Change, 2014).

Recognition involves examining how urban planning practices contribute to (solve or worsen) inequalities, vulnerabilities, and greenhouse gas emissions (Bulkeley et al., 2014), and also in understanding the geographical conditions of a group (Ntiwane & Coetzee, 2018). Its significance lies in identifying the parties responsible for climate change and its consequences, as well as those most affected by it, by being structurally vulnerable (Chu & Cannon, 2021). In the context of climate justice, it is crucial to not only assign accountability for climate change but also ensure that everyone has the right to benefit from climate change responses and protection from its impacts. Expanding on this framework, some authors (Bulkeley et al., 2014; Mohtat & Khirfan, 2021) illustrate that recognizing a neighbourhood's exclusion from the advantages of climate actions underscores the government's duty to

uphold these rights for its citizens. Moreover, these rights must be upheld through procedural and distributive mechanisms (Bulkeley et al., 2014).

Procedural justice entails establishing mechanisms for public participation in decision-making processes. To ensure equity in this participation, institutions must support public involvement by providing adequate training and resources to ensure its quality (Ntiwane & Coetzee, 2018). This collaborative approach must prioritise the inclusion of the population at all stages, as decisions may ultimately be influenced more by powerful actors despite efforts to involve minorities (Chu et al., 2018).

Lastly, the principle of distribution pertains to the fair allocation of services, resources, activities, and rights (Ntiwane & Coetzee, 2018). Typically, the unequal access to resources is not due to their scarcity, but rather stems from their uneven distribution. This uneven distribution of resources, coupled with environmental degradation, exacerbates vulnerabilities, and leads to unequal distribution of risks, disproportionately affecting certain groups (Mohai et al., 2009; Thomas et al., 2019; WIREs Clim Change, 2014).

In urban planning, integrating considerations for justice dimensions and their associated processes ensures better spatialisation of needs when designing and thus provides the necessary conditions for social well-being or even the equal fulfilment of socio-economic needs. This approach enables the promotion of fair policies that acknowledge population needs through the recognition, procedural fairness, and equitable distribution of rights (Bulkeley et al., 2014; Ntiwane & Coetzee, 2018).

Moreover, achieving climate justice requires a balanced approach across its three pillars (Bulkeley et al., 2014; Mohtat & Khirfan, 2021; Ntiwane & Coetzee, 2018). However, Mohtat & Khirfan (2021) highlight several gaps in the existing literature regarding the intersection of adaptive interventions in urban form and climate justice, an argument reinforced by Malloy & Ashcraft (2020), who say that adaptation studies generally focus on results rather than processes, and do not look at the origins of these injustices. Specifically, they note a lack of exploration into how such interventions contribute to climate justice, a disconnect between theory and practice in addressing justice within urban design, and a scarcity of multi-scalar empirical studies examining this relationship. These gaps underscore the need for further research and practical integration of justice considerations within urban planning and climate adaptation efforts (Malloy & Ashcraft, 2020; Mohtat & Khirfan, 2021; Ntiwane & Coetzee, 2018).

In the broader context of climate adaptation planning, the recognition of groups most in need of governmental attention, the equitable distribution of strategies, and the transparency of the planning process are crucial for achieving justice for the most vulnerable populations (Malloy & Ashcraft, 2020). Additionally, how projects and policies are communicated to the community significantly influences their acceptance (Royal Town Planning Institute, 2020).

Within the framework of climate justice, it is also essential to assess climate change impacts and evaluate existing plans and legislation aimed at ensuring justice within both mitigation and adaptation measures (Ntiwane & Coetzee, 2018). Despite common interventions targeting urban forms for climate change adaptation — such as green and blue infrastructure, adaptive land use, and urban design measures — these initiatives often fail to align with principles of climate justice and address broader inequalities (Mohtat & Khirfan, 2021). In some instances, adaptation plans have inadvertently perpetuated vulnerabilities among low-income and minority groups, leaving them at continued risk of flooding despite the implementation of new infrastructure within urban areas. This failure to consider climate justice is evident when these populations are subsequently displaced to less protected areas or areas near canals (Anguelovski et al., 2016). Moreover, disparities in the availability of environmental amenities, like parks and trees, are observed, with higher-income regions typically enjoying greater access. Also,

the mere presence of such amenities can exacerbate gentrification by driving up land values in surrounding areas (Anguelovski et al., 2016; Hoover et al., 2021).

The impacts of climate change manifest most prominently at the local level, encompassing economic, social, and physical dimensions. Recognizing the significance of local action, researchers emphasise the importance of integrating local knowledge from those directly experiencing climate-related challenges (McManus et al., 2014), achieved through meaningful public involvement in the planning process. However, for public engagement to succeed, the community must grasp the concepts and imperatives of climate change to ensure effective procedural justice. Initially, municipalities faced the challenge of engaging stakeholders due to limited public understanding of climate change, highlighting the critical need for increased awareness to enhance the acceptability of climate change planning (Chu et al., 2018). Another critical aspect pertains to the integration of climate change considerations into existing structures of multi-level urban governance. Effective integration demands robust connections between local land use and development plans and national climate change strategies (Bulkeley & Tuts, 2013).

To ensure effective climate action, a comprehensive approach is necessary, encompassing political commitment, well-aligned multilevel governance, institutional frameworks, laws, policies, and strategies, along with enhanced access to finance and technology (IPCC, 2023b). Clear goals and inclusive governance processes are also essential components of successful climate action initiatives.

Carefully crafted laws, policies, and participatory processes are more likely to achieve the goal of reducing vulnerabilities and risks in cities (IPCC, 2023b). Inclusive decision-making processes that incorporate diverse perspectives and experiences enable meaningful participation from all stakeholders (Breil et al., 2018). By making processes more participative, cities can foster greater acceptance of changes while ensuring that decisions reflect the realities of those affected. Local actors play a vital role in identifying community concerns, and involving local stakeholders is essential given the heterogeneous and complex nature of cities, which may be beyond the comprehension of urban planners alone (Royal Town Planning Institute, 2020). Additionally, engaging local stakeholders provides valuable insights into how adaptation and mitigation measures will impact the quality of life (Greiving & Fleischhauer, 2022).

In cases where municipalities lack internal capacity to address climate adaptation, they often establish external partnerships with representatives from civil society organisations and various entities. These partnerships commonly involve collaboration with academic and scientific institutions, community-based organisations, and local small businesses (Chu et al., 2018; The World Bank Group, 2011). Academic institutions contribute technical expertise to inform decision-making processes, while community-based organisations play a vital role in engaging directly with communities, particularly those belonging to the most vulnerable groups, thereby enhancing inclusivity within social networks (The World Bank Group, 2011).

Often, a municipality's lack of capacity comes from internal tensions over different priorities, visions, or capacities between departments (Chu et al., 2017). Efforts to integrate government departments are crucial for facilitating information sharing and fostering more integrated planning processes. Municipalities play a key role in promoting such integration (Breil et al., 2018).

As has been said, effective planning for climate change, while ensuring climate justice for all, presents a significant challenge for cities worldwide. But hopefully, numerous strategies are being implemented globally that can serve as examples of climate change adaptation. Planning activities in cities may take place through both formal and informal processes, with informal processes sometimes inadvertently addressing climate change issues within communities (The World Bank Group, 2011). Assessing the temporal and spatial dimensions of vulnerability and resilience involves mapping and scenario

simulation. Despite advancements in concepts and analysis methodologies, effectively integrating different sectors, socio-economic elements, vulnerabilities, and resilience to analyse climate change and its impacts at local and regional levels remains challenging (Greiving & Fleischhauer, 2022).

In addition to these factors, it is valuable to consider the principles associated with resilience, such as preparedness, responsiveness, connectivity, inclusion, learning/innovation, diversity and redundancy, self-organisation, social cohesion, and thresholds (OECD, 2014). Also, it's important to distinguish between adaptation as an actor-centred concept and resilience as a systems-based approach. While adaptation focuses on addressing perceived risks, resilience entails managing systems to navigate future challenges (Greiving & Fleischhauer, 2022). A climate adaptation strategy focused on reducing risks and limiting exposure, rather than solely increasing adaptive capacity, may have limitations in achieving long-term results. Therefore, achieving a more radical transformation of the system at various levels is necessary, including a re-evaluation of urban planning as a “tool to support adaptation and promote sustainable development” (Bulkeley & Tuts, 2013, p. 655).

Building resilience within vulnerable communities is crucial to mitigate the negative impacts of climate change. This can be achieved through various means, including raising awareness, engaging, and empowering community members. Involving communities in decision-making processes, such as through flood plans and flood groups, allows for tailored adaptation measures that meet local needs (Climate Just, n.d.-b). Additionally, integrating "resilience thinking" into planning and governance practices has emerged as a valuable approach to reducing vulnerabilities (Shokry et al., 2020). At the local level, planning strategies must prioritise resilience to address the variability, dynamism, and uncertainty associated with climate change and its impacts (Greiving & Fleischhauer, 2022).

Furthermore, resilience is closely linked to disaster management and urban sustainability. Assessing the environmental impacts of climate change is crucial for informed decision-making in climate adaptation efforts and should be incorporated into regional plans and local land use plans (Greiving & Fleischhauer, 2022). By considering resilience and environmental impacts, cities can develop robust regional plans and local land use plans to adapt to climate change while promoting social equity and justice for all residents.

Taking into account the above considerations and focusing on action, cities can use a range of tools for promoting climate justice, as outlined by Climate Just (n.d.-a), include workshops, mapping exercises, awareness-raising initiatives, learning about the impacts of extreme events, and understanding how to support community resilience. Engaging with the community being studied allows for the collection of diverse perspectives (Diezmartínez & Short Gianotti, 2022), fostering acceptance of policies and facilitating the development of resilience strategies tailored to community interests and priorities. This approach enables more efficient resource allocation, identification of organisations to aid in building resilience, the establishment of partnerships, advocacy supported by empirical data for adaptation with a social perspective and referencing of other case studies for guidance (Climate Just, n.d.-a).

Otherwise, green infrastructure is also frequently employed as a strategy to mitigate the impacts of extreme temperatures, particularly heat. Nonetheless, its implementation often faces resistance from lower-income communities due to concerns that maintenance costs will disproportionately burden them. Consequently, the endeavour to adapt to climate change through green infrastructure may inadvertently exacerbate vulnerabilities among these communities. Moreover, vulnerable groups may encounter the phenomenon of green and resilience gentrification, wherein sustainability initiatives become associated with urban elite interests, further marginalising already disadvantaged populations (Chu et al., 2017; Hoover et al., 2021; Shokry et al., 2020).

As stated by Bulkeley & Tuts (2013), adaptation strategies such as leveraging urban ecosystems to prepare for increased flooding or altering urban form to mitigate urban heat island effects requires new approaches to conceptualising urban development and growth. This highlights the importance of innovative thinking and inclusive decision-making processes that prioritise the needs and perspectives of all community members, particularly those traditionally marginalised or overlooked, to achieve more sustainable and equitable outcomes over the long term (Anguelovski et al., 2016).

Furthermore, a combination of top-down analysis and bottom-up assessments is essential for ensuring fairness in the planning process. While top-down approaches provide a broad analysis of vulnerabilities on a larger scale, participatory planning involving local communities offers a more detailed understanding at the community level, enabling planners to tailor strategies to specific local contexts (Breil et al., 2018).

The table (Table 2) below shows some examples of how some regions worldwide have addressed vulnerability issues in their adaptation planning and how they appear in different studies and reports published on the subject. As it is possible to see, many strategies are aimed at boosting the social capital and resilience of communities to improve their responses to climate events and their impacts.

Table 2 - Examples of climate change adaptation approaches. Source: Adapted from several authors.

Author	Location	Main Risks	Approach	Measures
Care International (2015)	Kenya, Africa	Droughts and flooding	Build resilience of vulnerable communities through Community-Based Adaptation. Through participatory scenario planning, where communities take part in workshops where they learn how to interpret weather forecasts and produce these forecasts, these people end up better understanding the risks they run and how to avoid the impacts of climatic events.	To protect themselves from droughts, they began to produce short-duration crops and from floods, removing irrigation pumps from the places most susceptible to flooding and using the land for planting, as well as vaccinating their animals.
Care International (2015)	Niger, Africa	Pest outbreaks in crop harvests	Community-based Disaster Risk Reduction and Early Warning Systems.	Early warning systems allowed the government to take action in time and prevent too many losses, and it also enhanced social cohesion and improved the knowledge of how to respond to the problem of pests. Emergency Response Committees.
(Chu et al., 2017)	Durban, South Africa	Flash floods, droughts, and coastal erosion	Plans focused on municipal water, health and disaster management functions; Improve the capacity of local communities; Focus on the environmental risks; Locally appropriate climate change tools; Multi-stakeholder partnerships.	Ecosystem-based component in interventions; Actions to mainstream climate protection, such as events to raise awareness.

(Amorim-Maia, Anguelovski, Chu, et al., 2023; Amorim-Maia et al., 2022)	Barcelona, Spain	Heatwaves	Plans to increase green coverage; “Feminist approach that recognizes and aims to rectify the gendered allocation of time for work, family, socialising, resting, and caregiving responsibilities”; Plans to improve neighbourhoods and rehabilitate building in socio-economic vulnerable areas; Transversal actions; Care centred approaches; Place-based efforts to reduce intersecting vulnerabilities.	Climate Shelters – public infrastructures that provide thermal comfort to vulnerable groups, in indoor spaces, such as schools, museums, civic centres, or outdoor spaces, such as parks and gardens. Superblocks – interventions in streets, such as pedestrianisation and landscaping. Initiatives to reduce energy poverty – “projects to subsidise and finance building retrofits, promote community solar energy generation, and provide information and technical advice”; “Opening of 11 district-level Energy Advice Points”; Mobility Plan and Low Emission Zones.
(Breil et al., 2018)	Paris, France	Heatwaves	Through the National Plan, all cities in France must register vulnerable people to heat waves at the local level; “The Paris Adaptation Plan calls for increased social cohesion within neighbourhoods and the development of stronger social networks” (p. 55).	Cooling rooms – in the face of a heat event, people are contacted through their phone number, home visits, and have facilitated access, even with transportation to these facilities; Improvement of public spaces, with blue and green infrastructures, nightly open parks and use of water sprinklers in public spaces.
(Breil et al., 2018)	Helsinki, Finland	Flooding and heatwaves.	“Spatial analysis of social vulnerability determined by adaptive capacity (ability to prepare for, respond to and recover after extreme weather events), sensitivity (related to age), and enhanced exposure (type of housing and presence of green space)” (p. 48-49).	The results of these mapping of vulnerabilities and climate hazard will allow a better prioritisation of interventions to reduce the risks of vulnerable groups to climate hazards.

(Breil et al., 2018)	United Kingdom	Flooding and heatwaves.	Climate Just Tool – “combines diagnostic maps with guidance documents” (p. 34), in which the maps overlay several indicators of social vulnerability, such as unemployment, tenure, age, and local knowledge, with climate hazards information. In London, residents were engaged in the process.	Implementation of blue and green infrastructure; Light engineering solutions, such as small basins, rain gardens and green roofs; Programs of employment and apprenticeship; Improve of several urban spaces.
Climate Just	Hampshire, UK	Flooding	Build community resilience through a community-led approach, in which the HIOWLRF (Hampshire and the Isle of Wight Local Resilience Forum) engaged with the residents to enable them to respond to flooding; First, they identified flood risk areas, by mapping the flow of water during floods.	They engaged with local schools to raise awareness, they also published a book for children and distributed it in the schools.
Climate Just	York, United Kingdom	Not specified.	Encourage residents to achieve a healthier lifestyle; Stimulate pro-environmental behaviour; Public engagement; “Achieve a measurable reduction in household carbon emissions; Raise public awareness of low-carbon lifestyles; Foster community cohesion through joint actions; Support connections between community action and JRHT [Joseph Rowntree Housing Trust] work on sustainability; Enhance local skills for self-sufficiency and build local resilience” (p. 1).	Practical activities with the community, such as walking in nature and fruit picking, planting, “providing material for lessons and organising and running an environment summit with the local secondary school and developing a shared vision for the future with residents using community maps to identify opportunities for improvements to the neighbourhood” (p. 1).

In this context, climate adaptation efforts should strive to optimise outcomes, efficiency, and equity, ultimately leading to enhanced adaptation and community resilience, while concurrently mitigating risks through the reduction of vulnerabilities and exposure. Efficiency pertains to the effective allocation and management of resources and logistics, needing coordinated efforts to enhance cost-effectiveness. Equity, on the other hand, underscores the imperative of justice, entailing the empowerment of vulnerable groups and their meaningful inclusion in the decision-making processes (Enamul Haque et al., 2022).

Navigating the planning process is intricate, particularly when striving to embed methodologies that foster climate justice within adaptation planning. Public institutions rely on community engagement to facilitate efficient climate adaptation. Recognizing and valuing public participation as a cornerstone of this process is pivotal, as it offers invaluable insights into the genuine needs of communities, rooted in their unique historical, economic, and social contexts.

Acknowledging the distinctiveness of each community and its varied susceptibility to climate change, planners face challenges in intervening proactively in every instance of impending danger. Consequently, there is a reliance on communities to be prepared to withstand the impacts of climate change, particularly in the immediate aftermath of a disaster, hence underscoring the concept of community resilience. Subsequent sections will delve into this concept further, examining how bolstering social infrastructure and implementing climate shelters can fortify resilience within urban environments.

2.2. BUILDING A CLIMATE RESPONSIVE PLANNING

In the context of known climate change scenarios and impacts, cities must be prepared to confront extreme weather events and their associated risks. The objectives outlined in the Paris Agreement target both climate mitigation and adaptation, seeking to diminish greenhouse gas emissions while bolstering cities' resilience to climate change impacts. In response, numerous cities across the planet have embarked on initiatives to address these challenges, often spurred by incentives originating from international, national, or municipal agreements (Reckien et al., 2018; UN Environment Programme, 2022).

However, in this respect it is important to distinguish between climate-responsive urban design and urban planning amidst these efforts. Climate-responsive urban design integrates the elements of location, climate, and human activity to mitigate the adverse effects of climate change on the built environment. This approach underscores the importance of considering microclimatic factors and necessitates a focus on localised interventions (Cortês et al., 2020; Tamminga et al., 2020). Conversely, urban planning is primarily concerned with land use on a broader scale, shaping the overall urban fabric and spatial organisation. Given the urgent need to address climate change, urban planning should adopt a more holistic approach to crafting urban policies (Kozłowski & Yusof, 2016).

Both planning scales hold significance and should be developed in tandem. As climate action predominantly unfolds at the local level, cities assume a pivotal role in responding to climate change by formulating local plans and policies (Kozłowski & Yusof, 2016; Reckien et al., 2018).

The urban fabric enables people to move between climate-controlled environments (such as home and indoors work) and non-controlled ones (such as parks and beaches). [...] The impacts of climate responsive urban planning and design can also be observed through the factor determining the degree of inclusiveness or

exclusiveness of social environments in which a broad range of people can spend time in. (Tavares et al., 2020, p. 1–2)

In the context of interventions to deal with the impacts of climate change, the case of heat islands has been given a very high profile on urban agendas. Heat islands represent a prevalent phenomenon in urban areas, wherein the process of urbanisation alters the ground surface, leading to temperature spikes of up to 10°C in urban environments. This temperature escalation adversely impacts public health and necessitates increased energy consumption for cooling strategies within building (Liu et al., 2023). In addition to heat islands, flooding poses a significant threat to urban life, underscoring the importance of policies related to effective water management (Lee et al., 2018).

Within this framework, various architectural and urban strategies exist to address climate change impacts, yet these interventions must be implemented proactively to ensure the preparedness of buildings and the urban landscape. Climate-responsive planning, particularly concerning elevated temperatures, entails manipulating urban morphology to facilitate ventilation corridors and shading (Liu et al., 2023). Furthermore, urban design can contribute to temperature mitigation through strategies such as:

“[...] creating breezeway or air path, aligning main street in parallel to prevailing wind, linking open spaces, avoiding blockage of sea/land breezes and prevailing wind, introducing nonbuilding areas, improving the building height variation, adopting terraced podium design in large development sites, providing wide gaps between building blocks, removing obstructions, etc.” (Liu et al., 2023, p. 264)

Shading strategies, such as tree planting, are also crucial for mitigating heat in urban environments. Notably, streets oriented on a north-south axis tend to experience warmer temperatures compared to east-west streets. Additionally, the ratio of building height to street width significantly impacts the amount of shade provided. Another effective approach involves integrating green spaces within cities. Beyond offering shade, vegetation plays a pivotal role in cooling the surrounding areas through evapotranspiration and diminished heat absorption. At an architectural level, green roofs and walls further enhance the integration of vegetation into urban environments (Liu et al., 2023).

In line with this approach, Tamminga et al. (2020) introduce the concept of green convivial streets, which prioritise both climatic comfort and human interaction. These spaces serve as a planning strategy to address climate change adaptation while also fostering social capital, an essential element of urban resilience. Community gardens, in particular, serve as valuable hubs for socialising, thereby fostering a sense of community.

In conclusion, all the proposals and approaches collected from the literature and summarised over the last few pages, are presented as contributions or solutions that enable cities to adapt to climate change and alleviate its impacts on their populations. Achieving climate responsiveness necessitates holistic planning that comprehensively addresses the diverse needs of all groups within the urban landscape. Moreover, considering climate adaptation in the fabric of the city can take various forms. By fostering community resilience and social capital, each group becomes better equipped to address vulnerabilities and respond to disasters more effectively. Social infrastructures play a pivotal role in reinforcing these connections and providing refuge during extreme weather events such as heat waves or flooding. Finally, the deployment of climate shelters throughout cities serves to mitigate the adverse impacts of such extreme events on the population. These aspects of urban planning will be explored in greater detail below.

2.2.1. COMMUNITY RESILIENCE AND SOCIAL CAPITAL

As has already been extensively explained in the literature, the built environment, encompassing streets, buildings, and infrastructures, significantly influences greenhouse gas emissions and can disrupt natural processes such as evapotranspiration, exacerbating phenomena like droughts and floods. Consequently, cities have a major responsibility to develop adaptation plans to safeguard their residents from the impacts of climate change. However, institutions alone may be insufficient in addressing the needs of all groups of the population, underscoring the necessity to develop adaptive capacity by the communities, to better respond to these impacts and mitigate risks (Rafael et al., 2015). On the other hand, strengthening the **resilience** of communities can reduce dependence on external assistance during possible future disasters (Shirleyana et al., 2023).

According to the Intergovernmental Panel on Climate Change (IPCC, 2023b), resilience is defined as "the capacity of interconnected social, economic, and ecological systems to cope with a hazardous event, trend, or disturbance, responding or reorganising in ways that maintain their essential function, identity, and structure" (IPCC, 2023b, p. 128). It can be related to both "bouncing back" to its initial state and "bouncing forward" to a new state (Heinzlef et al., 2022). A resilient city represents a network of interconnected systems, encompassing both physical and human elements. In essence, it encompasses not only the natural and built environment but also the diverse characteristics of communities (Ray & Shaw, 2018).

Resilience has garnered increased attention, as evidenced by its inclusion in frameworks such as the Sendai Framework for Disaster Risk Reduction, the UN Sustainable Development Goals, and the Paris Agreement (Enamul Haque et al., 2022; Wilkin et al., 2019). It is a concept that is increasingly being addressed by researchers in various fields of study, such as the social and natural sciences (Lv et al., 2024), gathering more researchers every day in various areas of knowledge (Carmen et al., 2022).

The concept of resilience in urban contexts has expanded to encompass not only ecological systems but also social and economic systems (Enamul Haque et al., 2022). With its broad applicability, resilience finds relevance in ecology, engineering, social sciences, socio-ecological studies, disaster management, urban planning, and community development (Enamul Haque et al., 2022; Rafael et al., 2015; Shirleyana et al., 2023). In ecology, resilience denotes a system's capacity to absorb impacts, accommodate unpredictable variables (Shirleyana et al., 2023), achieve rapid recovery (Lv et al., 2024), and revert to its original state following a disturbance (Enamul Haque et al., 2022). In engineering, resilience pertains to the stability of a system to recover and restore its original form post-disruption. In disaster risk management, resilience is crucial for communities to withstand, adapt to, and recover from disasters. These conceptualisations have led to the formulation of community resilience, which integrates social and ecological systems, incorporating spatial, environmental, social, economic, and institutional dimensions (Shirleyana et al., 2023). Ultimately, in this respect, the reinforcement of resilience must also be intertwined with principles of sustainable urban development (Rafael et al., 2015).

On the other hand, urban resilience focuses on understanding the human-environment relationship and views cities and urban networks as adaptive systems. It pertains to communities' capacity to adapt in the face of challenges (Carmen et al., 2022). The literature on urban resilience addresses this concept in its various dimensions: urban ecological resilience, urban hazards (stressors) and disaster risk reduction, resilience of urban and regional economies, and promotion of resilience through urban governance and institutions. Urban hazards and disaster risk reduction emphasise enhancing the capacity of cities, infrastructures, and populations to respond to both natural and anthropogenic stressors. The resilience of urban and regional economies examines the interplay between resilience and economic development in urban areas and regions. Lastly, resilience, through urban governance and institutions, evaluates how

different governance mechanisms and resilience-oriented approaches impact resilience across different contexts, including financial instruments, insurance policies, regulatory procedures, program formulation, and community and investor participation (Rafael et al., 2015).

The pluridisciplinarity of the concept of resilience presents a challenge in developing methodologies for its assessment (Wilkin et al., 2019). Standardising the concept of resilience in the context of climate change within urban environments is crucial for enhancing understanding among political decision-makers and facilitating more effective dialogue (Lv et al., 2024). As a result, urban resilience policies are emerging in areas such as water management, social infrastructure, and green strategies (Lee et al., 2018).

One of the hurdles in determining community resilience to climate change is the scarcity of assessment methods. However, Twigger-Ross et al. (n.d.) highlight several important aspects to consider. Firstly, assessments should integrate various dimensions beyond climate change, incorporating broader community issues and evaluating the community's competencies, understanding, and adoption of responses to climate change. Secondly, it is essential to understand the capacities of a community by examining its social capital and institutional capacity, including the existing organisations and their interconnections. Third, and lastly, analysing the support available to the community, including voluntary organisations and residents' associations, is crucial. These organisations serve as intermediaries between the community and governments or institutions. Examining these elements is imperative for understanding the resilience of a community and its ability to effectively respond to the impacts of climate change (Twigger-Ross et al., n.d.).

In this sense, building resilience can be defined as the collective ability of interest-based communities to collaboratively enhance their capacity to adapt to shocks and stresses. This endeavour extends beyond mere technical knowledge and infrastructure interventions; it encompasses social and psychological dimensions, local knowledge, effective communication, social learning, and interpersonal connections (Carmen et al., 2022). Resilience-building efforts can employ a combination of soft measures, such as information dissemination and institutional support, as well as more tangible measures, such as grey infrastructure or green initiatives based on nature or ecosystems (Lv et al., 2024).

Everyday resilience is vital for reducing vulnerability, addressing acute disasters such as floods and fires, and confronting daily challenges related to economic insecurity, crime, and social conflicts (Shirleyana et al., 2023). However, when contemplating long-term climate adaptation, resilience defined merely as returning to a baseline state is insufficient, particularly for highly vulnerable communities (Twigger-Ross et al., n.d.). Resilience, rather than being a static goal, is an ongoing process. It requires systemic considerations, and collaboration among diverse stakeholders, perspectives, and needs, encompassing all dimensions pertinent to climate change.

As conceptualised in the extant literature, resilience can be seen in three distinct ways: reactive resilience (Carmen et al., 2022; Twigger-Ross et al., n.d.), responsive resilience (Carmen et al., 2022), and proactive resilience (Carmen et al., 2022; Twigger-Ross et al., n.d.). Reactive resilience involves immediate actions taken post-shock to restore the system to its initial state and stabilise it (Carmen et al., 2022; Twigger-Ross et al., n.d.). Typically, this approach entails top-down interventions by the government or unsupported actions by the local population (Carmen et al., 2022). This immediate response might not be as efficient in the long-term (Twigger-Ross et al., n.d.). Responsive resilience entails learning from shocks to adapt social, environmental, and physical aspects and fortify the existing system. This perspective of resilience requires the involvement of multiple actors and capacities in processes of change. Proactive resilience, conversely, entails fundamental changes to the system, such as adaptation and transformation (Twigger-Ross et al., n.d.) through a process of experimentation,

reflection, and learning, incorporating multi-scalar perspectives and engaging community norms, identities, and values. While the first two interpretations of resilience primarily aim to restore the initial state, proactive resilience recognises the necessity of system-oriented change for more effective adaptation. This approach, known as System-Oriented Change, emphasises restructuring governmental arrangements and power dynamics. However, these changes must occur in a flexible and redundant manner to shape a complex, nonlinear, and dynamic system (Carmen et al., 2022).

Considering the elements that collectively contribute to the resilience of systems by enhancing their capacity to absorb shocks, adapt to changing conditions, and maintain essential functions over time, it can be mentioned, according to Carmen et al. (2022):

1. Adaptability and flexibility;
2. Consider shocks and stresses, whether foreseen or not;
3. Connect horizontally to develop solutions that encompass diverse issues, including the various perspectives of different social levels;
4. Transformative action to reduce carbon emissions;
5. Strengthen vertical connections between social levels and enable collaborative actions;
6. Positive narratives to generate hope and inspire action;
7. Stimulate creativity to see alternative futures;
8. Climate disadvantages and reducing inequalities at the centre of the issue to reduce climate injustices and generate climate action;
9. Design processes and pathways encouraging participation, learning and empowerment; and
10. Create transformative change.

Lv et al. (2024) note a scarcity of literature concerning resilience within climate-vulnerable communities, with existing studies predominantly focusing on geographically isolated communities and factors pertinent to disaster resilience. However, it is imperative to consider important elements of urban policies related to climate change at the local scale, as emphasised by Rafael et al. (2015). These elements include good governance, national programs, participatory and democratic institutions, municipalities equipped with expertise in climate change, city commitments to addressing these issues, and the availability of financial resources, knowledge, and information for climate action.

Consequently, taking these components into account facilitates knowledge dissemination, awareness building, and risk information dissemination to empower communities to apply this knowledge during times of risk (Rafael et al., 2015). The processes aimed at reducing vulnerabilities are intrinsically linked to the cultivation of resilience to climate risks, underscoring the interconnectedness of vulnerability and resilience in the development and implementation of urban policies. Accordingly, these concepts can be perceived as complementary facets within a system, with each influencing the other (Lv et al., 2024; Rafael et al., 2015).

Various actors, including governments, communities, non-governmental organisations, researchers, the private sector, and the media, play crucial roles in responding to climate change by employing science, policies, knowledge, technology, and financial resources. Collaboration among these actors is essential for effective mitigation and adaptation efforts in the face of climate change challenges (Enamul Haque et al., 2022). The Stockholm Resilience Centre has outlined seven principles for fostering resilience: maintaining diversity and redundancy, managing connectivity, addressing slow variables and feedback, promoting complex adaptive system thinking, fostering learning, enhancing participation, and advocating for polycentric governance (Hauge Simonsen et al., 2015).

Resilience, as highlighted by Lv et al. (2024), is closely linked to the **adaptive capacity** of a group, enhancing its ability to anticipate, respond to, and recover from external shocks; it is central to

building resilience (Care International, 2015; Lv et al., 2024). Building adaptive capacity often involves bottom-up planning processes, where programs need to be flexible enough to allow communities or non-governmental entities to take the initiative. This can be achieved through educational initiatives and participatory solutions at the local level, complemented by actions at regional, national, and international scales (Enamul Haque et al., 2022). Various factors influence adaptive capacity, including social capital, aspirations, trust, livelihood diversification, asset ownership, and human capital (Lv et al., 2024).

In addition to adaptive capacity, absorptive capacity is another crucial concept. Absorptive capacity involves anticipating events and planning accordingly to respond and recover effectively, through protective action, aiming to return to its initial state (Jeans et al., 2017). It encompasses measures to prevent and mitigate the negative impacts of shocks and also involves integrating external experiences for educational, financial, and developmental diversification (Lv et al., 2024).

Transformative capacity, on the other hand, is more closely related to deeper changes in the societal structure (Jeans et al., 2017). Lv et al. (2024) describe it as encompassing laws, socio-cultural norms, local community connections, social safety nets, and other factors that create an environment conducive to social change. This capacity involves generating accessibility to products and services and addressing systemic issues. The transformative factor implies that after a disaster, the system does not simply return to its previous state but adapts and transforms into something new. This transformation process involves community inclusion and participation in decision-making processes, indicating a shift towards more systematic changes within society (Lv et al., 2024), achieving reduced vulnerabilities, poverty, inequalities, and risks. All three capacities – adaptive, absorptive, and transformative – are interconnected and must exist at multiple levels, from individual to national (Jeans et al., 2017).

In geographically isolated areas like Riverine Island in Bangladesh, the population, particularly the poorest, grapple with food insecurity and limited access to essentials due to factors like river erosion, droughts, flooding, and other natural calamities. To bolster resilience to such disasters, a range of strategies has been implemented, focusing on building adaptive, absorptive, and transformative capacities. Initiatives to enhance adaptive capacity include risk management training, local leadership development, and the establishment of disaster shelters to prepare the community for extreme weather events. Strengthening absorptive capacity involves providing access to informal safety net programs, encouraging savings, facilitating support from relatives, and distributing food aid through voluntary organisations, among other measures. Transformative capacity is fostered through donations of materials for rebuilding structures post-disaster, financial incentives from public entities, and the provision of evacuation services, among other interventions. Notably, climate shelters emerged as a critical factor for resilience during research conducted in the coal islands of Bangladesh, alongside health recommendations from health and family agencies (Lv et al., 2024).

Disasters are characterised by their unpredictability, ranging from timing and magnitude to the extent of damage and the challenges in mounting an adequate response. They often result in loss of life and displacement, with many affected communities lacking immediate access to vital resources such as food, water, shelter, and medicine (Mutch, 2023). Studying disaster resilience is essential for comprehending the impact of catastrophes on vulnerable groups, and elucidating causes, variables, and the ways climate change exacerbates hazards. Such studies enable the formulation of evidence-based policies aimed at mitigating risks and enhancing resilience (Lv et al., 2024).

Disasters are inherently local events, impacting different communities in diverse ways, underscoring the significance of community resilience in effectively managing and responding to them (Wilkin et al., 2019). Community resilience encompasses the preparedness, response, mitigation, and recovery efforts aimed at minimising the adverse effects of disasters on communities. However, it is common for risk

management plans to prioritise the physical aspects of the territory while overlooking the social dimensions of the impacts of these risks (Sanyal & Routray, 2016).

In some communities, disasters can occur with a certain frequency, on a smaller or larger scale, affecting homes and further increasing vulnerabilities, through theft, damage to physical structures, flooding, crime, and disease. These events often result in economic losses, social disruption, and loss of life, exacerbating chronic problems within affected populations (Shirleyana et al., 2023).

Responding to the impacts of disasters involves various phases of disaster risk management, as outlined by Sanyal & Routray (2016). The preparedness phase encompasses actions taken before a disaster to minimise its impact, including local-level mitigation measures. It involves implementing strategies for disaster response through education on emergency protocols, recovery procedures, communication networks, and emergency supply readiness (Lv et al., 2024; Sanyal & Routray, 2016). The response phase spans from the receipt of early warning information to the immediate aftermath of the disaster, while the relief phase encompasses the period following immediate response until the commencement of recovery efforts. Finally, the recovery phase is the duration it takes for a community to recuperate from the impacts of a disaster, rebuild infrastructure, and restore essential services (Sanyal & Routray, 2016).

While the population, with its networks and capacities, plays a crucial role in responding to the impacts of climate change, they require support from institutions and governments at various levels to enhance their resilience (Care International, 2015; Rafael et al., 2015). Municipalities must take initiatives at the local level, tailoring their public policies to specific audiences, while national governments must provide incentives and improve communication of up-to-date information to ensure broad access. However, it is insufficient for vulnerable populations to merely receive information; they must also be empowered to participate in capacity-building processes (Rafael et al., 2015; Twigger-Ross et al., n.d.).

In this context, **Community-based Adaptation (CBA)** is gaining prominence in the discourse on climate change response, emphasising the empowerment of communities in resilience-building efforts (Patnaik, 2021; Roy et al., 2022). Community-based planning is essential for fostering resilience to climate change, enabling initiatives to be developed by NGOs, cooperatives, closely bonded ethnic groups, villages, or societies with specific objectives in mind (Enamul Haque et al., 2022). CBA primarily targets vulnerable groups and rural communities, implementing measures to promote disaster risk reduction, preparedness, agricultural protection, water management, food security, and resilient livelihood solutions within these communities (Care International, 2015; Enamul Haque et al., 2022; Lasage et al., 2008).

CBA should foster self-organisation through community governance systems. To achieve this, it should incorporate resilience principles and draw insights from case studies. Enamul Haque et al. (2022) outline the process of developing such solutions, which should involve analysing the root causes of vulnerabilities, building capacity, implementing participatory solutions, adopting an integrated approach with multiple smaller and redundant solutions, prioritising risk management, and emphasising monitoring and learning (Basel et al., 2020; Enamul Haque et al., 2022; Fry et al., 2023; Ikhlas & Ramadan, 2024). Therefore, it can be concluded that CBA should be bottom-up, participatory, and place-based, prioritise the most vulnerable and low-income populations, involve multilateral, multi-level, and cross-sectoral initiatives, and benefit from the growing number of professionals in the field (Enamul Haque et al., 2022; Roy et al., 2022). Finally, through a CBA approach in planning, it is possible to achieve community resilience in a more equitable way (Fry et al., 2023).

Then, incorporating community involvement in the climate adaptation process through CBA enhances transparency, representation, and overall management effectiveness. However, external support is

essential to facilitate this process and develop policies outlining how this participatory approach will be implemented (Care International, 2015; Enamul Haque et al., 2022; Ikhlās & Ramadan, 2024). Collaboration with higher-level institutions supportive of climate adaptation, including international agencies, global agreements, academic research institutions, local, national, and international governments, as well as local NGOs, is crucial to promote sustainable and resilient measures (Enamul Haque et al., 2022).

To encourage community participation, mechanisms facilitating communication between governments, international agencies, and communities were established (Enamul Haque et al., 2022). Social movements and the efforts of NGOs played a pivotal role in amplifying the voices of these communities (Markphol et al., 2021). Additionally, with the growing recognition of CBA, several international institutions have begun allocating more resources to address the issue. Institutions such as The Global Environment Facility, Green Climate Fund, United Nations Development Programme (UNDP), and NGOs like CARE International have initiated programs and funds to support this methodology (Enamul Haque et al., 2022).

While effectively applied CBA processes can reduce risks and enhance resilience, several challenges persist. These challenges include socio-political barriers, resource constraints, limitations within physical systems and processes, and lack of political will (Enamul Haque et al., 2022; Patnaik, 2021). Evidence suggests that policies often overlook differences between communities, individuals within a community, and their access to resources (Patnaik, 2021; Twigger-Ross et al., n.d.). Communities may initially exhibit reluctance due to unfamiliarity with technologies, projects conflicting with cultural values, or communication barriers such as language differences or unclear stakeholder responsibilities. Additionally, the political dependence of CBA projects on governments may hinder resource allocation to marginalised communities. Resource constraints encompass financial resources, time, information, and infrastructure access. Furthermore, physical systems may pose challenges as climate change risks exceed the adaptive capacity of CBA initiatives (Enamul Haque et al., 2022).

It's crucial to ensure that resilience-building efforts do not inadvertently exacerbate vulnerabilities within communities. If resilience is viewed as part of the community's capacity, there's a risk that the responsibility for responding to shocks and stresses falls solely on the people, rather than on those in positions of power. Moreover, individuals in vulnerable situations often lack control over their circumstances. Each community possesses unique needs and capacities, asking for programs and policies that account for these differences to achieve more effective outcome (Roy et al., 2022). Various aspects, such as social factors including social, economic, and local inequalities, as well as the starting point and precedence associated with community actions, can be evaluated to assess if a community is progressing towards resilience (Twigger-Ross et al., n.d.).

In conclusion, some authors (Breil et al., 2018; Care International, 2015; Enamul Haque et al., 2022; Markphol et al., 2021) advocate for the need to establish more holistic guidelines for Community-based Adaptation (CBA) to enable efficient and flexible replication. Enamul Haque et al. (2022) also emphasise the importance of developing monitoring and evaluation mechanisms for implemented projects to provide reliable feedback, facilitating the understanding of what works well or poorly for future interventions.

A compelling case study that exemplifies the application of CBA for building resilience is seen in Thailand (Enamul Haque et al., 2022). Thailand contends with various extreme weather events, including tropical storms, floods, and droughts, along with rising sea levels impacting rice plantations, mangrove ecosystems, and coral reefs. These ecological impacts further impede fishing activities and access to essential resources in the region. The government implemented a top-down CBA methodology,

but with significant community involvement, acknowledging indigenous knowledge. This approach led to the development of a Climate Vulnerability and Capacity Analysis (CVCA) methodology to gather indigenous knowledge. This methodology was applied to 16 coastal areas in Thailand and 20 coastal areas in Indonesia through the Building Coastal Resilience to Reduce Climate Change Impact Program (BRC-CC), which is a three-year project, funded by the European Commission (Enamul Haque et al., 2022).

This program was structured into four categories to address various aspects of building resilience and adaptation to climate change. The first category focused on enhancing resilience in livelihoods by establishing a platform for sharing knowledge about the impacts of climate change on livelihoods. This initiative aimed to adapt this knowledge to the community's language for effective communication and facilitated a bottom-up flow of information to better address community needs. The second category centred on disaster risk reduction (DRR) by raising awareness about climate change impacts on natural environments, such as mangroves, and providing education on their preservation and recovery. The third category aimed to build the capacity of civil society and local governments through training and the dissemination of accessible information. Lastly, the fourth category addressed the root causes of vulnerabilities on the ground by incorporating feedback, knowledge, questions, and concerns from communities to inform decision-making at the national government level (Enamul Haque et al., 2022).

Each of these categories leveraged community engagement, education, and involvement to underscore the significance of empowering communities in climate adaptation processes (Enamul Haque et al., 2022). Empowering communities in decision-making processes fosters a sense of belonging and ownership, making adaptation efforts more effective (Basel et al., 2020). Equipped with resources and knowledge, communities can respond more swiftly and efficiently to climate impacts when disasters occur, complementing institutional interventions (Care International, 2015; Enamul Haque et al., 2022).

Resilient planning plays a crucial role in ensuring the inclusion of vulnerable groups and addressing the unequal distribution of climate change impacts within urban environments. It is essential to integrate principles of equality and justice into the planning process itself (Fry et al., 2023). Particularly concerning community resilience, the involvement of diverse stakeholders and resources is imperative (Lv et al., 2024).

A cornerstone of resilience is **social capital**, increasingly recognised as pivotal in fostering community resilience (Shirleyana et al., 2023). Social capital spans various disciplines, including sociology, political science, economics, and international development, and can be delineated into four dimensions: social networks, social networks and outcomes, social networks, trust, and norms of reciprocity, and social networks and socio-cultural dimensions (Carmen et al., 2022).

Social networks are integral components of social capital, encompassing communal aspects like the sharing of norms and values that foster mutual trust and cooperation among group members (McCann & Fünfgeld, 2016). It pertains to the connections between individuals and has an impact on aspects such as health, access to information, or civic engagement. Both concepts are related to the increase in participation and community decision-making (Patnaik, 2021). They encompass aspects such as norms, trust, and reciprocity, which foster cooperative attitudes and actions, engendering pro-environmental behaviours and more sustainable outcomes (Carmen et al., 2022).

To delineate the dimensions of social capital more comprehensively, three categories have been developed: bonding, bridging, and linking social capital (Carmen et al., 2022; Masik, 2022; McCann & Fünfgeld, 2016; Shirleyana et al., 2023).

1. Bonding social capital - characterised by close-knit connections based on shared identities, such as family ties, friendships, neighbourhood relationships, or affiliations based on common cultural, religious, ethnic, or geographic backgrounds (Carmen et al., 2022; Mutch, 2023). These connections represent the closest and most intimate social circles, comprising individuals upon whom one can readily rely, in an informal manner (Masik, 2022; Mccann & Fünfgeld, 2016).
2. Bridging social capital - entails more distant connections that are nonetheless valuable when established, even though weaker (Carmen et al., 2022; Mccann & Fünfgeld, 2016). These connections typically extend beyond one's immediate social circles and involve interactions with individuals from other communities or groups. Bridging social capital is often instrumental in accessing resources, opportunities, or information beyond one's immediate sphere (Mccann & Fünfgeld, 2016).
3. Linking social capital - involves vertical relationships with institutions or individuals possessing varying levels of power or political influence. These connections are leveraged to pursue objectives that may be situated further afield from one's immediate social context. Linking social capital plays a crucial role in navigating formal structures and accessing resources or support from higher levels of authority (Mccann & Fünfgeld, 2016; Mutch, 2023; Sanyal & Routray, 2016).

Social networks, which encompass these forms of social capital, are essential for facilitating information exchange, fostering trust, and mobilising resources within communities. Networks characterised by dense connections indicate a robust flow of information and a high level of mutual trust among members. Moreover, identifying central figures within these networks, individuals with extensive connections and influence can be instrumental in disseminating information, coordinating community initiatives, and providing critical resources (Carmen et al., 2022; Mccann & Fünfgeld, 2016).

Of particular relevance is the recognition that the connections between social capital and community resilience are multifaceted and integral to understanding how social dynamics shape the capacity of communities to respond to and recover from shocks and stresses. These connections can be delineated into several key aspects (Carmen et al., 2022):

1. Networks Density: A greater number of social relationships fostered by social capital enhance social support, facilitate the circulation of information, and cultivate goodwill within communities. This bolstered social cohesion improves the community's ability to respond effectively to various shocks and stresses (Carmen et al., 2022). It is the most analysed aspect of a network (Mccann & Fünfgeld, 2016).
2. Networks Diversity: Social capital encompasses both bonding and bridging networks. Bonding social capital fosters intra-community support, while bridging social capital facilitates connections with external entities such as government agencies. This diversity of networks enhances the community's resilience by providing access to a broader range of resources and information during crises.
3. Management of Multiple Capitals: Effective management of diverse factors, including natural, human, economic, and physical resources, can positively influence the community's responsiveness to challenges. By leveraging social capital, communities can coordinate efforts to address multifaceted issues and build adaptive capacity.
4. Role of Formal Organisations: Formal organisations play a crucial role in resilience-building by leveraging social capital, particularly trust and reciprocity, to enact policies and regulations that promote responsive resilience at various levels of governance.
5. Slow Structural Changes: Over time, slow changes in social networks, experiences, and natural resources can influence the resilience of communities. These changes may lead to adaptive

structural adjustments that enhance the community's flexibility and adaptability in the face of evolving challenges.

6. **Socio-Cultural Dimensions:** Subjective aspects such as a sense of belonging, cultural norms, identity, and values profoundly influence community interventions and initiatives. These socio-cultural dimensions shape the community's proactive resilience by informing collective actions and decision-making processes.

These interconnected aspects illustrate the intricate relationship between social capital and community resilience, highlighting the multifaceted ways in which social dynamics contribute to the adaptive capacity and sustainability of communities (Carmen et al., 2022). To visualise these influences more comprehensively, a graph depicting the interconnectedness of these factors has been developed (Fig. 2).

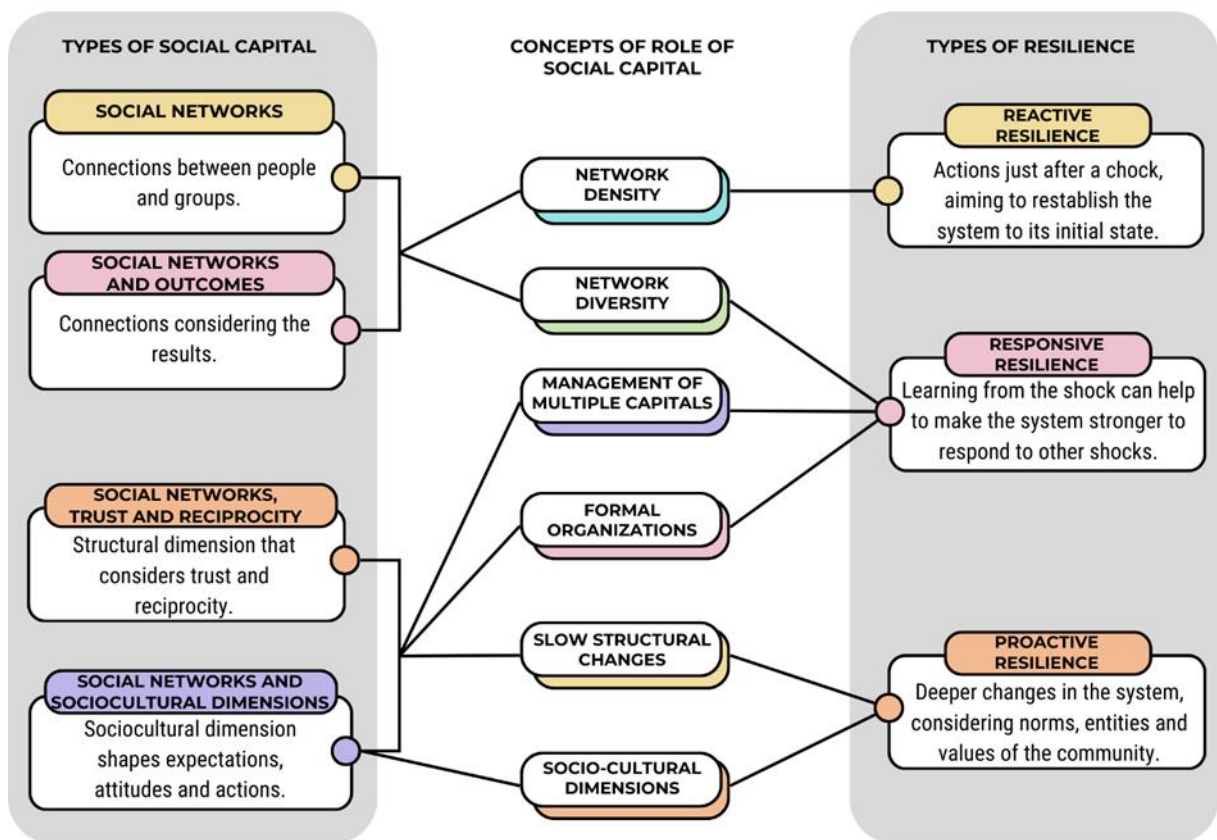


Fig. 2 - Scheme of influences of social capital in resilience types. Source: adapted from Carmen et al., 2022.

Social network analysis, which has roots dating back to the 1930s and was formally recognized as a distinct research area in the 1970s, has emerged as a valuable tool in social and behavioural science research (McCann & Fünfgeld, 2016). This approach employs mathematical methods and information technologies to study social structures, processes, and contexts, shedding light on how decisions related to climate adaptation and risk management are made, how information flows influence these decisions, and how adaptive capacity is cultivated (McCann & Fünfgeld, 2016; Wilkin et al., 2019).

In the realm of disaster risk reduction (DRR), analysing social networks within communities is paramount for fostering bottom-up processes and enhancing community resilience. Such studies provide

insights into the intricate social structures within communities, thereby contributing to the effectiveness of top-down policy implementations (Mccann & Fünfgeld, 2016; Wilkin et al., 2019).

The interplay between social capital and resilience is indeed crucial in understanding community responses to extreme events and their subsequent recovery processes. Social capital enhances recovery efforts by fostering mutual aid, resource sharing, and collective problem-solving, as well as it is enhanced after a crisis. As demonstrated by the earthquake example in Gili Trawangan in Indonesia, social networks played a pivotal role in expediting recovery and strengthening community bonds, thereby enhancing both bonding and bridging social capital (Shirleyana et al., 2023).

However, although it is recognised that social capital plays a critical role in building resilience (Abunyewah et al., 2023), Carmen et al. (2022) argue that while social capital can bolster resilience, it may not be sufficient on its own, especially in contexts marked by significant vulnerability, marginalisation, or inequality. Vulnerable and marginalised groups may face additional barriers to building resilience, requiring targeted interventions that go beyond social networks alone (Carmen et al., 2022).

Moreover, there are risks associated with over-relying on social capital as the solution for resilience. Social capital dynamics can inadvertently perpetuate socio-economic exclusion or resistance to change, particularly in the face of external pressures such as shifts in government policies or market-driven approaches. Additionally, social capital and resilience are not static; they can be eroded or diminished over time, particularly when confronted with systemic challenges or narrow, technical solutions that fail to address holistic community needs (Carmen et al., 2022).

In summary, while social capital is a critical component of resilience-building efforts, it must be complemented by targeted interventions addressing structural inequalities, systemic vulnerabilities, and broader socio-economic dynamics to ensure that resilience is inclusive, sustainable, and adaptive to evolving challenges. Also, incorporating principles of equity, justice, and inclusivity into resilient planning processes is crucial for addressing the unequal impacts of climate change on vulnerable populations. By actively involving vulnerable groups in decision-making processes and ensuring their needs and perspectives are considered, planners can help alleviate existing inequalities and promote climate justice (Fry et al., 2023).

Community resilience plays a key role in advancing climate justice by fostering more inclusive policies and actions that empower communities to effectively respond to climate change impacts. By understanding and addressing both vulnerability and resilience within communities, policymakers and practitioners can better support communities in building their capacity to adapt to and mitigate the effects of climate change, both reactively and proactively (Twigger-Ross et al., n.d.).

In essence, promoting community resilience alongside principles of equity and justice is essential for creating more resilient and equitable societies that are better equipped to confront the challenges posed by climate change. This approach not only helps to address existing disparities but also promotes more sustainable and inclusive forms of development that benefit all members of society.

2.2.2. SOCIAL INFRASTRUCTURE

Social infrastructures are pivotal spaces fostering interaction and the cultivation of relationships, crucial for individuals' well-being and sense of community (Högström et al., 2022; Williams-Eynon, 2023). Defined broadly, any setting conducive to social engagement qualifies as a social infrastructure, forming the background of structures which allow life to unfold (Latham & Layton, 2019). Social infrastructure

should be viewed as an integral component of urban planning, enriching the vibrancy of cities (Högström et al., 2022).

Infrastructure manifests in physical and economic forms, encompassing essentials like roads, airports, water, and sewage systems, as well as social components such as housing, educational institutions, and healthcare facilities. Social infrastructure, however, encompasses more aspects of the community beyond physical structures, which can also be referred to as "soft" infrastructure, namely the social environment, services and programmes that support human capital, public safety, jobs, and training. The symbiosis of both forms of infrastructure is imperative for nurturing thriving communities (Teriman et al., 2011). Ultimately, social infrastructures serve as conduits for interpersonal connections, underpinning the creation of social capital, a cornerstone in fostering resilience (Palanki, 2023).

Communities frequently rely on social infrastructures, which may include community centres, adjacent residences, schools, or libraries (Iglesias-Pascual et al., 2023; Khaled Al Shawabkeh et al., 2022; Latham & Layton, 2019; McShane & Coffey, 2022; Williams-Eynon, 2023). The significance of social infrastructures extends beyond strengthening the social fabric of communities, they also provide physical structures for protection against climate disasters. These spaces often become havens during crises, assuming the additional function of shelters (Tan, 2014). When adequately equipped, they serve as hubs for information dissemination, provisioning of food, medical aid, and communication, mitigating local vulnerabilities. Viewing social infrastructure as a strategy for fostering resilience in at-risk communities is therefore essential for promoting both protection and community engagement during disasters (McShane & Coffey, 2022; Tan, 2014).

Social infrastructure can be categorised into three primary groups as outlined by Teriman et al. (2011): community facilities encompassing structures like community centres, health centres, hospitals, and places of worship; community services spanning educational, services, library services, and vocational, recreational and sporting programmes; and physical support infrastructure comprising amenities tailored to enhance populace well-being, including pedestrian and cyclist-friendly infrastructure, recreational spaces, retail centres, facilities catering to individuals with special needs (Tan, 2014; Teriman et al., 2011), as well as green and blue spaces that serve as meeting points for communities, fostering interaction (Campbell et al., 2022).

Traditional physical infrastructure can determine the consequences of a flood or heat wave, but the ability of a community to recover from climate events is deeply affected by the strength of its social infrastructure and social networks. [...] Adequate social infrastructure creates the conditions for organizations and individuals to share resources, organise recovery activities, and maintain emotional attachment to places as they undergo long and difficult roads back from disaster (Williams-Eynon, 2023, p. 16).

In this sense, social infrastructures within urban environments play a crucial role in fostering social cohesion by facilitating interaction among individuals and diverse social groups, transcending distinctions of race, age, gender, sexuality, or income (Iglesias-Pascual et al., 2023). To effectively serve their purpose, social infrastructures must exist at various scales, from neighbourhood to city level, fostering social interaction, strengthening social networks, and contributing to a sense of belonging within communities (Khaled Al Shawabkeh et al., 2022). The built environment of cities serves as a canvas for the creation of social networks, thereby positioning urban spaces as pivotal elements in cultivating community resilience (Tan, 2014; Williams-Eynon, 2023).

The diverse mix of uses within the built urban environment, including mixed-use buildings, walkable areas, green spaces, and several services and activities, fosters increased density of human interactions, elevating opportunities for cross-path encounters and social engagement while bolstering feelings of trust, safety, and community (Williams-Eynon, 2023).

The following table (Table 3) highlights some examples of spaces that serve as social infrastructures:

Table 3 - Examples of places that can serve as social infrastructure. Source: adapted from Latham & Layton, 2019; Williams-Eynon, 2023

	Type of Space	Examples
Outdoor Spaces	Blue/Green Infrastructure	Parks, gardens, community gardens, vegetable gardens.
	Urban Infrastructures - Transit	Sidewalks, bus stops, bike lanes, subway, train stations, walking trails.
	Interstitial spaces	Lobbies, plazas, terraces, courtyards, spaces between buildings.
Indoor Spaces	Recreational Activities	Sports courts, swimming pools, skate parks, gyms, cinemas, theatres.
	Commercial Establishments	Coffee shops, restaurants, bars, markets, hair salons, barber shops, laundrettes, street vendors.
	Community Hubs	Community Centres, health care facilities, job centres, resilience hubs.
	Public Institutions	Libraries, museums, public schools, art galleries, universities, memorials
	Religious Institutions	Churches, mosques, synagogues, temples.

More than physical structures, social infrastructures are dynamic constructs that facilitate and nurture relationships through active engagement. Latham & Layton (2019) outline some key characteristics defining social infrastructures, including their embedded nature, transparency, repeated use, requisite learning processes, adherence to practise conventions, incorporation of norms, being built, and recognition of closure or cessation. These attributes underscore the interconnectedness of social infrastructures within a network, wherein their utilisation extends beyond functional necessity to encompass opportunities for community members to connect. Utilising such facilities entails the acquisition of specific behaviours or activities, necessitating a learning curve. Moreover, these facilities must adhere to certain standards to furnish users with basic physical amenities such as heating, lighting, plumbing, and communication infrastructure. Paradoxically, while social infrastructures may not be immediately recognised for their social function, their closure inevitably results in a palpable absence felt by the population (Latham & Layton, 2019; Stender & Nordberg, 2022).

A study conducted in a lower-income residential neighbourhood in Denmark during the COVID-19 pandemic delineated three tiers of social infrastructure: formal, informal, and digital (Högström et al., 2022). Formal spaces denote venues provided by institutions for specific functions yet are often repurposed by individuals to forge connections (Stender & Nordberg, 2022). The pandemic-induced closure of these spaces underscored communities' resilience in creating alternative socialising arenas (Högström et al., 2022).

Emerging from the exigencies of the pandemic, informal social infrastructures have arisen in unconventional spaces such as voids between buildings, staircases, corridors, car parks, or balconies, providing alternative venues for social interaction. These ad-hoc spaces, termed "pop-up" infrastructures, are temporary adaptations encompassing initiatives like extending restaurant seating onto streets, reconfiguring traffic flow to prioritise pedestrian and cyclist access, and repurposing schools and hotels as temporary shelters (Stender & Nordberg, 2022). Williams-Eynon (2023) also refers to informal infrastructures, referring to them as "third places", namely commercial establishments like cafés, restaurants, barbershops, and beauty salons, which also function as social infrastructure by serving as hubs for social interaction.

The final tier of social infrastructure, approached by Högström et al. (2022) and Stender & Nordberg (2022), is the digital, which facilitates social connection without physical proximity. These digital platforms range from mobile phone-based social networks to communication channels via radio or television. The pandemic underscored humanity's innate need for social contact, prompting the emergence of new spaces to sustain social connections during times of crisis or when access to formal venues is restricted (Stender & Nordberg, 2022).

As the event of the pandemic of Covid 19 illustrated by Stender & Nordberg (2022), crises accentuate the pivotal role of community involvement in the planning of social infrastructures, given that communities are the primary beneficiaries and users of such spaces (McShane & Coffey, 2022). Hence, community participation is indispensable from planning processes to implementation, particularly in the provision of community centres within vulnerable communities. These centres, crucial as critical infrastructure in climate change adaptation efforts, must be interconnected and accessible to residents, emphasising the significance of disseminating information regarding their locations and hours of operation. Given their community-based nature and often community-run operations, fostering networks among these centres enables mutual learning and collaboration (McShane & Coffey, 2022; Teriman et al., 2011).

An intriguing facet of social infrastructure emerges when communities take ownership of spaces and actively participate in their management, effectively transforming them into communal assets. Civic groups play a pivotal role in this transformation, impacting spaces "physically, discursively, and politically" (Campbell et al., 2022, p. 2). By fostering social encounters and facilitating the creation of social networks, these initiatives promote enhanced communication and social cohesion rooted in principles of respect and trust, thereby fostering the development of social capital (Campbell et al., 2022; Iglesias-Pascual et al., 2023; Shirleyana et al., 2023; Tan, 2014). Recognising the social dimension of social infrastructures is imperative as they serve as catalysts for the formation of social networks. To effectively contribute to social cohesion and resilience-building, social infrastructures must transition into everyday spaces through inclusive strategies that integrate community input into their design and implementation processes (Tan, 2014).

Amidst the climate crisis, there arises an imperative to transform spaces to safeguard populations, with local-level social infrastructure emerging as a pivotal component of this process. Community centres, in particular, offer a myriad of services including shelter, accommodation, meeting spaces, information

dissemination points, and distribution hubs for essential supplies such as food and medicine, thereby playing a critical role in supporting communities (McShane & Coffey, 2022). The shelter and refuge functions of these infrastructures are especially vital in safeguarding populations during extreme weather events (Williams-Eynon, 2023).

During disasters, the initial response often stems from communities themselves, emphasising the critical role of social connectivity in climate change adaptation processes. By facilitating contact between individuals, social infrastructures contribute to the resilience of social structures, thereby engendering a sense of security crucial during disasters (Tan, 2014). Despite their recognition as critical infrastructure in climate change literature, urban policies have often overlooked the importance of social infrastructure. For instance, Australia, until 2019, had yet to incorporate social infrastructure into its national infrastructure plan (McShane & Coffey, 2022).

Studies conducted by Mutch (2023) underscore the pivotal role of schools during times of crisis, highlighting their ability to bolster the social capital of communities across multiple dimensions. Schools foster bonding within communities, facilitating preparedness and swift responses due to established relationships. Additionally, they exhibit bridging functions by providing support to families during the recovery phase, serving as conduits for resources from external communities. Furthermore, schools play a crucial linking role in the reconstruction of infrastructure, as they maintain connections with various levels of government. During crises, schools often serve as shelters where community members seek refuge, finding solace, sustenance, and emotional support. Moreover, school events can serve as milestones in the community's rebuilding journey, further strengthening social capital and resilience (Mutch, 2023).

The primary function of social infrastructure in fostering resilience lies in reducing vulnerabilities exacerbated by inequalities. Addressing these stressors, which impact health, well-being, and adaptive capacities, is essential for reducing vulnerabilities within communities (Williams-Eynon, 2023). Given their dispersed and embedded nature within the urban fabric, infrastructures encompass technological, social, material, and political dimensions, significantly influencing city functionality (Latham & Layton, 2019). Urban planning endeavours must thus prioritise the creation of spaces conducive to functioning as social infrastructure during crises, as these spaces promote community resilience and adaptation (Stender & Nordberg, 2022).

It is crucial to underscore that by fostering greater social cohesion, social infrastructures possess significant potential as a strategy for climate adaptation. These infrastructures serve as critical resources for communities grappling with climate disasters. Therefore, prioritising the planning of these infrastructures with a climate adaptation focus will enhance community resilience in the face of environmental challenges.

2.3. CLIMATE SHELTERS

As the climate crisis unfolds, the imperative to transform spaces for safeguarding populations has become increasingly evident. At the local level, social infrastructure emerges as a pivotal component in this transformation, serving as critical infrastructure. These centres serve multifaceted roles, offering shelter, accommodation, communal spaces for gatherings, and information hubs, as well as dispensing essential provisions such as food and medicine, among other services, all aimed at supporting the population (Huddleston et al., 2022; McShane & Coffey, 2022).

Originally conceived as defences against terrorist threats, critical infrastructures have undergone a shift in focus due to mounting apprehensions surrounding climate change. Consequently, there has been a

call to reconfigure these infrastructures to confront emerging risks (Huddleston et al., 2022). Viewing critical infrastructures through the lens of community-based adaptation is essential for addressing the evolving needs precipitated by climate change and its ramifications on communities (Henshel & Ashby, 2023).

The conventional notion of critical infrastructure, once primarily fixated on physical structures, has now expanded to encompass broader considerations including social, cultural, and ecological dimensions. Huddleston et al. (2022) delineate four categories of critical infrastructure: physical, green (or nature-based), institutional, and cultural. Physical or hard infrastructures constitute the backbone of community support systems, focusing on delivering services and goods vital for human welfare, prosperity, and positive socio-economic and environmental outcomes. Green critical infrastructure, entwined with a network of natural and constructed elements, is increasingly viewed as a climate-resilient alternative to traditional physical infrastructure. Institutional infrastructure underpins the functionality of physical infrastructure, encompassing non-physical systems that underscore the significance of a skilled workforce, effective policies, and inter-agency collaborations. Cultural infrastructure is also intangible, represented by a sense of community, a sense of belonging, local knowledge, and culture (Huddleston et al., 2022).

Urban areas serve as primary arenas for climate action, such as climate shelters, given the heightened vulnerability of cities to climate change-induced repercussions. Damage incurred by urban centres due to climate change encompasses infrastructure deterioration, heightened mortality rates due to heat-related ailments, diminished energy availability, and scarcity of water and food supplies (Salimi & Al-Ghamdi, 2020). Instances of disaster often necessitate evacuations from homes and communities, engendering a series of health issues including anxiety, depression, and post-traumatic stress disorder among affected populations (Wu et al., 2019).

In the aftermath of a disaster, the provision of shelter emerges as a cornerstone for human survival, providing safety and protection (The Sphere Project, 2011). These shelters must not only exist but also be accessible to the public, particularly during times of heightened risk. Moreover, they must be adequately equipped to fulfil their intended role of safeguarding populations. For shelters designated for prolonged occupancy, provisions such as ample food, water, fuel, bedding, mattresses, and clothing are imperative. Disaster relief shelters are tasked with ensuring safety, hygiene, and livable conditions to mitigate the impact of crises (Bashawri et al., 2014). The requisites of communities affected by disasters vary depending on the nature and magnitude of the calamity, as well as the scale of displacement endured by individuals (The Sphere Project, 2011).

Climate shelters emerge as indispensable urban critical infrastructures crucial for facilitating adaptation to extreme weather conditions, whether situated indoors or outdoors. These shelters serve as integral components of people's daily lives, functioning as systems that bolster social connections within communities while offering vital services aimed at ensuring protection, safety, and comfort in urban settings. However, their utilisation and distribution can potentially exacerbate vulnerability, exerting influences on public health and environmental parameters (Amorim-Maia, Anguelovski, Connolly, et al., 2023).

These adapted urban spaces not only provide respite during extreme events but also protect against wind and ensure thermal and acoustic comfort on a day-to-day basis (Amorim-Maia, Anguelovski, Connolly, et al., 2023; Montero-Gutiérrez et al., 2023). Shelters play dual roles in preparedness and action (Henshel & Ashby, 2023), spanning a spectrum from private initiatives to facilities provided at municipal, state, or federal levels (Amorim-Maia, Anguelovski, Connolly, et al., 2023; Henshel & Ashby, 2023). They

may serve for extended periods, spanning from months to years following a disaster (Bashawri et al., 2014).

In many communities, schools and daycare centres often serve as critical infrastructures (Henshel & Ashby, 2023). Nevertheless, diversification of shelter options is imperative to ensure continuity of services in the event of disruptions affecting these primary facilities (The Sphere Project, 2011).

The utilisation of these shelters can, however, engender injustices contingent upon their utilisation and distribution, given their potential impacts on public health and environmental well-being. Additionally, for urban climate shelters to operate efficiently, it is imperative not only to ensure equitable distribution but also to foster public awareness regarding their network, enabling individuals to identify appropriate shelters based on their location and the prevailing event (Amorim-Maia, Anguelovski, Connolly, et al., 2023). The planning and adaptation of shelters need to take place on a large scale to provide community resilience in cities. In addition, a well-planned shelter network has better health outcomes (Wu et al., 2019). Critical infrastructure planning must be redundant (Henshel & Ashby, 2023).

Tan (2014) illustrates a compelling example of social infrastructure serving as a climate shelter and fostering community resilience through the boats in Bangladesh. Originally conceived as educational infrastructure for flood-prone communities, these vessels have evolved to encompass multifaceted roles as libraries, schools, and clinics. Beneath their functional aspects lies a deeper purpose of community connectivity, bolstering social networks at the grassroots level. This initiative underscores the significance of community engagement in the design process, fostering greater acceptance and ownership within the community, thereby establishing a self-sustaining and resilient framework.

Mutch (2023) points out that schools, because of their vast networks, tend to take the lead when disasters strike, providing support for communities in the short and long term. After all, they serve as a shelter because they have headmasters and teachers to serve as leaders and help the population, and because of the contribution of young people in the recovery. This shelter function that schools have is an important element in generating community resilience and social capital.

It's important to consider that only creating a network of climate shelters isn't enough to protect the population, but it's necessary to communicate to the population about the existence of these shelters, adapt them appropriately for the types of events and network within the community to help and encourage people to use these spaces.

2.4 SYNTHESIS

Currently, strategies aimed at enhancing community resilience are predominantly top-down. However, when confronted with climate-related disasters, communities often find themselves compelled to navigate short-term responses independently, lacking immediate institutional support. In such scenarios, local residents emerge as primary responders, extending assistance to neighbours or family members in distress (Henshel & Ashby, 2023), by offering their houses as refugees (Henshel & Ashby, 2023; The Sphere Project, 2011).

Adequate preparedness is the result of the work of governments, humanitarian agencies, and local organisations to respond to and anticipate dangers. This can be measured through risk analysis and early warning of disasters. With better preparation, shelters will be more effective in responding to disasters (The Sphere Project, 2011).

Climate shelters can make use of social infrastructures that the community is already accustomed to using daily. These spaces, if appropriate, make it more intuitive to use them during extreme weather

events. In everyday life, these spaces strengthen social capital and, consequently, community resilience, which, during crises, is an important factor for human survival. Furthermore, when people have to rely on their social networks, they also end up strengthening them. Adaptation must be based on the community to include it in the decision-making process. This community involvement is important both in the selection of spaces and interventions in them, to generate a greater sense of community and get people to integrate. Finally, a network of climate shelters is fundamental to climate adaptation.

The figure below (Fig. 3) highlights key points illustrating how climate adaptation planning must incorporate the principles of climate justice to achieve community resilience through the development of a climate shelter network. By reviewing the principles of climate justice—such as recognition, procedural, and distributional justice—the planning process must include both top-down and bottom-up approaches. This involves recognising vulnerable groups and assessing risks within the territory.

The procedural principle emphasises a bottom-up approach by involving the population, especially the vulnerable, in the decision-making process. This ensures that all voices are heard and considered, leading to equitable distribution of infrastructure. Identifying existing social infrastructure allows planners to understand how the population uses these spaces and select the most suitable ones to become climate shelters. Consequently, people can seek refuge in familiar spaces during extreme climate events, reinforcing their social capital and enhancing overall resilience.

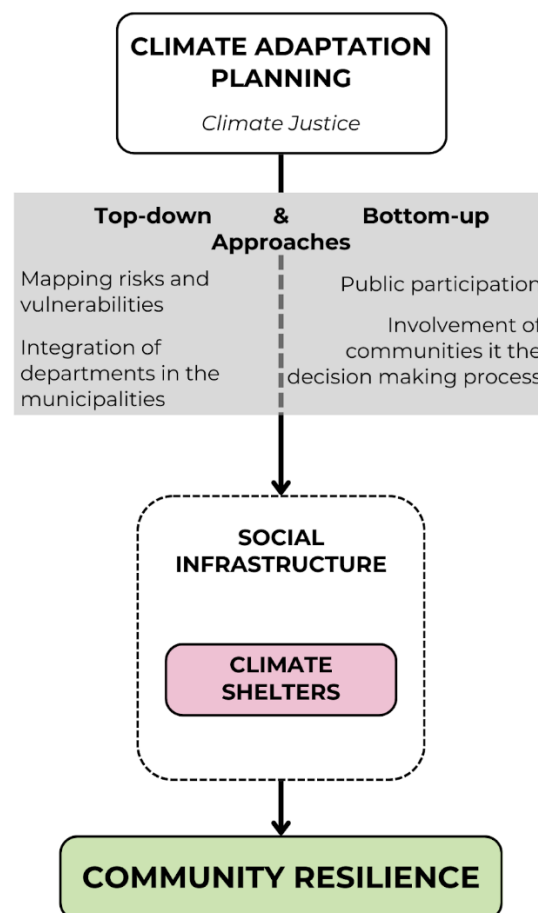


Fig. 3 - Scheme of the concepts studied in this topic. Author's own elaboration, 2024.

3

REFERENCE CASES OF CLIMATE SHELTERS

Studying different cities that have invested in strategies for climate shelters is crucial for understanding the methods applied, as well as the criteria selection and implementation of these facilities. Many other cities are undertaking initiatives that can be considered as climate shelters, utilising existing infrastructure, creating new structures, or implementing street adaptations to enhance pedestrian comfort, such as the green ventilation corridors in Stuttgart.

Moreover, there are projects focused on communicating more comfortable spaces during hotter days, like the Extrema App, developed in Athens but adopted by cities such as Paris, Rotterdam, Milan, and Mallorca. This application enables users to monitor temperatures, humidity levels, and thermal discomfort indexes, providing information on the safest and coolest areas, locations of drinking water, and recommending comfortable routes.

The following case studies evidence various approaches, ranging from isolated interventions for climate sheltering to comprehensive initiatives such as studies, competitions, and the establishment of a network of climate shelters. These case studies also detail the selection process and communication strategies employed to inform the population about these shelters. The majority of the presented case studies are from Spain, chosen due to its similar weather conditions to Portugal and its significant investment in climate sheltering initiatives, particularly in response to heat waves.

3.1. BARCELONA, SPAIN

With the advent of climate change, there is a discernible shift towards drier and hotter summers, marked by increasingly frequent and intense heat waves in Barcelona. This heightened heat poses significant risks to public health, particularly among vulnerable demographics such as the elderly. Furthermore, cold temperatures also present challenges for certain populations, including the elderly and the homeless (Ajuntament de Barcelona, n.d.). Moreover, marginalised communities often struggle to maintain optimal indoor temperatures, exacerbating their vulnerability (Amorim-Maia, Anguelovski, Connolly, et al., 2023).

To address these challenges, Barcelona has developed its Climate Plan comprising 242 actions aimed at both mitigating and adapting to climate change, fostering climate justice and citizenship. The foremost action of this plan revolves around enhancing resilience and adaptation measures to enhance citizens' quality of life. Central to this effort is the enhancement of thermal comfort in buildings and public spaces and the establishment of a network of climate shelters (Ajuntament de Barcelona, 2018).

In alignment with the European Commission, the Covenant of Mayors for Climate and Energy, and the Urban Agenda Partnership for Climate Adaptation, Barcelona City Council is spearheading integrated climate adaptation policies. This endeavour has garnered support from various institutions in the domains of energy, health, water, and education (López Plazas et al., 2023).

The creation of a network of climate shelters, initiated in 2020, stands out as a pivotal strategy. Selection criteria for these sites include the maintenance of temperatures at 26°C in summer and 19°C in winter, alongside considerations for accessibility, rest areas, and access to water for cooling (Brandon, 2022; Florian, 2022). These shelters serve as havens for vulnerable groups, including infants, the elderly, and individuals with chronic illnesses, with particular emphasis on their significance in low-income neighbourhoods (Ajuntament de Barcelona, n.d.).

These shelters encompass both outdoor spaces—such as parks and gardens rich in foliage and water features—and indoor venues, including schools, museums, libraries, and civic centres. Outdoor locations are activated during the peak heatwave season from June 15 to September 15, whereas indoor facilities remain accessible year-round to provide protection against both heat and cold (Ajuntament de Barcelona, n.d.; Florian, 2022).

Schools, in particular, have been repurposed as shelters through initiatives like the "Adapting Schools to Climate Change through Green, Blue, and Grey" project. Interventions such as installing water fountains and creating green wall gardens have bolstered their efficiency as shelters (Florian, 2022). Out of the city's 160 schools, 45 initially expressed interest, with 11 ultimately selected based on criteria such as geographical distribution, solar exposure, building energy efficiency, and vulnerability to noise and pollution. Conversion into climate shelters necessitated a combination of blue (water-related), green (foliage-based), and grey (built elements) measures to optimise thermal comfort (López Plazas et al., 2023).

In addition to establishing shelter locations, this initiative has facilitated public access through an online mapping tool (Fig. 4) and a targeted communication campaign via brochures distributed at strategic city points. By 2023, the project had rolled out over 200 shelters across the city, ensuring that 95% of the population had access within a 10-minute walk from their residences. Future plans aim to further reduce this radius to 5 minutes by 2030, with the ultimate goal of providing coverage for the entire population (Ajuntament de Barcelona, n.d.; Amorim-Maia, Anguelovski, Connolly, et al., 2023; Brandon, 2022; Florian, 2022).

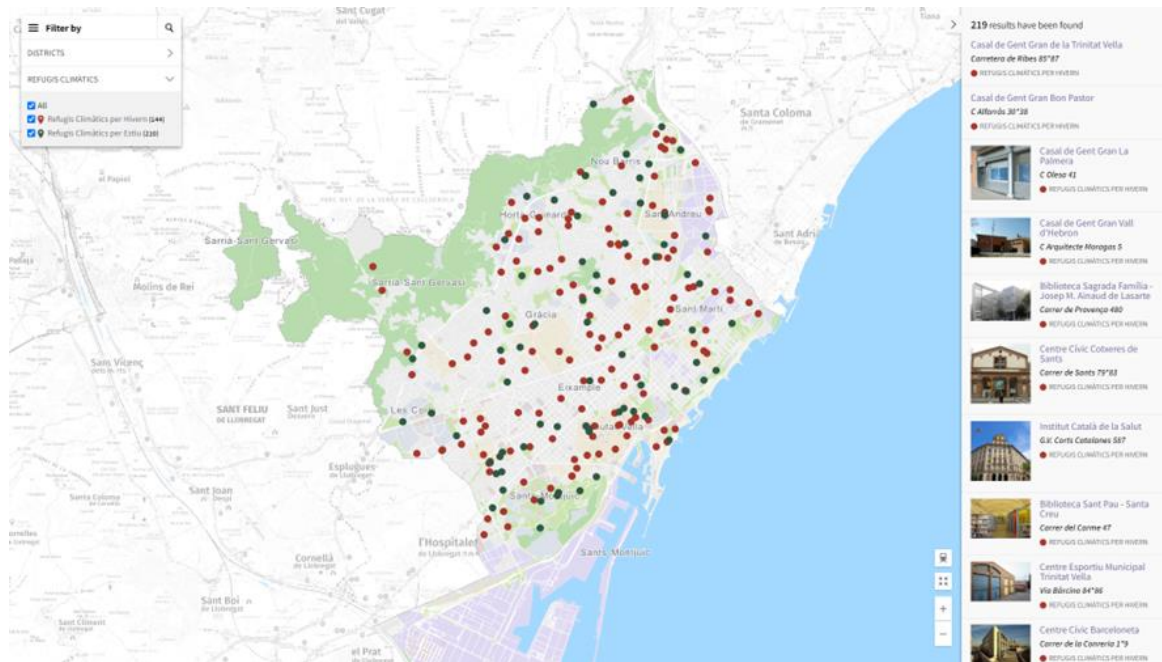


Fig. 4 - Webpage with Barcelona's map containing the climate shelters distributed in the city. Source: Ajuntament de Barcelona (n.d.)

Despite the considerable number of shelters established, a survey conducted among residents of Barcelona's La Prosperitat neighbourhood revealed persistent deficiencies in staff training and protocols within some shelters, as well as a dearth of engaging activities for shelter occupants. Additionally, many shelters operate on reduced hours during public holidays, coinciding with the hottest days in 2021, exacerbating accessibility issues (Amorim-Maia, Anguelovski, Connolly, et al., 2023).

Moreover, individuals from the most vulnerable demographics, including women, the elderly, and immigrants, often opt to remain at home during extreme weather events due to a lack of adequate thermal comfort infrastructure. Immigrants, particularly those from the Global South, exhibit lower awareness and willingness to utilise shelters (Amorim-Maia, Anguelovski, Connolly, et al., 2023).

This initiative in Barcelona underscores the municipality's commitment to enhancing residents' quality of life during extreme events. Despite challenges regarding shelter utilisation among certain groups, the city council is actively investing in communication and awareness campaigns to ensure widespread knowledge of these facilities. Continued investment in mechanisms to encourage shelter utilisation, particularly among vulnerable populations, is imperative. Moreover, maximising shelter efficiency has the potential to foster community cohesion by serving as meeting points and disseminating knowledge about climate shelters (Amorim-Maia, Anguelovski, Connolly, et al., 2023).

3.2. SEVILLE, SPAIN

Seville, nestled in the Andalusia region of southern Spain, holds the distinction of being continental Europe's hottest city, with temperatures projected to soar up to 50°C by 2030 amid the exacerbating effects of climate change. The city's climatic evolution towards aridity, marked by dwindling rainfall, has profound ramifications spanning health, economic development, employment, urban planning, and management (Karydi, 2022).

In response to the challenges posed by extreme heat events and urban heat islands, Seville has launched the Cartuja Qanat project, an urban initiative geared towards climate adaptation. Central to this endeavour is the Qanat, an underground water channel situated 20 metres beneath the surface, designed to harness cool air from subterranean water sources and channel it to the surface via ventilation shafts (Buces, 2021).

Led by the city council, the Cartuja Qanat project serves as a collaborative effort uniting the expertise and resources of public entities, universities, research institutions, and private enterprises. It encompasses a multifaceted structure aimed at enhancing environmental comfort, fostering social interaction, and catalysing the development of sustainable models, with the potential for replication across other city sectors (Karydi, 2022). This initiative unfolds in two phases, with the first phase focusing on urban regeneration and integration into the urban landscape as an ecosystem anchored on three foundational elements: bioclimatic Qanats for cooling, subterranean galleries (zoco) for social engagement, and bioclimatic amphitheatres (UIA, n.d.).

Crucially, community engagement and stakeholder education are integral components of the project, alongside fostering public-private partnerships, revitalising public spaces, and instituting a new governance framework (UIA, n.d.). Implementation of these innovative structures, depicted in Fig. 5, represents a pioneering step towards curbing energy consumption by providing bioclimatic comfort solutions. The incorporation of open green spaces, water features, and amenities throughout the city aims to enhance public enjoyment and well-being. Subterranean galleries will mitigate heat ingress while offering shade and greenery, facilitating fresher ventilation. Amphitheatres, leveraging water-based strategies including lakes and Qanats, further contribute to the overall cooling effect and enhance urban resilience (Buces, 2021).



Fig. 5 - Representations of the structures proposed in the Cartuja Qanat Project. Source: Karydi (2022).

Furthermore, in 2020, the European Climate Adaptation Platform Climate-ADAPT, in collaboration with the European Commission and the European Environmental Agency, initiated the LifeWaterCool program to assist Seville in addressing its escalating challenges of soaring temperatures, flash floods, and droughts. This program summoned urban planners, architects, and engineers to devise solutions for these pressing issues in the city, emphasising the integration of bioclimatic principles across short-, medium-, and long-term strategies (Taylor, 2023).

One innovative solution proposed by a team of researchers from the University of Seville involves repurposing bus stops into short-term weather shelters, leveraging cutting-edge technology. This

technology harnesses cold water circulating through pipes embedded within the walls and roof of the structure (Fig. 6). The water is cooled underground using energy generated by photovoltaic panels adorning the bus stop's roof (Mike, 2023; Montero-Gutiérrez et al., 2023). Implementation of this groundbreaking project is slated to commence in 2024.

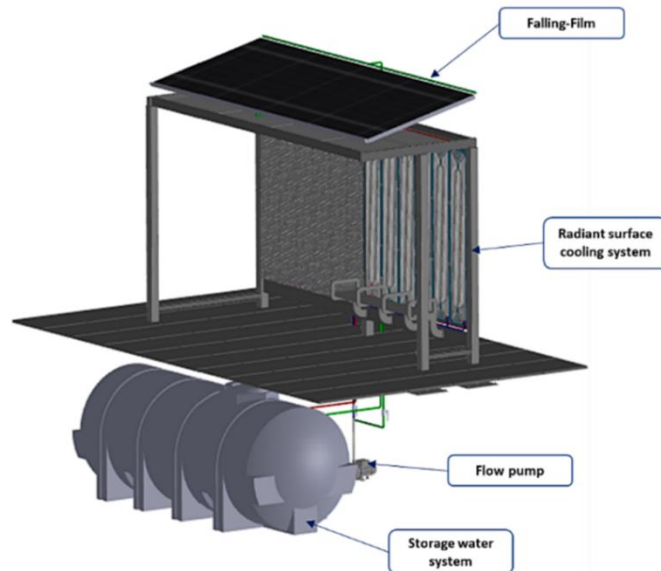


Fig. 6 - Scheme of the bus stop with its cold water circulation. Source: Montero-Gutiérrez et al. (2023).

Additionally, there are plans to extend this initiative to transform schools into shelters for children. Some schools have already undergone modifications, including the installation of roof structures over open spaces to shield them from solar radiation, thereby enhancing their suitability as shelters (Taylor, 2023).

Indeed, Seville has adopted several strategies that serve as climate shelters or offer spaces of enhanced climate comfort accessible to the population. While the Cartuja Qanat project may not be explicitly designated as a climate shelter initiative, it contributes to creating environments of greater climate comfort open to residents. Furthermore, it is anticipated that Cartuja Qanat will inspire the development of additional strategies and foster community engagement, thereby bolstering urban resilience in the face of climate change.

On the other hand, the bus stops repurposed into short-term weather shelters represent a tangible measure aimed at providing immediate relief for pedestrians traversing the city. These shelters offer temporary respite from extreme weather conditions, enhancing the overall comfort and safety of individuals navigating Seville's streets.

Together, these initiatives reflect Seville's proactive approach to climate adaptation, utilising innovative solutions to mitigate the impacts of rising temperatures, flash floods, and droughts. By providing accessible spaces of refuge and comfort, Seville endeavours to enhance the well-being and resilience of its residents in the face of evolving climatic challenges.

3.3. BILBAO, SPAIN

Bilbao actively participates in European climate adaptation projects like RAMSES, which assesses risk and vulnerability in the region, encompassing flooding, atmospheric pollution, rising sea levels, and

heatwaves. The establishment of the Bilbao Climate Change Office underscores the city's commitment to educating the populace about climate issues and fostering climate adaptation efforts at both individual and institutional levels. The office's initiatives include identifying and monitoring vulnerable transport infrastructure, promoting innovative design solutions, advocating for green infrastructure and nature-based solutions, and implementing adaptation policies and measures (Oficina del Cambio Climático de Bilbao, n.d.).

In response to the challenges posed by extreme heat, Bilbao has developed a network of climate shelters comprising 130 locations, 64 of which are indoors and 66 outdoors. These shelters, ranging from libraries and civic centres to sports facilities and public transport stops, serve their usual functions under normal weather conditions but are accessible to the public during hot spells for relief and rest. While not intended for medical care, these spaces are equipped with cooling amenities, water sources, and seating areas. Outdoor shelters are strategically located in the city's green areas, providing shade and access to water fountains for hydration (Bilbao's Council, 2022).

Primarily targeting vulnerable groups such as children, the elderly, and individuals with respiratory ailments, these shelters are designated for use specifically during hot days (Bilbao's Council, 2022). Communication about the shelters is facilitated through leaflets distributed to the population, featuring illustrative maps prepared by the City Council's Mobility and Sustainability Area, highlighting the locations of both outdoor (Fig. 7) and indoor shelters (Fig. 8) (Bilbao's Council, 2022). This comprehensive approach underscores Bilbao's proactive stance in addressing the challenges of extreme heat and enhancing the resilience of its communities.

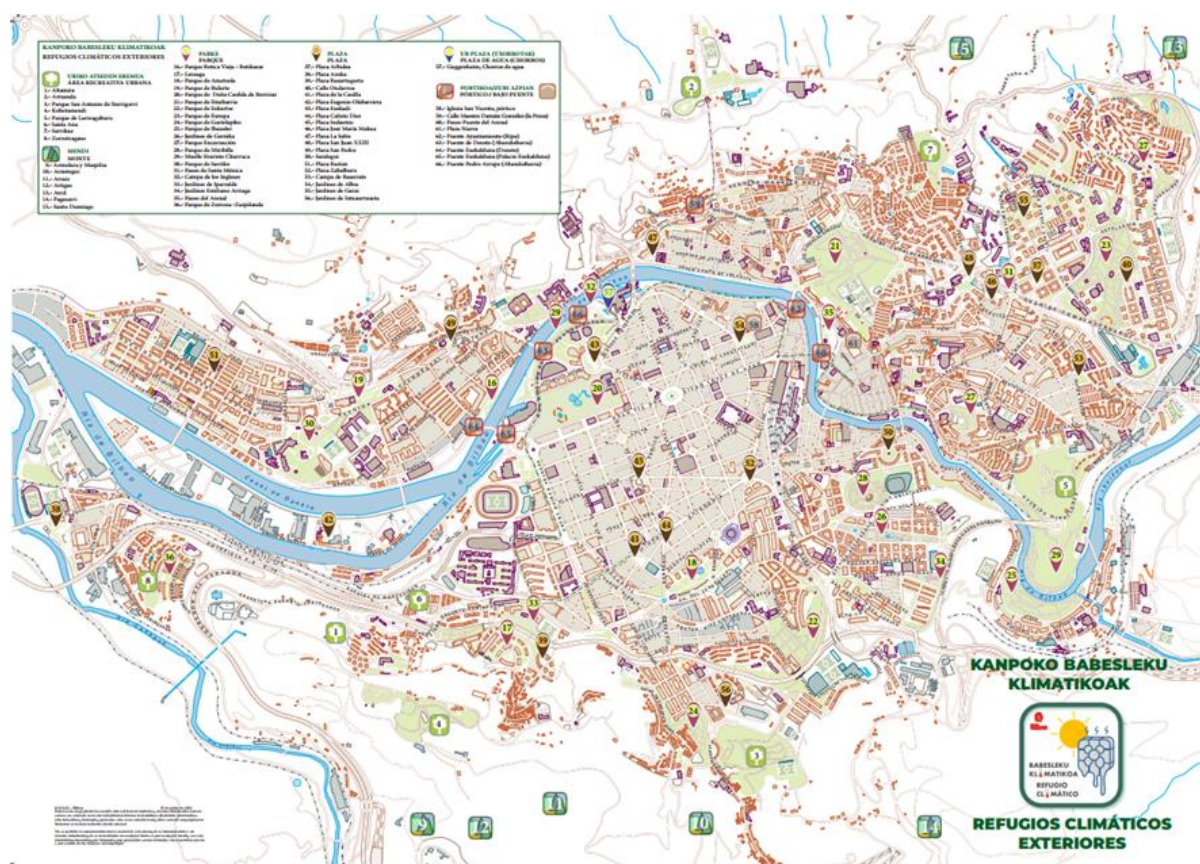


Fig. 7 - Climate Shelters in outdoor spaces of Bilbao. Source: Bilbao's Council (n.d.).



Fig. 8 - Climate Shelters in indoor spaces of Bilbao. Source: Bilbao's Council (n.d.).

3.4. PARIS, FRANCE

Given the escalating temperatures and frequency of heatwaves, along with the heightened risk of flooding due to increased rainfall, it is imperative for cities to establish cooler spaces and implement mechanisms for water infiltration, storage, and absorption. Moreover, with the growing population of vulnerable groups, particularly the elderly, prioritising their well-being amidst climate change-induced urban risks is paramount. This urgency is especially pronounced in cities like Paris, which grapple with a scarcity of green, breathable, and social spaces (Urban Innovative Actions, n.d.).

Paris has embarked on the development of short-, medium-, and long-term strategic plans to address these challenges, including the Paris Climate Adaptation Strategy (2015), Paris Resilient Strategy (2017), new Air, Energy, and Climate Plan (2017), and new Paris Biodiversity Plan (2018). These local initiatives are aligned with the European Union's Adaptation Policy.

One project aligned with the plans of climate adaptation in Paris is the OASIS project, which aims to complement these strategies by addressing specific objectives, as outlined by Sitzoglou (2020):

- Ensuring the provision of cooler spaces within a seven-minute walk of every Parisian's home by 2020.
- Establishing or opening to the public a minimum of 300 fresh islands and circuits.
- Increasing permeable green cover to encompass 40% of the city's area.
- Transforming schools into "oases" to enhance resilience and well-being.

By integrating these objectives into its urban planning and development efforts, Paris seeks to enhance the city's resilience to climate change while prioritising the needs of its residents, particularly the most vulnerable segments of the population. through initiatives like the OASIS project, Paris endeavours to

create a more sustainable, livable, and resilient urban environment for all its inhabitants (Sitzoglou, 2020).

An essential determinant of resilience is social cohesion. Accordingly, the Paris OASIS project endeavours to foster community engagement and climate adaptation by intervening in schools to establish cool islands accessible to the public. This initiative aligns with principles of co-design and co-construction, involving students and adults from the educational community in the planning and implementation process, while also promoting awareness, education, and engagement among citizens (Urban Innovative Actions, n.d.). The deployment of these fresh islands in the city relies on natural solutions and sustainable materials, with the aim of cultivating climate-friendly behaviour (Sitzoglou, 2020).

Implemented by the Innovative Urban Actions (IUA) in collaboration with the Paris City Council, Council of Architecture Urban Planning and the Environment (CAUE), Paris Federation of the Education League (LIGUE de l'enseignement), The French National Meteorological and Climatological Centre (Météo France), Interdisciplinary Research Laboratory for Future Energies (ESIEE Paris), and Laboratory for Interdisciplinary Evaluation of Public Policies (LIEPP), the project engaged these partners across various phases (Urban Innovative Actions, n.d.).

The selection of schools was guided by five key criteria: accessibility from the street, representation across different districts, meeting minimum surface area requirements, inclusion of areas with diverse demographics, and consideration of the students' age range, encompassing both primary and secondary levels. Initially, ten schools were chosen as pilot sites to kickstart the project (Fig. 9). These schools are envisioned to serve as community hubs during non-school hours, promoting social cohesion and offering a climate refuge within the urban landscape (Sitzoglou, 2020).

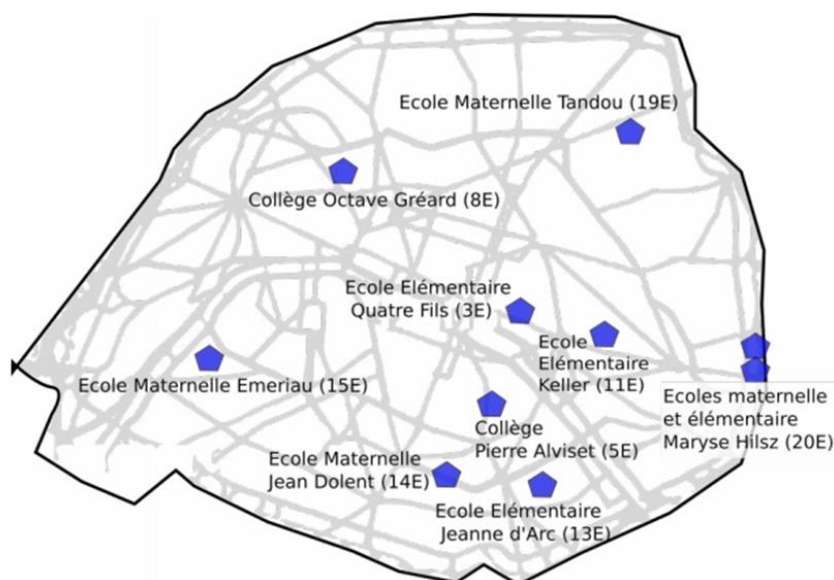


Fig. 9 - Map of Paris with the ten selected schools. Source: Sitzoglou (2020).

To execute the project within the schools, construction activities requiring specialised professionals were conducted during holidays, while weekends were dedicated to "hands-on" activities involving children, their families, and local residents. This approach enabled individuals to take ownership of the

spaces and gain awareness of the project's objectives through active participation in activities such as planting vegetation and constructing furniture and leisure structures (Sitzoglou, 2020).

This project holds significant importance in the discourse on community-based adaptation. By involving users and potential users of the spaces in the construction process, it fosters a sense of ownership and attachment to the sites. Consequently, these spaces, which already function as havens for Parisian communities, also serve as focal points for enhancing social cohesion and community resilience. Through collaborative efforts and shared engagement, these sites not only provide physical respite but also become catalysts for fostering stronger bonds among community members, thereby bolstering their ability to adapt and thrive in the face of environmental challenges.

3.5. SYDNEY, AUSTRALIA

In Australia, the impacts of climate change, including rising temperatures, have heightened the risks of heatwaves, fires, intense low pressure systems, and river and coastal flooding (Barns, 2017). Over the past century, heatwaves have emerged as the leading cause of death among natural disasters, with their severity and frequency projected to escalate over time. Among the most vulnerable groups during heatwaves are public transport users, with buses serving as the primary mode of transportation for approximately 600,000 individuals daily. However, on scorching days, these users often find themselves seeking refuge at bus stops ill-equipped to provide adequate thermal comfort. It is imperative that bus stop designs prioritise safety, comfort, and accessibility, especially for vulnerable groups such as the elderly, individuals with disabilities or reduced mobility, and parents with small children or strollers (Jacobs et al., 2018). Moreover, incorporating technological features such as travel information displays and environmental sensors can enhance the functionality of bus stops, enabling adjustments to optimise user comfort (Barns, 2017).

In response to these challenges, the University of Technology Sydney (UTS), in collaboration with local and state governments, initiated a bus stop design competition. The competition aimed to develop designs that maximise thermal performance and user comfort (Barns, 2017). The project was executed collaboratively, engaging transport users, local councils, planning and transport authorities, commercial entities, and other stakeholders (Jacobs et al., 2018). The initiative unfolded in three stages, involving co-designing stops in select locations, constructing the winning designs, and evaluating performance, occupancy, and feedback (Jacobs et al., n.d.).

The winning design, implemented at Penrith, featured a prototype that was installed and monitored during heatwaves to assess thermal performance, user satisfaction, and operational efficacy. The shelter design aimed to increase shade and ventilation through perforated details in the wall structure. Evaluation results indicated a significant reduction in temperatures at the roof level compared to the existing bus stop. Although there was no immediate preference for the new stops due to bus stop locations, user interviews revealed improved thermal comfort with the new structures. Moreover, insights gained from prototype evaluations led to proposed enhancements for CAPS, including the installation of drinking fountains to prevent dehydration and improvements in accessibility features such as guide strips for visually impaired individuals (Jacobs et al., 2018).

3.6. SYNTHESIS

It is evident that while the issue of climate shelters is gaining recognition and discussion, only a few cities in Europe, notably Paris, Barcelona, and Bilbao, have developed structured plans for such shelters. These cities have comprehensive strategies encompassing the selection, implementation, and

communication of their shelter networks. Although the subject of climate shelters is still emerging, other cities, such as Madrid and Lisbon, have shown intentions of implementing similar strategies, particularly for heat waves. These strategies are still in their early stages, often proposed by political parties (Diário de Sanse, 2023; Raposo, 2023), but their existence represents an important step towards the future implementation of climate shelter systems in these cities.

However, it's important to note that these interventions have largely been top-down, with city councils spearheading the projects. The OASIS project in Paris stands out for its greater public participation, involving residents, students, and parents in interventions at schools. Community involvement, particularly in implementation, is crucial for fostering acceptance of projects and ensuring that people feel a sense of ownership over new spaces.

Feedback from these projects highlights areas for improvement. For instance, in Barcelona, shelters are not always open when needed the most, with instances of indoor shelters in Barcelona closing on public holidays coinciding with extreme heat. As these initiatives are still in their early stages, adjustments are necessary to enhance their effectiveness.

In analysing the reference cases, certain criteria emerge to enhance our understanding of the selection and implementation process of climate shelters. Among the cases studied, Barcelona and Bilbao stand out for their detailed implementation strategies. Both cities utilised a variety of social infrastructures, including libraries, civic centres, and sports facilities, which could serve their typical functions during normal weather conditions. These facilities were selected for their public accessibility. Given the primary focus on addressing heat waves, these spaces were equipped to provide seating areas, water sources, cooling amenities, and, for outdoor locations, the provision of shade.

Nonetheless, in the case of Barcelona, on the city council's website, cold weather is also mentioned in the shelters strategy (Ajuntament de Barcelona, n.d.). The council outlines some of the characteristics of shelters, such as being indoors or outdoors, with air-conditioned indoors having temperatures of 27°C in summer and 19°C in winter, being activated all year round to deal with both cold and heat, providing thermal comfort while maintaining their functions, being aimed at vulnerable groups such as babies, the elderly, people with chronic illnesses and those on lower incomes, having good accessibility with chairs and benches, providing free water, being safe and, finally, being free to access. Finally, urban parks should have a Normalised Difference Vegetation Index over 0,4, be accessible to people with reduced mobility and have water fountains and benches (Ajuntament de Barcelona, n.d.).

It's crucial to emphasise that the study cases primarily focused on sheltering against extreme heat events, with only Barcelona mentioning considerations for cold waves. Additionally, the literature searched for cases of flooding typically approached the subject from the perspective of disaster circumstances, where the needs differ from the more frequent storms and urban floods experienced in the case of Porto. This highlights a gap in addressing the specific challenges posed by Porto's climate conditions and underscores the importance of tailoring adaptation strategies to local realities.

Finally, these initiatives represent important steps towards protecting populations from the impacts of climate change-induced extreme events. To improve the efficacy of these plans, it is essential to prioritise community input to identify key locations and vulnerabilities and to tailor the design and location of future shelters accordingly.

4

METHODOLOGY

The methodology proposed in this dissertation is based on the strategies studied in the literature review and reference cases, as important to achieve climate justice in climate adaptation through climate shelters. This way, it is imperative to underscore that the methodologies employed entail a combination of top-down and bottom-up approaches. While top-down methodologies are essential for providing overarching frameworks, it is equally crucial to incorporate bottom-up methodologies, such as questionnaires and interviews with local residents. These approaches facilitate an understanding of local needs and identify spaces already utilised by the community. Embracing this mixed approach is paramount to ensuring a fair and inclusive process in the planning of a network of climate shelters.

The following scheme outlines the steps involved in each phase of the methodology application, providing a clear understanding of the entire process. The overall methodology is divided into three main processes—preparation, data collection and analysis, and proposal and validation—executed across two phases (Fig. 10). Each task within these processes is explained in detail later in this chapter.

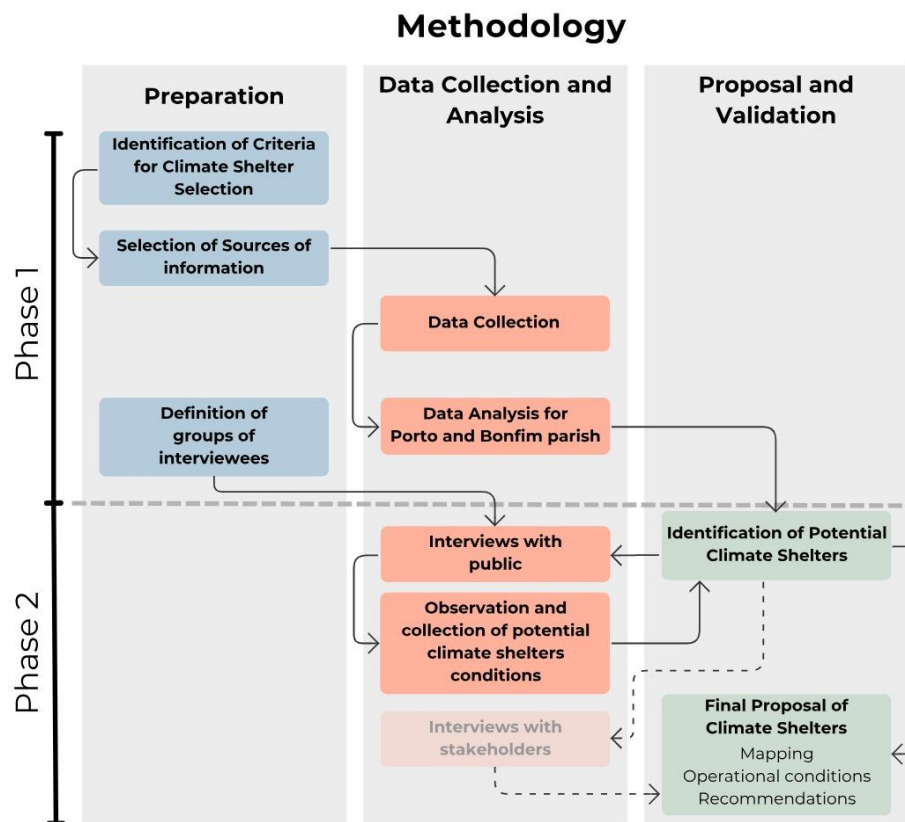


Fig. 10 - Scheme of the Overall Methodology. Author's own elaboration, 2024.

Although the methodology was applied to the parish of Bonfim, it is intended to be replicated throughout the municipality of Porto and beyond, as a strategy for creating a network of shelters. By studying the methods used elsewhere, it was possible to understand how to search for places that can serve as climate shelters.

4.1. PHASE 1

Phase 1 encompasses the preparation and data collection processes, which are fundamental to providing a contextualised proposal for the municipality. This methodology aims to be replicable to be applied to other parishes or even other municipalities.

4.1.1. PREPARATION

The preparation involves the identification of initial criteria for selecting potential climate shelters, retrieved from a review of reference cases and adapted to the context of the municipality of Porto. Four main criteria were identified that all shelters must fulfil according to their functions. These first four criteria will further be broken down into more detailed criteria, but they are the starting point to understand which information to look for in data collection and the characterisation of the territory, the public and their needs. These criteria include thermal comfort, accessibility, safety, and facilities.

Figure 11 presents the criteria that shelters must meet regarding each climatic risk. They are based on the reference cases, more specifically in the synthesis of the chapter (3.6. Synthesis). Thermal comfort is particularly crucial during heat and cold waves to mitigate health risks. Accessibility encompasses mobility, public access, and spatial considerations for individuals with disabilities. Safety entails protection from both crimes and extreme events, ensuring the population feels secure. Facilities refer to amenities such as public bathrooms, drinking water, and seating areas that enhance comfort (Fig. 11).

MAIN CRITERIA	SELECTION OF CLIMATE SHELTERS		
	 SHELTER FROM FLOODING	 SHELTER FROM COLD WAVES	 SHELTER FROM HEAT WAVES
THERMAL COMFORT	Indoor space with protection from wind.	Indoor spaces; Protection from wind; Minimum temperature of 19°C*, with the possibility of mechanical heating.	Indoor or outdoor spaces; Maximum temperature of 27°C*; Ventilation (outdoor); Water elements (outdoor); Trees or other structures that provide shadow (outdoor).
ACCESSIBILITY	Spatial accessibility; Public access.	Spatial accessibility; Public access.	Spatial accessibility; Public access.
SAFETY (CIVIL PROTECTION AND FROM CRIMES)	Safety from crimes; Safety from extreme events.	Safety from crimes; Safety from extreme events.	Safety from crimes; Safety from extreme events.
FACILITIES	Bathroom; Seating places.	Bathroom; Seating places.	Bathroom; Seating places; Free drinking water fountain;

*temperature indicators taken from reference case of Barcelona

Fig. 11 - Scheme of the criteria for the selection of climate shelters. Author's own elaboration, 2024.

Selection of Sources of Information

The selection of sources aimed to identify the most relevant documents, plans and reports at national and local levels, websites, and statistics for characterising the case study. These sources provide data on climate, risks, and vulnerabilities identified in the area, as well as outline adaptation strategies. With this information, the data obtained can be treated and analysed more efficiently.

One limitation might be the data currency provided by official sources. Some documents, analysed for spatialised socio-demographic data, date back to 2018, rendering them outdated. Consequently, changes in this data over time may impact the results obtained, potentially compromising the accuracy of the findings.

Definition of group of interviews

The selection of interviewees aimed to ensure a diverse range of perspectives and guide the process of interviews. The first criterion is that the interviews take place in the potential climate shelters initially selected, to engage with the potential public effectively. Another criterion is to involve individuals of diverse gender and age groups, selected randomly but with careful consideration to achieve this diversification. This approach ensures that a broad spectrum of perspectives is captured during the interviews, enhancing the richness and inclusivity of the data collected.

4.1.2. DATA COLLECTION AND ANALYSIS

After selecting the sources, the documents were carefully reviewed to extract key information for the case study. This included information on climate adaptation plans and strategies at national, metropolitan, and municipal levels, along with the studies conducted to develop these plans. Also, maps and tables regarding climate risks and vulnerable groups are used to provide better contextualisation for the municipality.

Following the collection of secondary information, the characterisation of the territory was pursued, which was crucial for understanding the municipality of Porto's progress in climate adaptation and its relationship with vulnerable groups. The extracted information was analysed by interpreting maps and data and by crossing information of these maps.

General information on the municipality and the parish of Bonfim was separated to enable a more focused local analysis for intervention and final proposal purposes. The parish of Bonfim was chosen within the municipality due to its diversity of climate risks, enriching the proposal of different types of climate shelters.

In conjunction with the data gathered from secondary sources, additional maps were created to extract the most up-to-date information, regarding areas with vegetation coverage within the territory. The mapping process aimed at understanding the climatological patterns with their risks, and their related vulnerabilities. This process utilised the QGIS tool, incorporating images from Landsat 8 obtained through the Earth Explorer platform of the United States Geological Survey (USGS).

Several maps containing information about climatic risks in the territory were examined. These maps provided insights into the specific challenges posed by climate-related hazards. These climatic risk data were overlaid with information on social vulnerability within the territory. This intersection allowed for the identification of priority areas for the future implementation of climate shelters. By considering both

climatic risks and social vulnerability, it became possible to target interventions towards areas most in need of support during extreme weather events.

4.2. PHASE 2

The second phase entails the proposal and primary data collection through interviews to refine it. The first step of the proposal involves identifying potential climate shelters, which will be continuously refined and validated through the data collection process until the final proposal is formulated. This iterative approach ensures that the proposal is grounded in empirical data and reflective of the actual needs and perspectives of the community.

4.2.1. IDENTIFICATION OF POTENTIAL CLIMATE SHELTERS

For the selection of climate shelters, an initial mapping was conducted using information on existing and proposed collective facilities provided by the municipality of Porto (PDM, 2021), the list of Social Network Institutions of Porto (Rede Social, 2023), and other infrastructure identified by the author as potential shelter locations. This initial mapping considered the suitability of each space for different climate events, it was also important to provide information on where interviews take place and guide which places to analyse.

The selection includes open and closed spaces, open spaces being those with vegetation or other elements that provide shade, which serve to mitigate high temperatures. Enclosed spaces are: religious temples, educational institutions (schools and universities), sports pavilions, cultural centres, community centres, museums, health centres, theatres and shopping centres. All these places were mapped in this initial identification to be further observed.

4.2.2. INTERVIEWS WITH THE PUBLIC

As primary data collection, interviews were held within the parish of Bonfim. These interviews are designed to identify opinions, experiences, and informal climate adaptation strategies within the region. Furthermore, the interviews aim to gauge people's perceptions of climate change to ascertain if there is a sense of responsibility among the population to take initiative during times of crisis and enhance adaptive capacity. Ultimately, the goal of the interviews is to elucidate the residents' profiles and their needs, in a general perspective, how the residents perceive the spaces as climate shelters, and how they see the importance of the elements in the urban territory, as well as to evaluate the current situation regarding coping with the impacts of climatic events. This information will serve as a refinement in the proposal of a network of shelters that addresses the community's specific requirements.

- *Sociodemographic Data:* The interviews aim to encompass individuals of diverse ages, genders, household compositions, and employment conditions. However, due to time constraints, the primary criteria for sample diversification will be gender and age. This approach ensures a degree of representation across key demographic categories.
- *Perception of climate change:* The interviews seek to capture participants' perspectives on various aspects of climate change, including the influence of human activities on climate change, individual responsibility in mitigating and adapting to climate change, and the role of government in addressing climate change. The overarching goal of this research is to understand how individuals perceive climate change and whether they prioritise and support climate adaptation strategies.

- *Personal Experiences:* This aspect focuses on exploring how individuals modify their behaviour during extreme climatic events. Specifically, the aim is to observe whether participants have specific locations they frequent to seek relief from the impacts of heatwaves, cold waves, or floods/storms. Understanding these patterns can provide insights into the practical responses of individuals to climate-related challenges.

Three open-ended questions were formulated to generate conversation with the interviewees, exploring changes in behaviour during extreme weather events, tendencies to seek refuge in specific places, and willingness to use formal shelters if available.

Following the interviews with the previously defined group, additional interviews will be conducted with stakeholders to validate the initial selection. This iterative approach allows for a comprehensive analysis of the feasibility of all proposed climate shelters and enables consideration of alternative options that may emerge during the validation process.

Regarding the primary data collection, the number of interviews conducted might pose a limitation. Due to constraints, such as time limitations in writing the dissertation and resource constraints for reaching a substantial number of samples, the sample size may not be sufficient to propose an effective intervention. As a result, the data collected will primarily serve to illustrate the process and gather preliminary insights for proposing guidelines rather than concrete intervention strategies.

4.2.3. OBSERVATION AND COLLECTION OF POTENTIAL CLIMATE SHELTER CONDITIONS

During the interviews, a detailed analysis of potential climate shelters was conducted, considering the criteria established in the preparation phase and insights gleaned from the interviews. This process enabled a more precise selection of shelters that align with the community's needs and preferences. It was noted that some potential spaces may require adaptations, such as the addition of benches or drinking fountains, to better serve the community. These observations are valuable for informing the final proposal and ensuring its feasibility and effectiveness in meeting the needs of the community.

4.2.4. INTERVIEWS WITH STAKEHOLDERS

After conducting interviews with the public and refining the initial proposal, obtaining input from stakeholders was crucial to validate the selected locations to serve as climate shelters. Securing stakeholder approval is essential to ensure their awareness of these shelters and their maintenance. This collaborative process ensures that the identified shelters are acknowledged and endorsed by relevant stakeholders, thereby enhancing their effectiveness in assisting the population during extreme climatic events. However, this action is dependent on the time available to develop the research and proposal.

4.2.5. FINAL PROPOSAL OF CLIMATE SHELTERS SYSTEM

After, the first results obtained are refined, focusing on more feasible aspects of the proposal. While the initial mapping considers all the locations that could serve as climate shelters, the final proposal takes into account its feasibility, considering the radius of coverage of these shelters for a 5-minute walk, or 400 metres, operational conditions, location regarding risks and proximity to vulnerable groups in the region.

This step considers aspects relating to the ease of implementation for each space initially selected, thinking about the infrastructure needed for the efficiency of these shelters. Spaces that already have

this infrastructure are prioritised for implementation. Those that don't have these infrastructures will be considered according to the shelters' coverage needs, so that the entire area of the parish is covered considering the coverage radius of a 5-minute walk.

In addition, this phase brought the results obtained in the stakeholder interviews to a deeper understanding of the sites used, also addressing informal infrastructures and sites favoured by users, as well as a greater focus on the site's vulnerable groups.

The information gathered on these facilities will enable institutions to intervene by either enhancing the quality of these places or simply informing the population about them. In addition to the criteria mentioned earlier, the study of climate shelters will also address their informality, serving as an indicator of community resilience. Not all shelters are formalised. Sometimes, their use arises from social connections, and these places can be maintained by the local population themselves, without the need for civil protection intervention in every extreme event. This recognition of informal shelters underscores the importance of community networks and grassroots resilience in effectively responding to climate challenges.

The strategy of identifying informal sheltering alongside potential formal shelters is crucial for prioritising institutional intervention in spaces that can serve as shelters, particularly in areas where risks are higher and the population is more vulnerable. By pinpointing these locations, civil protection agencies can focus their efforts on these specific areas, ensuring that resources are allocated where they are most needed. This targeted approach helps ensure that vulnerable groups have access to shelter and support during extreme events, while also allowing other community groups to rely on alternative resources and support networks.

Finally, the selected climate shelters were drawn on a map, so they could be easily identified by population. Recommendations regarding a communication plan, implementation of new equipment and monitoring were also provided in the final proposal.

5

CHARACTERISATION OF THE CASE STUDY

The city of Porto is located in the North of Portugal, being part of the Metropolitan Area of Porto (Fig. 12). The Porto Metropolitan Area has 17 municipalities and a population of 1.7 million inhabitants (PDM, 2021). In 2021, Porto had 231,800 inhabitants, which represents a reduction of 2.4 per cent compared to 2011, according to INE (Instituto Nacional de Estatística, 2024). In the municipality, while the number of young people (0 to 14 years old) and adults (15 to 64 years old) is falling, the number of elderly people is rising, with 228 elderly people for every 100 young people in 2021.

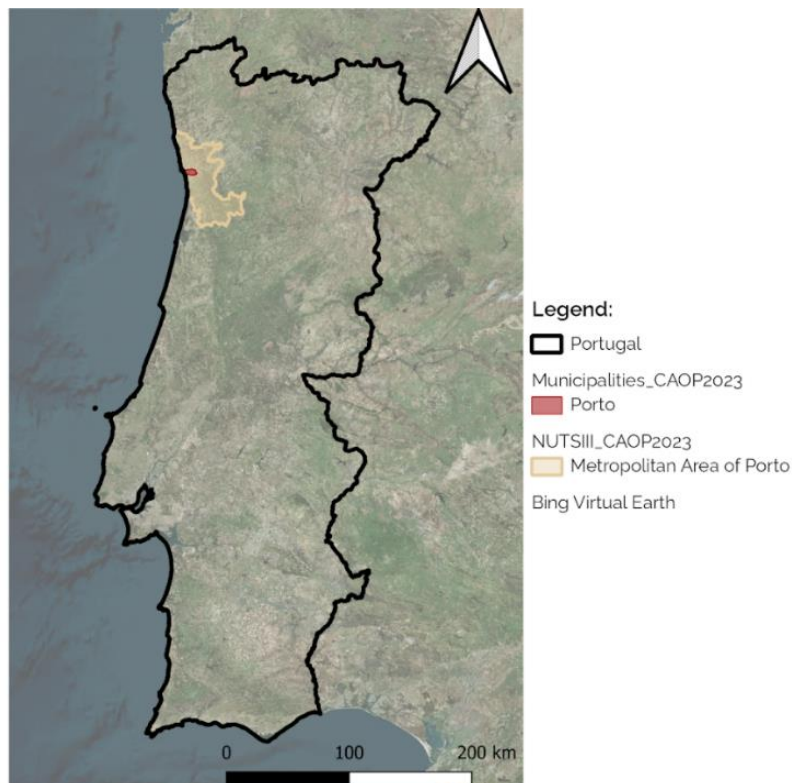


Fig. 12 - Scheme of the criteria for the second phase of implementation of climate shelters. *Source: Adapted from GDTerritório, 2024.*

The city of Porto is among the 21 cities in Portugal with the highest climate risk, and its climate risks affect a large part of the population (Expresso, 2022). The municipality is committed to mitigate climate change impacts by reducing carbon emissions and providing more green infrastructure (Porto, n.d.-a). Also, it defends the need of adaptation strategies at the local level, with the aim of reducing vulnerabilities and increasing adaptive capacity (Porto, 2016).

5.1. STRATEGIES FOR CLIMATE ADAPTATION

Porto, like all Portuguese municipalities, operates within the framework of the National Spatial Planning Policy Plan (PNPOT), which delineates five territorial challenges: sustainable management of natural resources, promotion of a polycentric urban system, fostering inclusion and territorial diversity, enhancing internal and external connectivity, and advancing territorial governance (Programa Nacional Da Política de Ordenamento Do Território, 2019). This overarching plan also prioritises sustainability in resource utilisation, emphasising the circular economy, waste reduction, carbon emission mitigation, and resilience enhancement through the establishment of green and blue infrastructures (PDM, 2021).

Moreover, Porto adheres to the national Climate Law (2021), obligating it to uphold climate balance by "protecting, preserving, respecting and ensuring its safeguarding (Porto, n.d.-b). The Portuguese Environment Agency (APA) has consequently issued guidelines for Municipal Plans to align with this commitment (Agência Portuguesa do Ambiente, 2024).

At the regional level, Porto is subject to various instruments such as the Douro Flood Risk Management Plan (PGRI) 2016-2021, the Caminha/Espinho Coastline Programme (POC CE), and the Entre Douro e Minho Regional Forest Management Plan (PROF EDM), all designed to regulate and manage territorial concerns (PDM, 2021, p. 22). Additionally, regional and metropolitan scales are addressed through instruments like Norte 2020 and AMP 2020, aimed at implementing national directives while fostering inclusive, sustainable, and intelligent growth.

The establishment of the Porto Energy Agency in 2007 marked the initiation of greenhouse gas emission monitoring in 2008. Porto subsequently joined the Covenant of Mayors in 2009, progressing to the Covenant of Mayors for Climate and Energy a decade later (Porto, n.d.-b), achieving a 48% decarbonization milestone in the same year (Porto, n.d.-a).

In 2016, the city unveiled its Municipal Strategy for Adaptation to Climate Change (EMAAC - *Estratégia Municipal de Adaptação às Alterações Climáticas*) (Porto, 2016). The EMAAC came as a result of the project ClimAdaPT (2015), which aimed to promote the development of climate change adaptation strategies in several municipalities, as well as its integration in planning tools. The project also promoted the training of the municipal staff, the awareness of local actors.

In the EMAAC, the municipality of Porto highlights climate change as "one of the most significant challenges of the 21st century" (Porto, 2016, p. 7), underscoring the urgency of addressing it. In response to climate change, the city emphasises adaptation actions, including grey infrastructure, green infrastructure, and non-structural options (soft measures), aimed at enhancing adaptive capacity and mitigating vulnerabilities.

The city aspires to become more resilient and equitable in the face of climate change through actions spanning local, national, and international levels. According to the latest Master Plan report for Porto, the planning process was participatory, engaging various urban stakeholders including institutions, associations, and residents (PDM, 2021).

Aligned with the Sustainable Development Goals and the 2030 Agenda, Porto aims to enhance its development through the principles of the circular economy, emphasising greater energy efficiency, water resource reuse, solid urban waste reduction and recovery, as well as efficient telecommunications and transport systems (PDM, 2021, p. 12). The Climate Pact outlines Porto's ambitious goal to reduce greenhouse gas emissions by 85% by 2030, surpassing EU cities aiming for a 55% reduction by 2030 and carbon neutrality by 2050 (Porto, n.d.-b).

5.2. CLIMATIC RISKS AND VULNERABILITIES IN THE MUNICIPALITY OF PORTO

The metropolitan plan (Monteiro, Madureira, Fonseca, & Gonçalves, 2018) conducted a survey involving various stakeholders to gain insight into their perspectives on the challenges posed by climate change in the city. The findings revealed a notable lack of awareness regarding climate change and its associated risks, as well as limited knowledge or engagement in transitioning to a low-carbon economy. Despite this lack of awareness about climate issues, there exists apprehension regarding environmental risks such as flooding, coastal erosion, and forest fires, among others.

The survey indicated a low level of public engagement with risk management and a lack of familiarity with potential solutions to address these challenges. Furthermore, there appears to be a general disinterest in implementing such solutions. These findings underscore the municipality's imperative to develop strategies aimed at raising awareness about the consequences of climate impacts and facilitating the adoption of preventive or mitigative measures. It's worth noting that the survey was conducted in 2017, implying that the data may be outdated. Conducting a new survey could provide insights into whether the municipality has initiated any measures to address previously identified issues and offer updated data to inform future strategies (Monteiro, Madureira, Fonseca, & Gonçalves, 2018).

Among the risks identified for the Porto metropolitan area, stakeholders highlighted drought, heavy rainfall, extreme low temperatures, and extreme high temperatures. These concerns are depicted in the map below (Fig. 13). However, the monitoring of events in the Metropolitan Area of Porto lacks consistency, hindering a comprehensive understanding of climatic patterns and impeding the anticipation of potential climate-related risks and their consequences (Monteiro, Madureira, Fonseca, & Gonçalves, 2018).

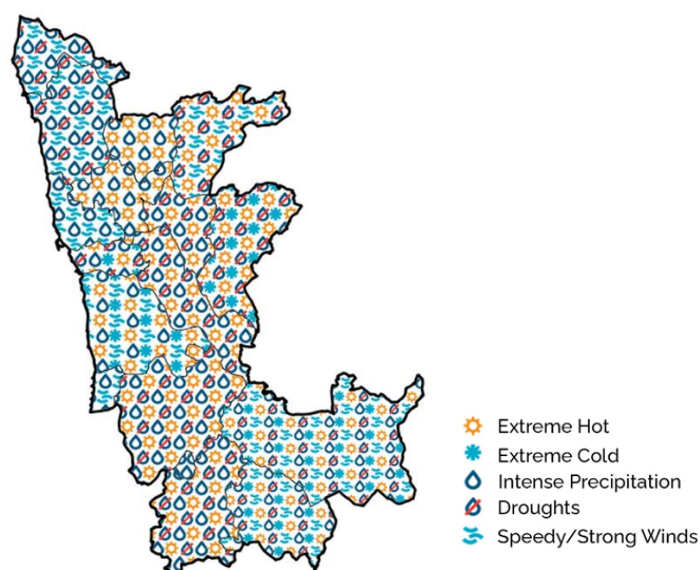


Fig. 13 – Map of climatic risks in each council of the Metropolitan Area of Porto. Source: PMAAC – AMP, 2017.

According to the Streams of Porto map (Fig. 14), the city features a limited number of open watercourses, constituting merely 18% of all streams (Porto, 2024). This scarcity of open water bodies can exacerbate the risk of heat islands due to extensive soil sealing, which presently covers 75% of the municipality's land area (Fig. 15) and contributes to a decline in biodiversity.

Efforts are underway by Águas e Energia do Porto to revive tubed streams, recognising them as opportunities for environmental, economic, social, recreational, cultural, and identity enhancement (Monteiro, Madureira, Fonseca, & Velho, 2018). As a result of these initiatives, the Plan for the Valorisation and Rehabilitation of the Water Lines of the Municipality of Porto (PVRLA) was introduced in March 2024 (Aguas do Porto, n.d.). This plan aims to restore clogged stream sections, establish retention basins, and enhance soil permeability across the municipal territory, thus promoting renaturalisation efforts.

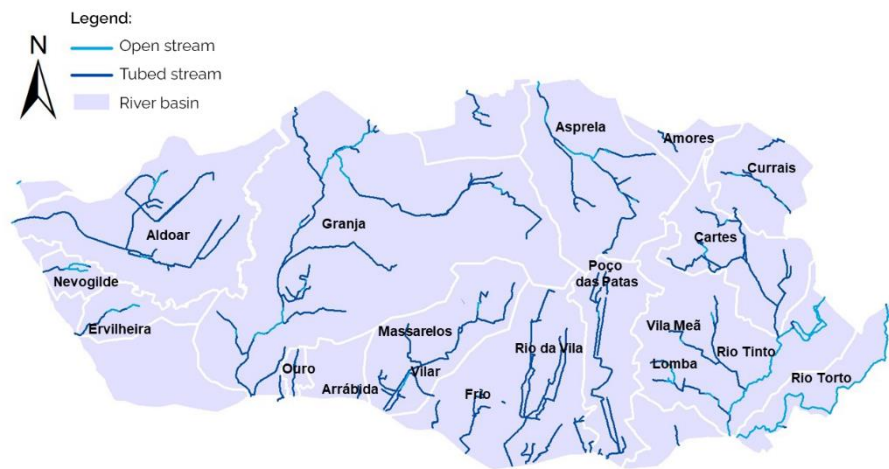


Fig. 14 – Streams of Porto. Source: Águas e Energia do Porto, n.d.

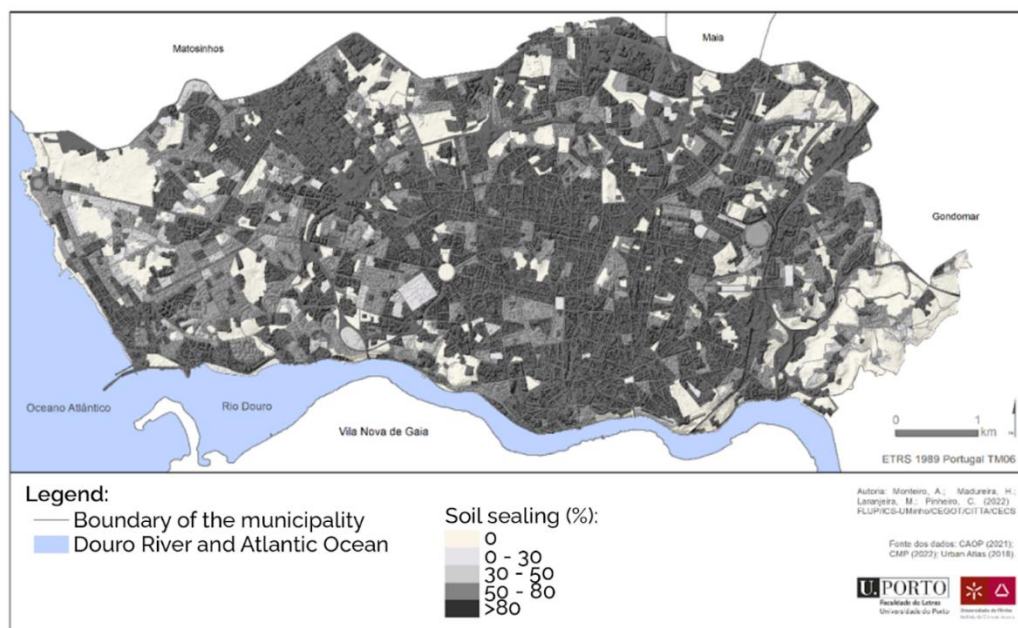


Fig. 15 – Land Use. Source: Monteiro et al., 2022.

Porto frequently experiences floods triggered by heavy and recurrent rainfall, particularly during the winter season. The most recent flood event affecting the city occurred on January 7, 2023 (Teixeira e Costa et al., 2023), with the majority of floods typically observed between October and December (Monteiro, Madureira, Fonseca, & Velho, 2018).

Additionally, to assess the impacts of urbanisation, a Normalised Difference Vegetation Index (NDVI) map was generated (Fig. 16). The NDVI is a metric indicating vegetation density, derived from the reflection of infrared and red light. Landsat 8 satellite imagery obtained from USGS Earth Explorer, dated March 6, 2024, was utilised to create this map. The NDVI values range from -1 to 1, where negative values represent clouds, water, and snow, values near zero denote bare soil, values around 0.2 to 0.3 indicate shrub vegetation and values exceeding 0.6 signify dense tree coverage (EOS Data Analytics, 2024). The findings for Porto reveal that a significant portion of the territory registers NDVI values between 0.0 and 0.1, with few areas surpassing these values. This suggests limited dense vegetation coverage within the city, which could potentially mitigate surface temperatures during summer months.

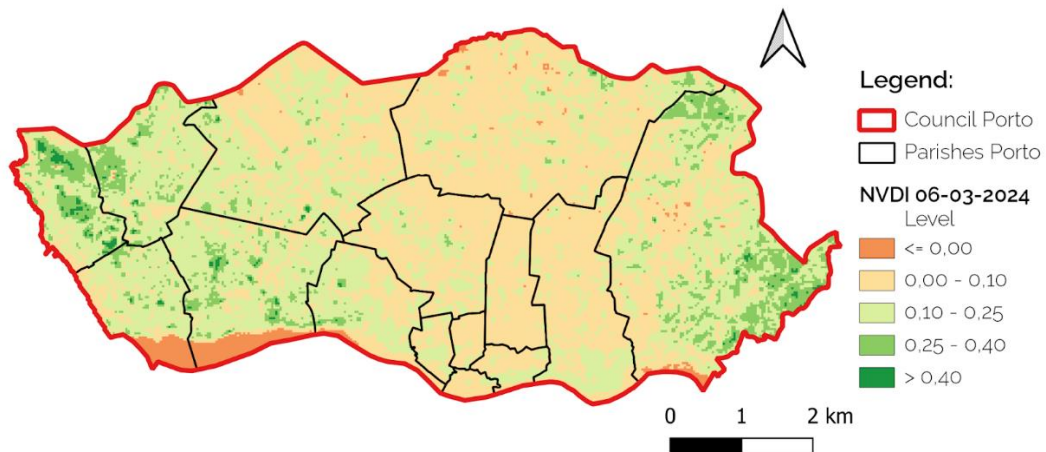


Fig. 16 – NDVI Porto on March 6th 2024. Author's own elaboration, based on USGS information (LandSat 8), calculated on QGis, 2024.

The green structure map used by EMAAC (Fig. 17) shows that there is a wide variety of public and private green areas, totalling 330 ha. The largest of these areas is the City Park, near the coast to the west, with 82 ha, which connects the seafront to the city and has a great diversity of fauna and flora. The coastal areas represent around 12% of the municipality's territory and are characterised by low altitudes (maximum 30 m) (Porto, 2016). Most of the municipality lies between 31 and 90 metres above sea level (51%), followed by areas with altitudes above 91 metres (37%) and the area near the coast with an altitude of less than 30 metres (12%) (Monteiro, Madureira, Fonseca, & Velho, 2018).

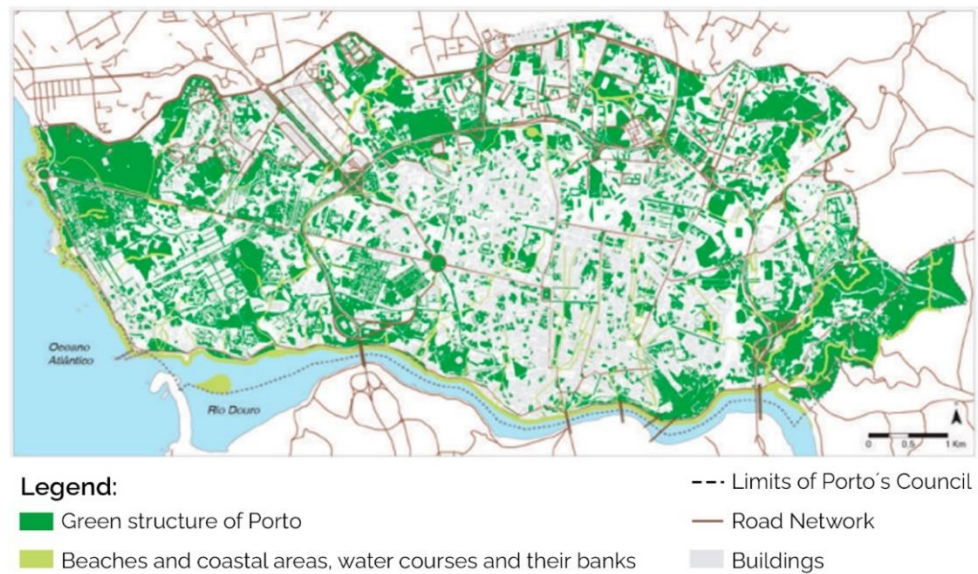


Fig. 17 – Green Structure of Porto. Source: EMAAC, 2016.

Utilising surface temperature data for the municipality of Porto during summer (Fig. 18) and winter (Fig. 19), it becomes feasible to examine the relationship between vegetation and temperatures, particularly during summer months. The juxtaposition of low Normalised Difference Vegetation Index (NDVI) values and extreme temperatures highlights the central parishes of the municipality as areas of heightened vulnerability. In essence, populations residing in these regions may be more susceptible to extreme weather events.

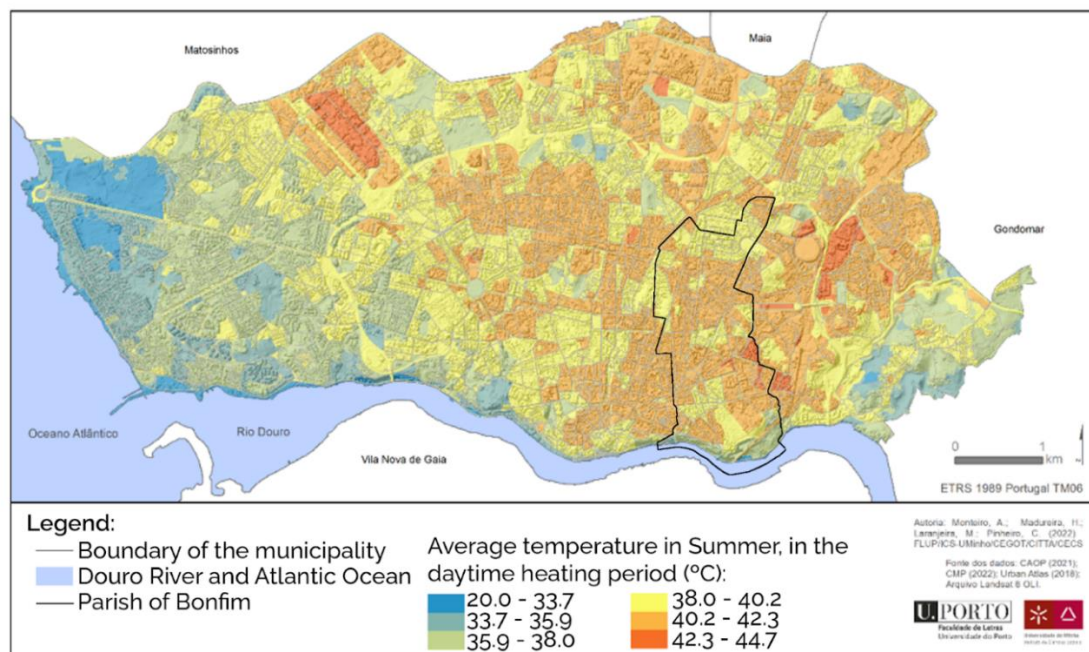


Fig. 18 – Land Surface Temperature in Summer in Porto. Source: Monteiro et al., 2022.

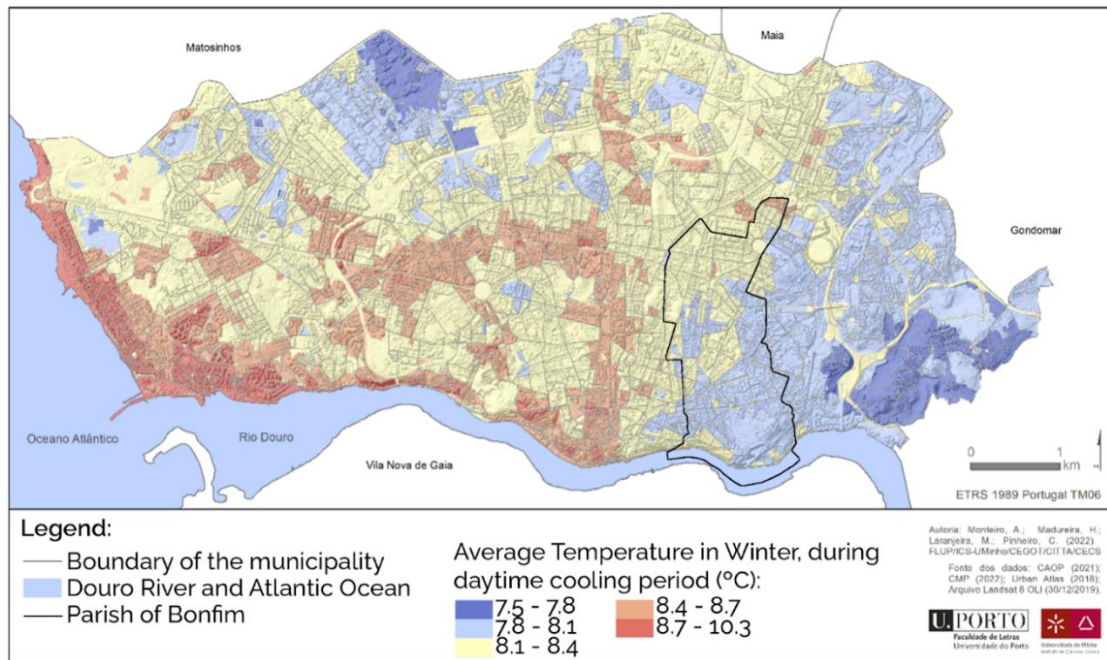


Fig. 19 – Land Surface Temperature in Winter in Porto. Source: Monteiro et al., 2022.

Regarding bioclimatic comfort, data from the Characterization and Diagnosis Report indicates that discomfort due to cold conditions (47%) surpasses that stemming from heat (31%) in Porto between 2002 and 2007. Notably, only 22% of days were perceived as comfortable by residents during this period. However, it is imperative to conduct updated studies to obtain a more accurate assessment of current bioclimatic comfort levels, facilitating more tailored urban planning strategies (Monteiro, Madureira, Fonseca, & Velho, 2018).

Furthermore, the evaluation of risks associated with climatic events in Porto extends beyond the events themselves to include how they are perceived by the population, encompassing the diversity of responses through the lens of bioclimatic (dis)comfort (Monteiro, Madureira, Fonseca, & Velho, 2018).

The document outlines projected changes, foreseeing higher maximum temperatures in summer and fall, along with reduced annual rainfall but increased intensity in precipitation. It's worth noting that the municipality's integrated strategy meticulously identifies risks and prioritises existing vulnerabilities across the territory.

EMAAC (Porto, 2016) also provides insights into projected climate changes in Porto (Fig. 20), including rising average annual temperatures and diminished average annual precipitation, with less certainty regarding winter trends. Notably, the document pinpoints major impacts such as powerful waves, intense precipitation-triggered floods, storms, heat waves, and landslides, exacerbating vulnerabilities within the region. However, quantifying the impact of cold waves proves challenging due to their dispersed nature across the territory.

Climatic Variable	Synthesis	Projected changes
	 Decrease in annual average precipitation	Annual Average Decrease varying between 3% and 25% in the end of the XXI century. Seasonal precipitation In winter months, there isn't a clear tendency (between -19% and 17%), with a decrease projected in the rest of the year, which can vary between 10% and 35% in spring and 9% and 36% in fall. More frequent and intense droughts Decrease in the number of precipitation days, between 12 and 29 days per year. Increase in the frequency and intensity of drought in the south of Europe (IPCC, 2013).
	 Increase in annual average temperatures	Annual Average and seasonal Increase in annual average temperatures, between 1°C and 4°C, in the end of the century. Sharp increase in maximum temperatures in fall and summer (2°C and 5°C). Very hot days Increase in the number of very high temperature days ($\geq 35^{\circ}\text{C}$), and tropical nights, with minimum temperatures of $\geq 20^{\circ}\text{C}$. Heat waves More frequent and intense.
	 Sea level rise	Average Average sea level rise between 0,17m and 0,38m until 2050, and between 0,26m and 0,82m until the end of the XXI century (global projections) (IPCC, 2013). Extreme events Average sea level rise with more serious impacts, when combined with storms (IPCC, 2013).
	 Increase in extreme precipitations	Extreme phenomena Increase in extreme phenomena, in particular intense and very intense precipitation (national projections) (Soares et al., 2015). More intense winter storms, accompanied by rain and strong winds (global projections) (IPCC, 2013).

Fig. 20 - Synthesis of the main projected climate change for the municipality of Porto until the end of the century.

Source: EMAAC, 2016.

The EMAAC (Porto, 2016) provides a comprehensive overview in Table 4, delineating the degree of risk associated with various events in the present, medium, and long terms. Notably, it highlights that strong waves/sea level rise and excessive precipitation leading to inundations pose a significant risk in the medium term. Looking ahead, heat waves emerge as the foremost concern in the long term. These insights serve as valuable guidance for decision-makers in crafting effective adaptation strategies to mitigate risks posed to the population by these events.

Furthermore, it's noteworthy that the table overlooks cold waves as a potential risk factor. However, according to the Biophysical and Environmental Support report (Monteiro, Madureira, Fonseca, & Velho, 2018), an analysis of bioclimatic comfort in the municipality reveals that days of thermal discomfort due to cold occur more frequently (47%) than those due to heat (31%). Moreover, the occurrences of perceived extreme cold and extreme heat each represent 4% of the total, emphasising the need for climate adaptation strategies to address both aspects of thermal comfort for the population effectively.

Table 4 - Degree of risk of each extreme event in the territory of Porto. Source: EMAAC, 2016.

Event	Degree of Risk		
	Now	Medium-term (2041 – 2070)	Long-term (2071 - 2100)
Strong waves/sea level rise	2	6	4
Excessive precipitation/flood	2	2	2
Excessive precipitation/damage	2	2	2
Excessive precipitation/landslides	2	1	2
Excessive precipitation/inundations	2	6	3
High temperatures/heat waves	1	4	6
Storms/tornadoes	1	2	2

The Porto Metropolitan Area Climate Change Adaptation Plan (Monteiro, Madureira, Fonseca, & Gonçalves, 2018) acknowledges that vulnerabilities exacerbate the severity of impacts stemming from extreme weather events. Vulnerabilities within the AMP encompass cultural, demographic, social, and socioeconomic dimensions, including illiteracy. As outlined in the MAP Action Plan for Disadvantaged Communities (Plano de Ação para Comunidades Desfavorecidas da AMP, PACD-AMP, 2021), key vulnerabilities in Porto encompass families in precarious housing situations, overcrowding, homelessness, individuals with low incomes, unemployment, and the elderly population. Additionally, the risk of storms in the municipality can impact between 60% and 70% of the population (CDP, 2024).

For the EMAAC, the lower-income population stands out as the most susceptible to the impacts of climate change in the territory. For instance, heat waves can necessitate increased energy consumption for mechanical air conditioning and higher water usage, consequently raising energy and water costs, which disproportionately affect these groups.

Considering these vulnerabilities, the Porto Municipal Civil Protection Emergency Plan (Almendra et al., 2023) delineates the responsibilities of various Organisational Units within the City Council and Municipal Companies. Notably, the Municipal Department of Social Cohesion is tasked with directly intervening with specific groups of vulnerable or at-risk populations to promote social inclusion.

(Lopes et al., 2022) underscore that areas exhibiting the highest levels of vulnerability also tend to be the most impermeable. Conversely, regions characterised by lower vulnerability levels often coincide with those boasting abundant tree vegetation, such as Parque da Cidade to the west and Soutelo to the east. This observation underscores the potential significance of vegetation in mitigating extreme temperatures and associated risks, emphasising the importance of strategic urban planning and green infrastructure development in enhancing urban resilience.

At the parish level, the Biophysical and Environmental Support provides more granular insights through detailed maps, highlighting vulnerabilities related to risks associated with high and low temperatures. The mapping of vulnerabilities in terms of socioeconomic and environmental deprivation underscores challenges in the parish of Campanhã and the Union of Parishes of Cedofeita, Santo Idelfonso, Sé, Miragaia, São Nicolau, and Vitória, with additional vulnerability points identified in the parish of Bonfim (Monteiro, Madureira, Fonseca, & Velho, 2018).

However, despite the identification of vulnerable groups in the municipality, there is no mapping of these groups at parish level. For efficient planning, it is important to have a relationship between the risks and vulnerabilities of territories on a smaller scale.

5.3. THE PARISH OF BONFIM - CASE OF STUDY

The parish of Bonfim was selected because of its location in a central region of the Porto municipality and its diverse climatic risks and vulnerabilities, which enriched the exercise of proposing climate shelters attending to these varying situations. The area features pronounced topography, particularly in its proximity to the Douro River. Moreover, the urbanisation of the region, coupled with its proximity to natural areas, results in a range of extreme temperatures, making it a suitable subject for analysis, taking into account all the research objectives. These aspects will be further elaborated on in the subsequent sections.

General Characterisation

The parish of Bonfim was founded in 1841 and became the city's industrial centre in the mid-19th century, with the textile industry predominating. Due to the factories in the area and the increase in the number of factory workers, the housing typology known as an island emerged. Even at this time, industrialists were building palaces in the parish. As the industrial use disappeared, the spaces of the old industries took on other uses, giving way to shops, health centres, education, banking institutions, and also boosting tourism in the region (Junta de Freguesia do Bonfim, n.d.).

Currently, the parish, with an area of 3.05 km², has 22,978 inhabitants, according to the 2021 census, which represents 9.91% of the population of the municipality of Porto (Instituto Nacional de Estatística, 2024). Within the parish of Bonfim, the percentage of population over 65 years old represents 28% of its total population (Instituto Nacional de Estatística, 2024) (Fig. 21). The parish of Bonfim also stands out for having one of the largest isolated elderly populations, comprising between 7.1% and 8.9% of the resident population. This demographic group, as highlighted earlier, is particularly vulnerable during extreme events as they may lack immediate access to assistance, often relying on neighbours or family members for support (PDM, 2021).

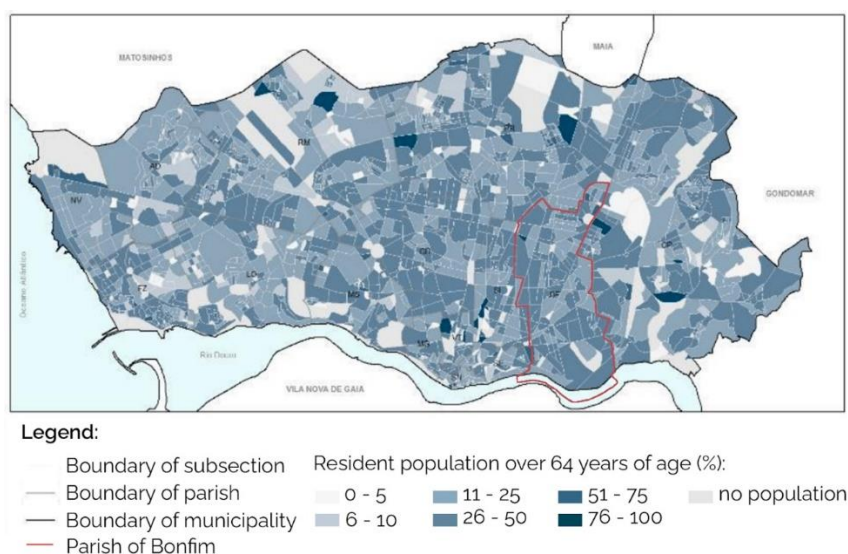


Fig. 21 - Map with elderly population by block. Source: CMP, 2016; Monteiro et al., 2012.

Climatic Risks

The map in Fig. 22 depicts existing green areas within the parish perimeter, as well as retention basins strategically located to mitigate the damage caused by potential floods. However, the existence of a tubed stream reflects a risk of flooding, especially when conjugated with the high soil impermeability which hinders water infiltration.

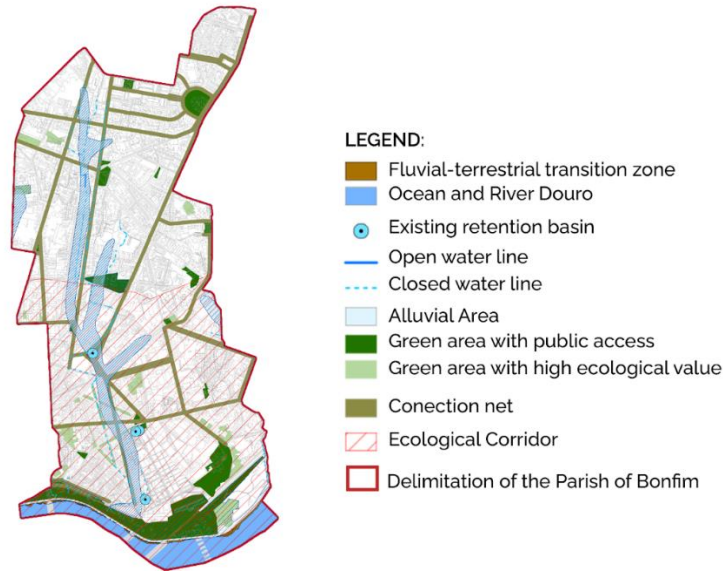


Fig. 22 - Maps of ecological structure of Porto, in the parish of Bonfim. Source: PDM, 2021.

Additionally, the parish of Bonfim faces natural risks associated with flooding and unstable areas due to the channelling of streams within the parish and its proximity to the river Douro, characterised by its steep slope (Fig. 23).

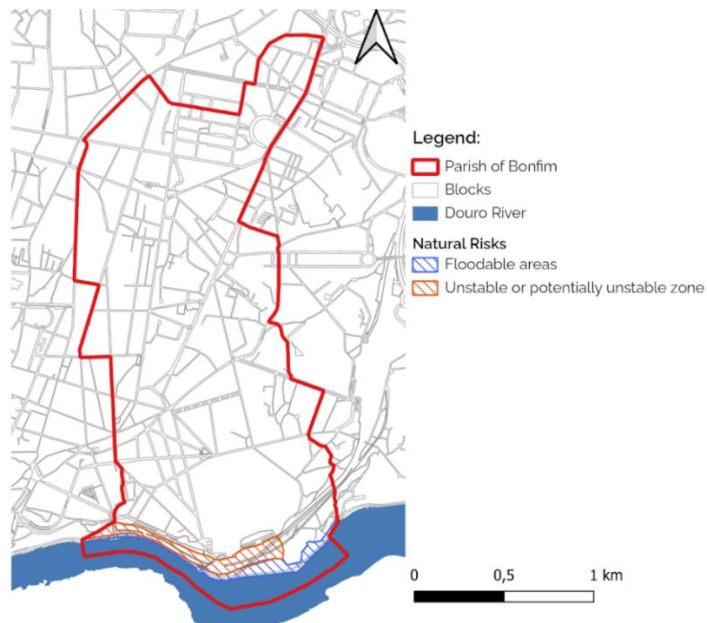


Fig. 23 - Maps of natural risks of Porto, in the parish of Bonfim. Source: PDM, 2021.

The Biophysical Characterisation and Diagnosis Report (Santos & Bateira, 2018) for the municipality of Porto lists the city's flood hotspots, which recorded 1,407 occurrences between 1974 and 2014. The map below (Fig. 24) highlights these occurrences within the parish of Bonfim. By integrating flood data with information on Porto's streams (PDM, 2021), it is evident that most flood hotspots are located near these watercourses or alluvial zones.

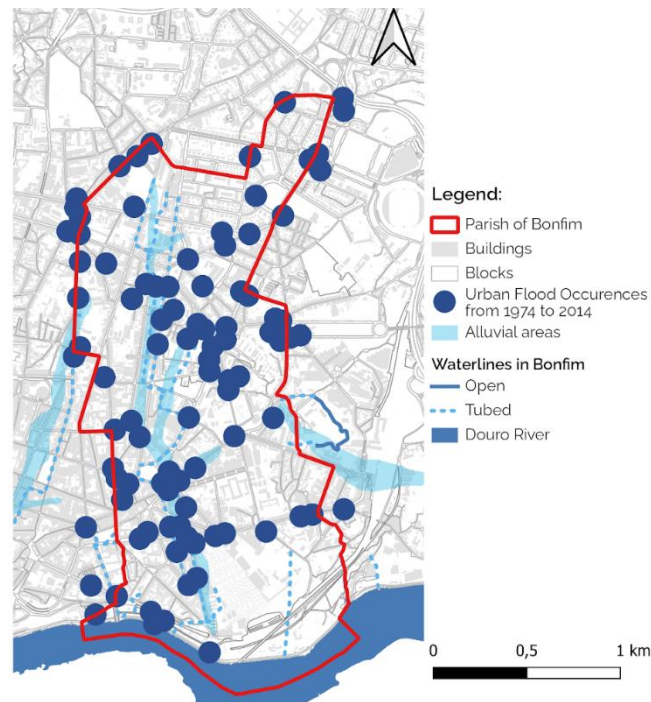


Fig. 24 - Map of streams and flood points from 1974 to 2014, in the parish of Bonfim. Source: Santos & Bateira, 2018; PDM, 2021.

The following map (Fig. 25) provides a detailed representation of the thermal load for each block within the municipality of Porto. It categorises the thermal load into three classes. Firstly, there is the low thermal load category, which comprises green areas capable of producing fresh air through shading and evapotranspiration. While these areas are advantageous during summer, they may lead to thermal discomfort due to cold during winter months. Secondly, the moderate thermal load areas are characterised by a more heterogeneous landscape, featuring a mix of building structures and permeable soil. These areas are usually the transition between high and low thermal load areas. Lastly, the high thermal load areas exhibit higher building density and soil sealing, leading to elevated air temperatures and the formation of urban heat islands. In summary, areas with higher thermal load pose greater challenges during summer due to overheating, while areas with low thermal load may present issues during winter months (Monteiro et al., 2022).

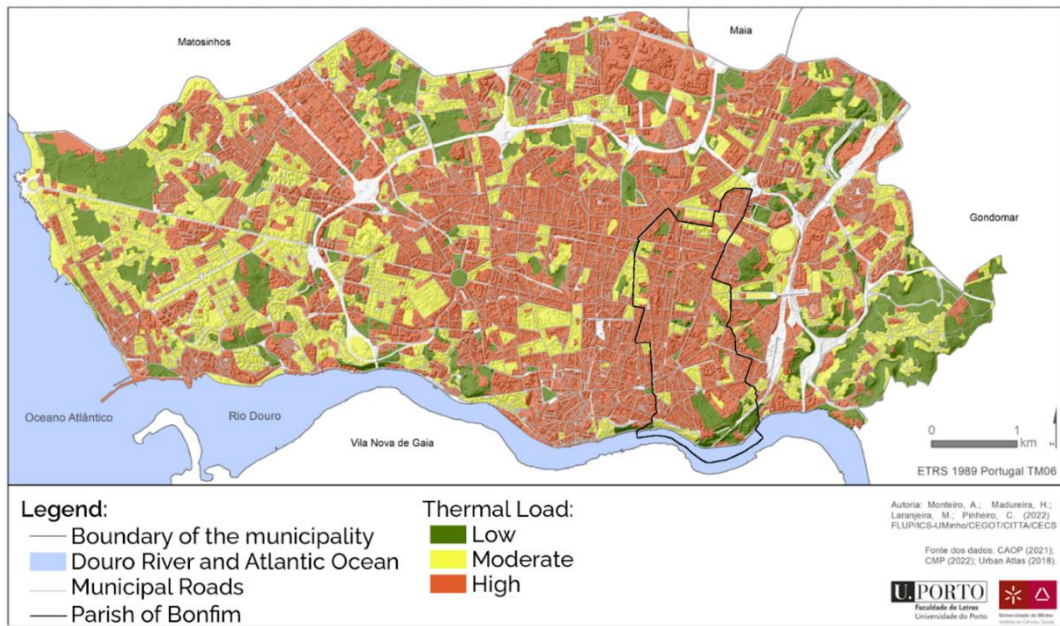


Fig. 25 - Map of thermal load for each block in the parish of Bonfim. Source: Monteiro et al., 2022.

In the Biophysical and Environmental Support of the municipality of Porto, risks were analysed by correlating highly ventilated areas with a higher probability of extreme cold and poorly ventilated areas with extreme heat (Monteiro, Madureira, Fonseca, & Velho, 2018). It is evident that extreme heat predominantly affects the entirety of Porto, a phenomenon exacerbated by low wind speeds in many areas. Monteiro et al. (2022) provide various maps delineating thermal load, ventilation potential, and criticality pertaining to different areas within the municipality. Fig. 26 highlights that numerous areas in the city centre display extreme criticality due to their low ventilation and elevated temperatures during summer, leading to a rise in bioclimatic discomfort. These areas require the possibility of outdoor sheltering.

Furthermore, during the winter season, the ventilation potential varies from very low to moderate in the city centre, contributing to a reduction in thermal discomfort even in areas with lower temperatures. The map below (Fig. 27) illustrates that the areas experiencing more critical bioclimatic discomfort are predominantly peripheral, where ventilation ranges from moderate to very high.

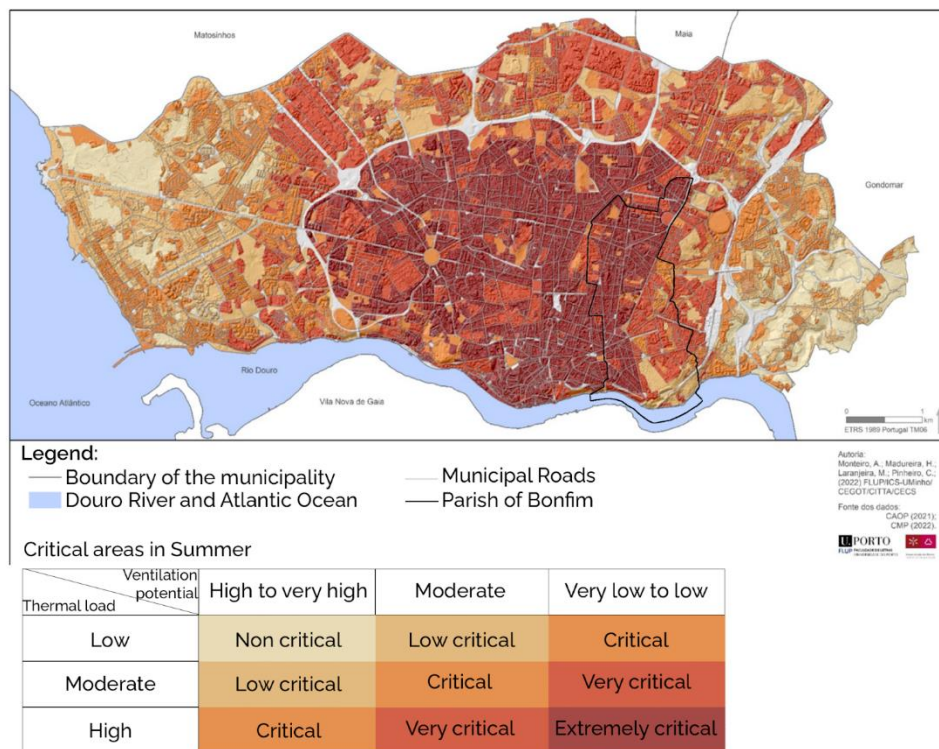


Fig. 26 - Map of bioclimatic discomfort for each block in the parish of Bonfim during summer. Source: Monteiro et al., 2022.

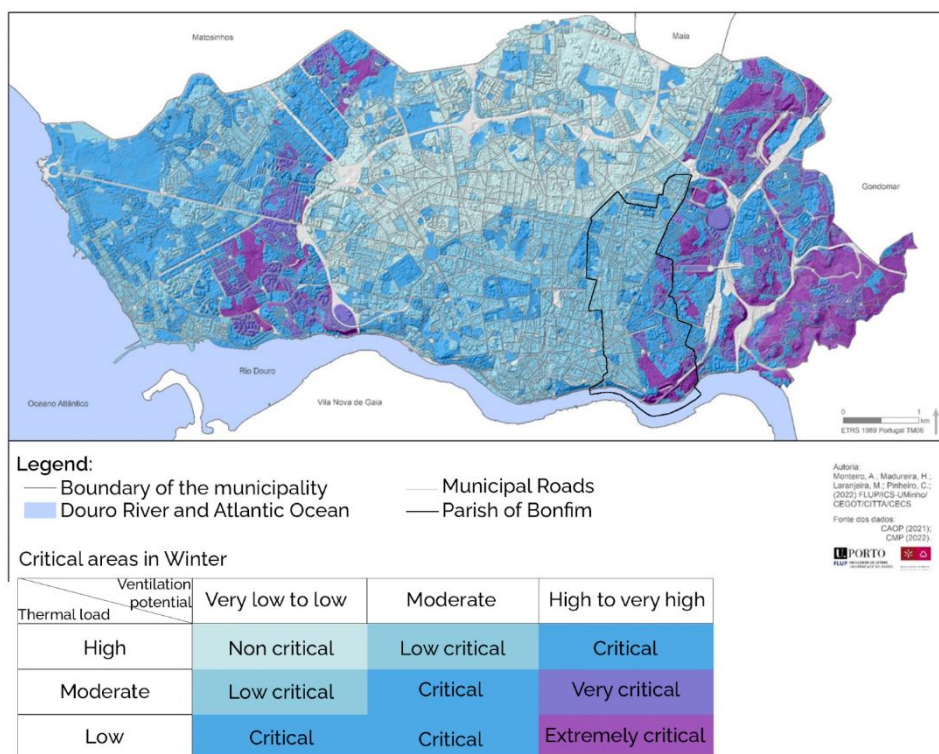
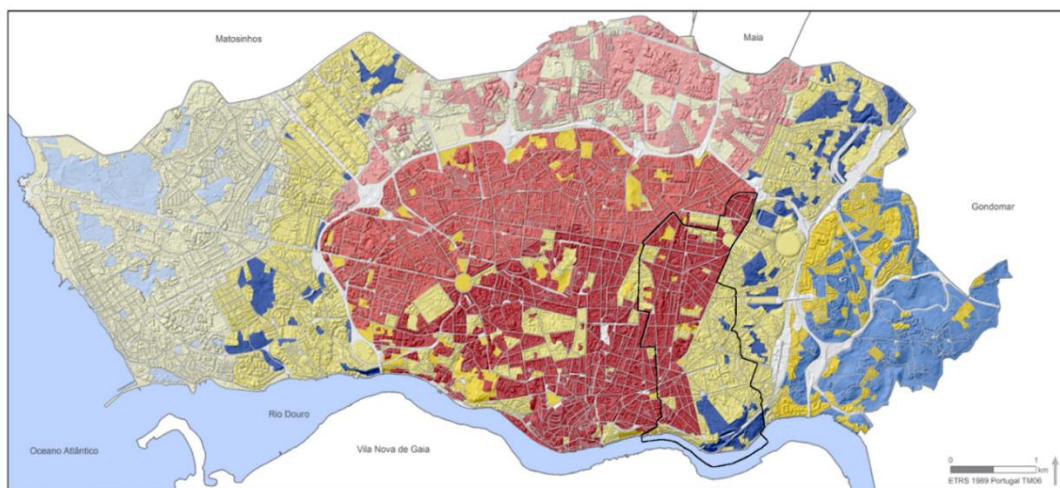


Fig. 27 - Map of bioclimatic discomfort for each block in the parish of Bonfim during winter. Source: Monteiro et al., 2022.

In addition to the prevalence of high thermal load areas within the parish, ventilation throughout its territory is markedly low during summer, with only conditioned or obliterated ventilation corridors traversing it. Furthermore, during winter months, the ventilation potential is moderate (Monteiro et al., 2022).

In the EMAAC (Porto, 2016), the parishes of Porto are categorised based on their level of vulnerability to housing thermal discomfort, ranging from 1 (least vulnerable) to 20 (most vulnerable). Notably, the parish of Bonfim falls within the lower vulnerability range, typically between 7 and 9. However, elderly individuals (aged over 65) residing in parishes with vulnerability levels surpassing 10 face additional challenges regarding housing thermal comfort during heat waves.

Taking into account both the maps of bioclimatic discomfort for summer and winter, Monteiro et al. (2022) devised a matrix of priority for interventions aimed at enhancing the environmental quality of outdoor spaces (Fig. 28). This map delineates the varying needs for interventions, prioritising central areas due to their discomfort during summer and peripheral areas due to their discomfort in winter. Consequently, it is noteworthy that the majority of areas requiring interventions correspond to critical discomfort zones observed during summer.



Legend:

- Boundary of the municipality
- Douro River and Atlantic Ocean
- Municipal Roads
- Parish of Bonfim

Priority of Outdoor Environmental Qualification

		Critical areas regarding Extreme Cold (Winter)				
		Extremely critical	Very critical	Critical	Low Critical	Non Critical
Critical areas regarding Extreme Heat (Summer)	Extremely critical	N.O.	N.O.	N.O.	High Priority	Priority
	Very critical	N.O.	N.O.	High Priority	Priority	REC
	Critical	N.O.	High Priority	Priority	REC	N.O.
	Low Critical	High Priority	Priority	REC	N.O.	N.O.
	Non Critical	Priority	N.O.	REC	N.O.	N.O.

N.O. - No Observation
REC - Recommended

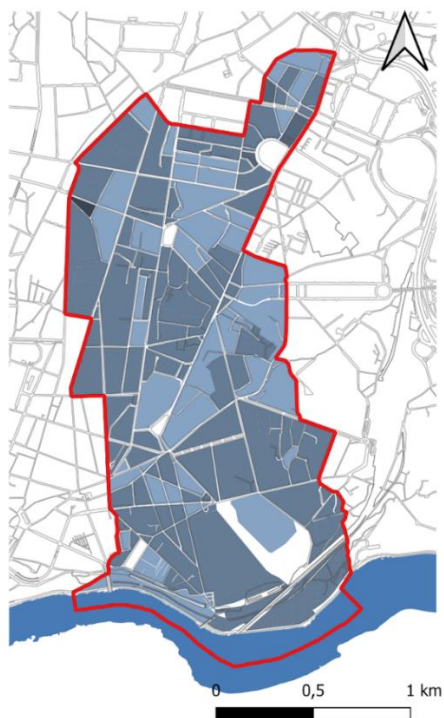
Autoria:
Monteiro, A.; Madureira, H.;
Laranjeira, M.; Pinheiro, C.;
(2022) FLUPHICS-UMinho/
CEGOT/CITTA/CECS
Fonte dos dados:
CAOP (2021);
CMP (2022).
PORTO
FLUPHICS-UMinho

Fig. 28 - Map of priority of outdoor environmental qualification. Source: Monteiro et al., 2022.

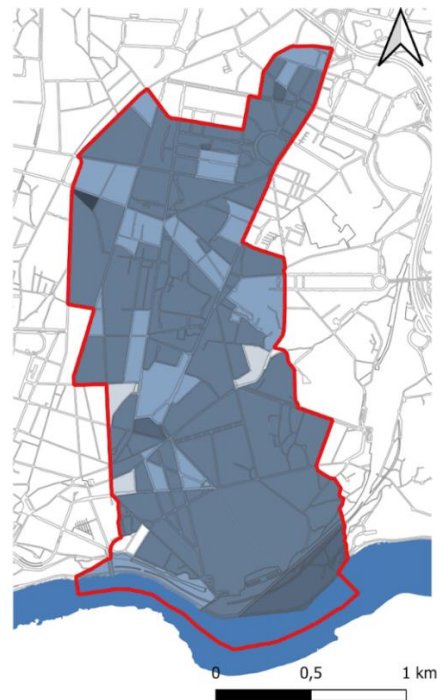
Vulnerabilities

Closer to the Douro River, there exists a convergence of high socio-economic deprivation and unstable zones, attributable to the risk of landslides. Given the vulnerability of the elderly population in these areas, it is possible to observe that from 2011 (Fig. 29) to 2021 (Fig. 30), the number of elderly had increased, achieving 75.3% of subsections within the parish with 51% or more of the population older than 65 years old (Fig. 30). Considering that the parish has the highest levels of elderly individuals living alone in the municipality, this demographic data must be taken into account when prioritising interventions in mapping priority zones (INE, 2021; Monteiro, Madureira, Fonseca, & Velho, 2018).

Map 1 - 65 + years old Population in 2011



Map 2 - 65 + years old Population in 2021



Legend:

Parish of Bonfim

Douro River

Blocks

Resident Population over 64 years of age (%)

0 - 5

6 - 10

11 - 25

26 - 50

51 - 75

76 - 100

Fig. 29 - Map of the parish of Bonfim, with percentage of elderly population per subsection, in 2011. Source: adapted from CMP, 2018; Monteiro et al., 2018.

Fig. 30 - Map of the parish of Bonfim, with percentage of elderly population per subsection, in 2021. Source: adapted from INE, 2021.

The elderly population requires shorter walking distances to reach climate shelters, and they necessitate a robust network to receive assistance during crises, particularly as they are more susceptible to adverse effects of extreme temperatures, both high and low.

Finally, the map below (Fig. 31) illustrates intersecting vulnerabilities, including age demographics (INE, 2021), socio-economic deprivation (Monteiro et al., 2018), and the housing typology of the “ilhas” (PDM, 2021). The “ilhas”, characteristic of the municipality of Porto, are low cost working-class housing or set of houses, from the XIXth century. Of the 8,265 “ilhas” in the municipality, only 7% are in good living conditions (PDM, 2021). These are notably prevalent in the parish of Bonfim, with São Vítor Street being a well-known area for this type of housing. The map shows that these typologies often occur in clusters, typically near or within zones of socio-economic deprivation.

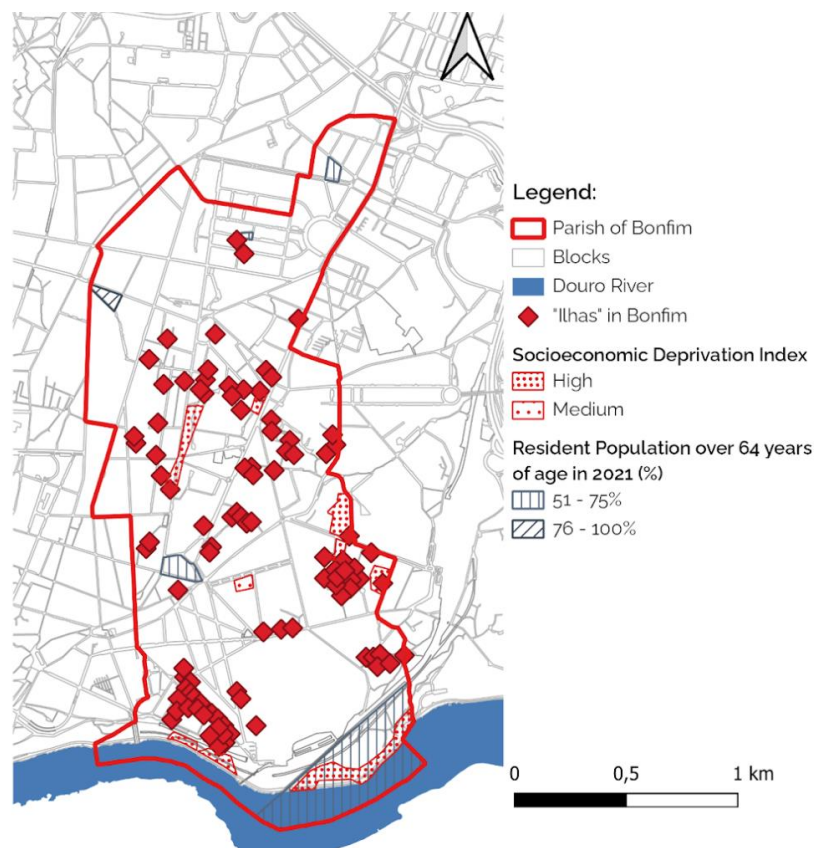


Fig. 31 - Maps of the parish of Bonfim, with percentage of elderly population per subsection, in 2011 and 2021.

Source: adapted from INE, 2021; PDM, 2021.

5.4. SYNTHESIS

In the parish of Bonfim, certain small areas exhibit higher levels of socio-economic vulnerability (Monteiro, Madureira, Fonseca, & Velho, 2018). The mapping of socio-economic index was taken from the Environmental and Biophysical Support (Monteiro, Madureira, Fonseca, & Velho, 2018), while the priority of qualification from the Report of Environmental Index (Monteiro et al., 2022), which presents a detailed diagnosis of the bioclimatic discomfort for the municipality of Porto. When combined with areas more prone to extreme weather events, such as extreme high and cold temperatures, as well as areas with varying degrees of ventilation, these zones pose greater risks to the local population. It is

possible to observe that there are some small areas of socio-economic vulnerability in the parish of Bonfim, and that many of the “ilhas” located inside the parish, especially in the centre, are near watercourses and flooding spots. Some of them are located in a high priority area for environmental qualification, meaning that the thermal discomfort may enhance these vulnerabilities (Fig. 32).

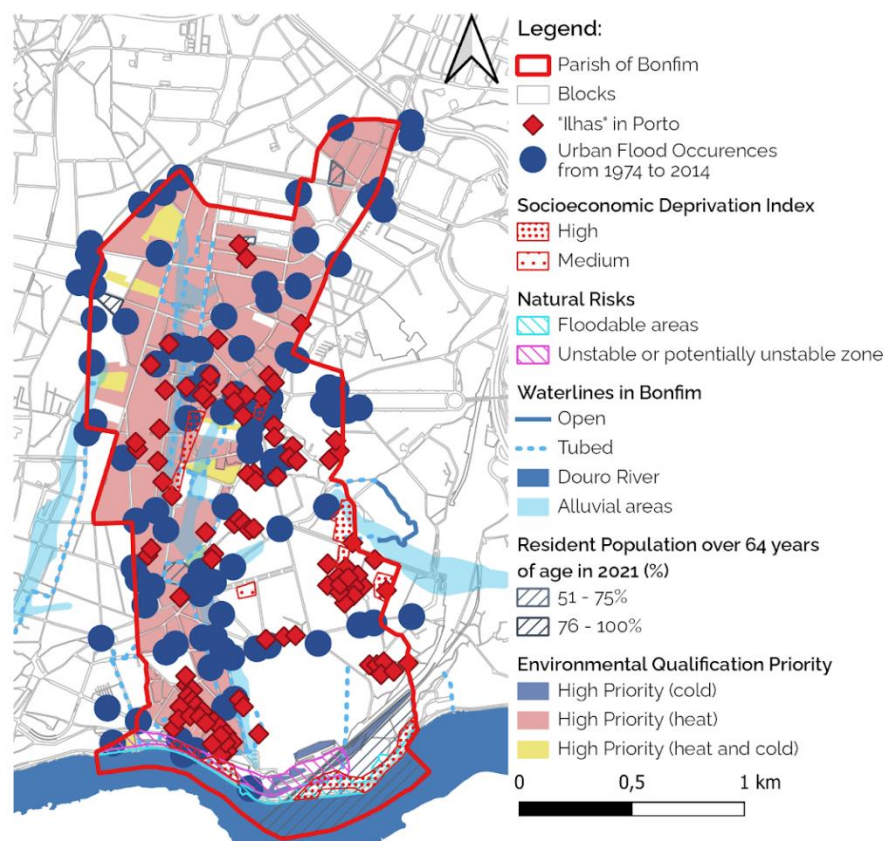


Fig. 32 - Synthesis map risks and vulnerabilities considering environmental qualification priority. Source: adapted from Monteiro et al., 2018; Monteiro et al., 2022.

As previously noted, there is currently no comprehensive mapping of all vulnerabilities present in the territory of Porto on a small scale. Mapping vulnerabilities is a crucial method to be applied in a top-down approach, aiding in the understanding of intersecting vulnerabilities and their exposure to risks. Such mapping endeavours are essential for informed decision-making and effective intervention planning.

The correlation between climate change-induced risks and social vulnerabilities within the municipality is of utmost importance in categorising areas requiring interventions with greater urgency. The proposition of climate shelters offers a swift solution that caters to the entire population. In times of extreme events, such as extreme temperatures or heavy rains leading to flooding, having designated shelters ensures people have a safe haven, particularly in vulnerable areas where housing conditions may not provide adequate protection. The use of social infrastructures for these purposes fosters a safer environment and strengthens connections among neighbours. The planning process for these shelters must consider locations already familiar to and trusted by the population, enhancing community resilience and promoting climate justice effectively.

6

CLIMATE SHELTERS SYSTEM IN THE PARISH OF BONFIM

The proposal for climate shelters focuses on the parish of Bonfim, adhering to the methodology detailed in Chapter 4. The final proposal results from refining the selection of potential climate shelters based on their compliance with climate risk requirements, the necessary qualifications to fulfil their shelter function, and their accessibility within a 5-minute walking radius. This work is part of the second phase of the methodology, following the preparation and collection of data for the analysis and contextualisation of the city.

6.1. PHASE 1

For the preparation of the methodology, key sources of information were selected, including municipal reports and legislation, such as the Municipal Master Plan, Environmental and Territory Characterisation Reports, and data from the Statistical Institute (INE). These sources provided relevant data for analysing the territory and its vulnerabilities.

Following the selection of sources, the documents were downloaded and thoroughly studied to generate the Characterisation of the Case Study (Chapter 5). Most of the information collected was mapped using QGIS software, facilitating the analysis and cross-referencing of data. This approach was crucial for identifying areas where vulnerabilities and risks intersect, thereby highlighting where interventions are most needed. The proposal for climate shelters was developed based on these maps, enabling more precise location of the shelters.

6.2. PHASE 2

6.2.1. IDENTIFICATION OF POTENTIAL CLIMATE SHELTERS

To identify potential climate shelters, a survey was conducted on facilities considered by Porto City Council as collective equipment (both existing and proposed) (PDM, 2021) and social facilities (Rede Social, 2023). Additionally, other institutions that could fulfil this role were identified. This initial survey did not consider the fulfilment of the requirements for the climate shelter function but aimed to analyse all existing social infrastructures in the area (Fig. 33 and Fig. 34).

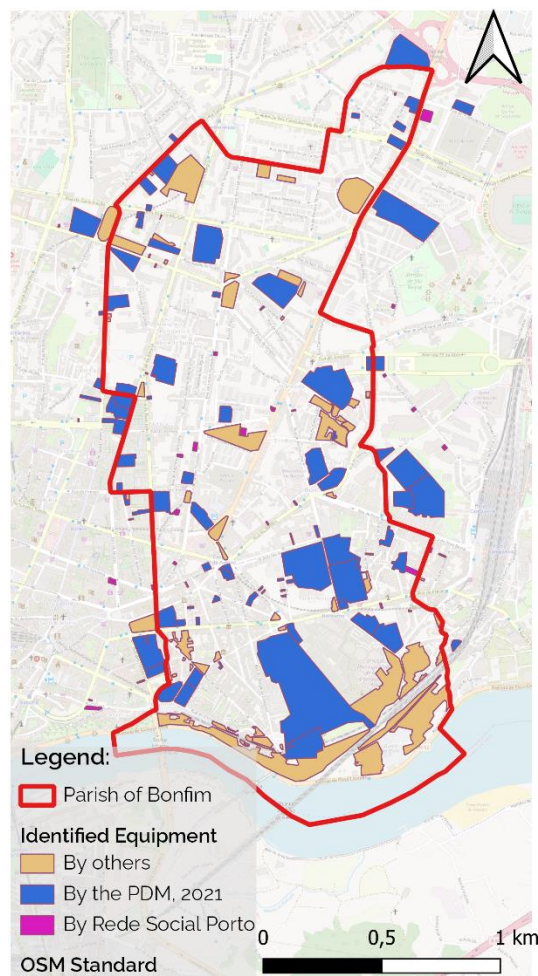


Fig. 33 - Mapping of Infrastructures that could be used or adapted to climate shelters classified by the institutions that mapped the equipment. Source: PDM, 2021; Rede Social, 2023.

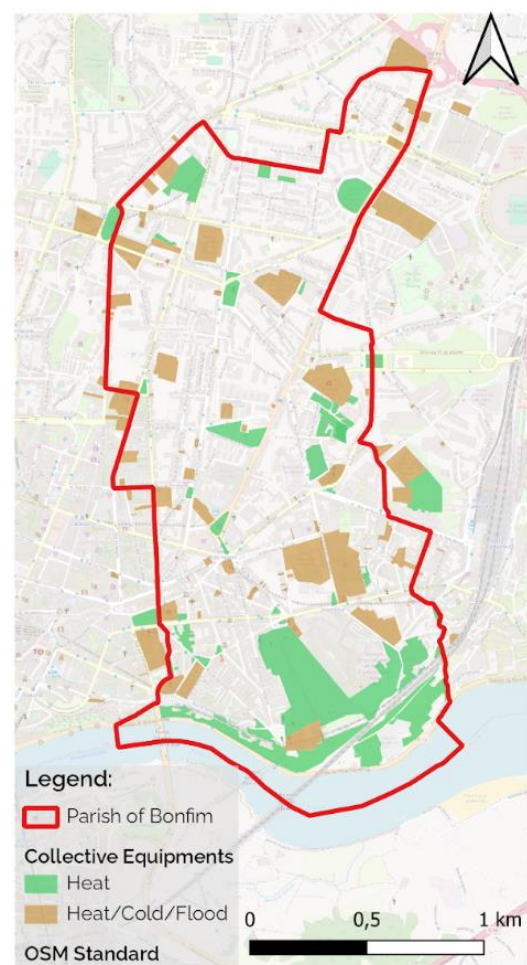


Fig. 34 - Mapping of Infrastructures that could be used or adapted to climate shelters, classified by the type of risk they respond to. Source: PDM, 2021; Rede Social, 2023.

All these sites were geo-referenced using QGIS 3.22.11 software, with details on whether they are open or closed, the source of the proposal, the name of the facility, its regular use, and they were numbered for the creation of a table. This table facilitated the subsequent analysis of the sites' real usefulness in the face of climate risks and the type of support they could provide to the population.

The table, initially created, listed 183 mapped sites (see Appendix 9.2 - Table with Potential Shelters). These sites were analysed further after on-site visits and verification via Google Maps to determine their current usage and condition. At this stage, the assessment of which criteria each site meets to serve as a climate shelter was carried out, concerning the types of risks they can mitigate.

Several issues were considered during this stage, influencing the decisions about which spaces are potential climate shelters:

- **Proposed but Inactive Spaces:** Some spaces mapped by the PDM (2021) have been proposed as collective equipment but are currently inactive (not being used, such as abandoned buildings), and in some cases, have not undergone any intervention. Some proposed green spaces remain

undeveloped, complicating the immediate implementation of the shelter network. However, future development of these spaces should include design guidelines to ensure they fulfil climate shelter requirements.

- **Health Centres:** Initially included, health centres were later removed from the list due to their specific regular use. Allowing unrestricted access could disrupt their normal functioning, especially during major weather emergencies when they are needed for medical help. Nonetheless, these centres will be marked to guide the population in need of medical assistance during extreme events.
- **Educational Institutions:** Schools, childcare centres, and universities were initially identified as potential climate shelters. However, their specific use could be disrupted by an influx of people. Despite this, educational institutions foster a strong sense of community and can serve as reference points during extreme events, such as floods. Therefore, they will be marked on a separate map for identification by the surrounding population during such times.
- **Closed Spaces:** Analysing closed spaces posed difficulties due to limited public access, leading to the prioritisation of already open public spaces where criteria fulfilment could be verified. Closed spaces often have restricted hours, necessitating operational changes if they were to be activated as climate shelters.

It should be noted that spaces outside the limits of Bonfim parish were excluded, although the coverage area might be partially inside the parish.

6.2.2. RESULT OF INTERVIEWS

After the initial selection of shelters, it was possible to start the interviews. The interviews were conducted at potential shelter sites within the parish of Bonfim over the course of one week, varying the days and hours to include both weekdays and weekends. This approach aimed to engage a diverse group of individuals, varying gender and age, to gather a broad range of opinions. Most of the interviews took place in parks, where people go to interact with each other and sit on the benches.

In total, 32 people were interviewed using three open-ended questions (Fig. 35). Of these respondents, 56.25% were women, and 65% were adults. When asked if they feel affected by climate change, 78% indicated that they do. Respondents mentioned experiencing more extreme cold and rain in winter and noted that the climate has become more unpredictable. Additionally, they pointed out the problem of air pollution, describing the city's air as "heavy".

Many respondents engage in outdoor activities related to warm weather, such as visiting parks, beaches, and using restaurant patios ("esplanadas"). In contrast, during winter, most respondents prefer staying at home, with only 12.5% mentioning that they go to indoor places during cold weather. Regarding heavy rain/flood, people associate it with the winter season, mentioning that they tend to stay at home during these events.

When asked if they would use climate shelters, 84.35% of respondents said yes, 6.3% said maybe, and 9.35% said no. Interestingly, although people often mention cold temperatures when discussing how they are affected by climate change, they are more accustomed to engage in activities during the summer. This suggests a lack of awareness or availability of public places to go during cold waves.

One notable challenge during the interviews was engaging people on the topic of climate change. While many acknowledged feeling affected, few could articulate why. When asked about their activities during extreme events, the interviewer often had to clarify the types of events being referred to, and respondents typically considered heat waves, mentioning parks and beaches. There was a general lack of awareness

about changes in behaviour during summer and winter, indicating that people do not seek specific places based on climate events but rather visit familiar locations out of habit.

Many respondents struggled to elaborate on the subject, making it challenging to extract detailed answers, even though the questions were open-ended. Consequently, responses began to repeat themselves, making it difficult to identify specific places used as informal climate shelters, which was one of the goals of the process. Rethinking the interview questions to elicit more relevant answers would be beneficial.

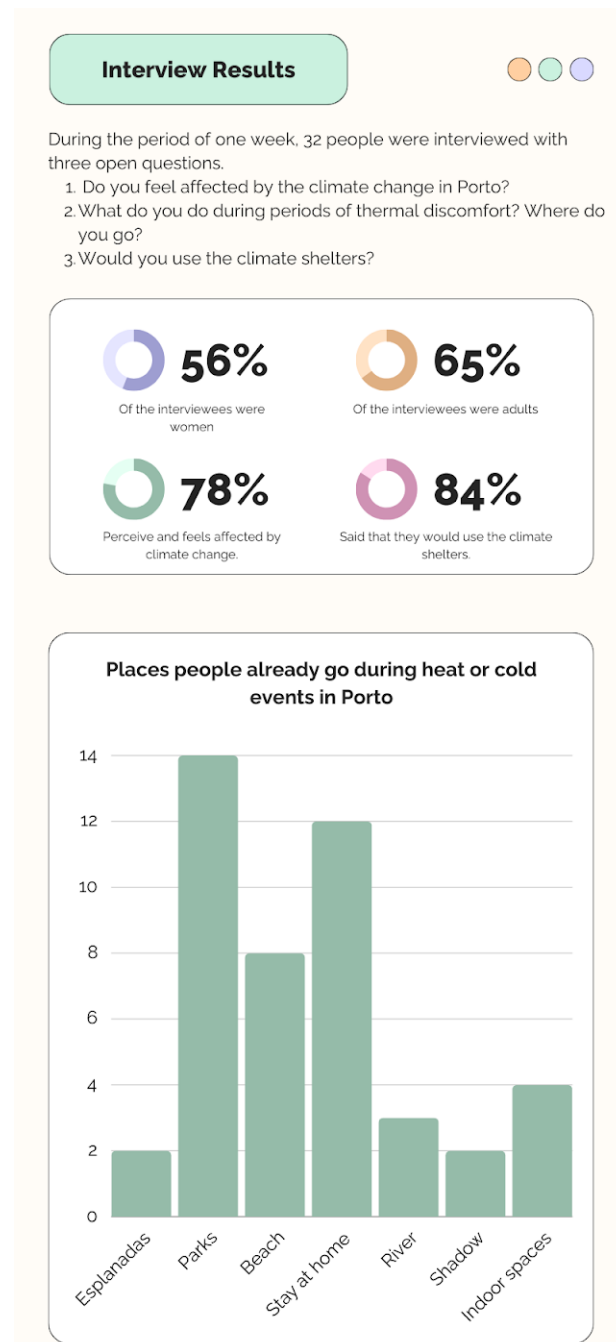


Fig. 35 - Results of interviews with the public. Author's own elaboration, 2024.

The interviews aimed to perceive public awareness of climate change adaptation and the potential use of climate shelters. However, for future research, it would be beneficial to conduct a broader survey to better understand the population's knowledge of climate change and validate their feelings of being affected by it. Additionally, questions should explore the social infrastructure they frequent and how their use of these places varies by season. Interviews should serve as one tool in a bottom-up planning approach, complemented by other strategies to both understand and engage the target population in the decision-making process.

Finally, although initially previewed, interviews with stakeholders were not conducted due to the time constraints of this project. However, it is important to note their significance in the planning process. Stakeholders can provide valuable insights into potential locations for climate shelters and facilitate community integration in the decision-making process. Their involvement would ensure a more comprehensive and inclusive approach to planning and implementing the climate shelter network.

6.2.3. FINAL PROPOSAL FOR CLIMATE SHELTERS SYSTEM

After the initial filter, observations made during the interviews provided insights into the degree of need for requalification of the remaining potential shelters. This information was further drawn on a map (Fig. 36). The classification legend was structured as follows:

Outdoor (Heat):

- **None:** Spaces that already meet all criteria to function as climate shelters.
- **Very Low:** Spaces that only need free drinking water, and/or to be open to the public.
- **Low:** Spaces that need free drinking water, toilet and seating.
- **Medium:** Spaces that have some shade but still need to provide free drinking water, toilet, and seating.
- **High:** Spaces that require a change in pavement material and/or accessibility.
- **Very High:** Green spaces within walls, inaccessible from the street, but could be valuable where there are few heat shelters.

Indoor (Heat/Cold/Flood):

- **None:** Spaces that already meet all criteria to function as climate shelters.
- **Very Low:** Spaces that only need extended opening hours to be available throughout the day and night.
- **Low:** Spaces that need free drinking water and seating.
- **Medium:** Spaces that require intervention to provide toilets and/or spatial accessibility.
- **High:** Spaces not currently in use but could become climate shelters with some renovation.
- **Very High:** Abandoned buildings located in areas lacking climate shelters within the coverage radius.

Spaces classified as high or very high need of qualification are not yet suitable to be used as shelters. Those classified as medium can be used but may not meet all the necessary conditions to serve as effective shelters. Spaces requiring low or very low intervention are ready to be used and provide the necessary conditions. Finally, there were no spaces classified as needing no intervention, indicating that all potential climate shelters require some modifications to meet the necessary conditions. Essentially, most outdoor potential shelters need at least toilet facilities or free drinking water, while indoor shelters need to extend their operating hours to be accessible to the public for longer periods of time.

This mapping also provides information on when each shelter can begin to be used, allowing the implementation of the network to occur in phases according to the prioritisation of areas and the qualification of spaces. It is important to mention that these sites are qualified for use by all types of the public on a regular and short-term basis. In other words, they are intended for daily use during extreme heat or cold waves and rainy days. In case of flooding that causes damage and loss of residential properties, a different type of emergency shelter will be utilised, which will be explained further.

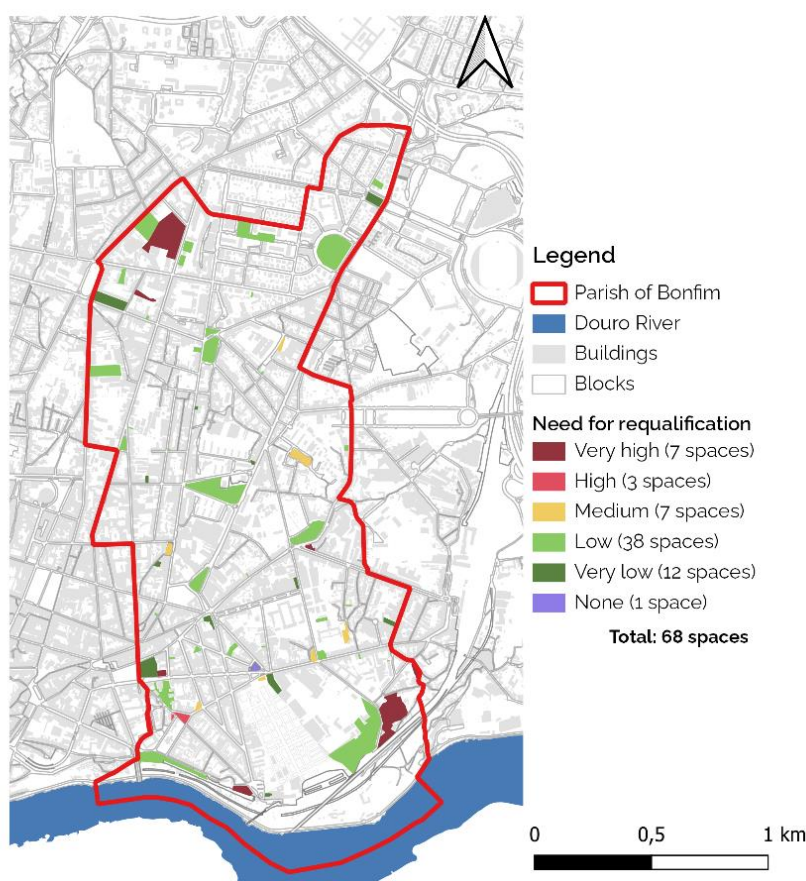


Fig. 36 - Need for requalification of Potential Climate Shelters. Author's own elaboration, 2024.

Shelters must meet the coverage radius requirement, creating a network that people can use for short or longer periods during extreme events. These shelters can have cultural, commercial, or institutional regular uses and provide refuge during such events. For example, an art gallery or museum could offer its entrance hall for people to take refuge from the heat during summer, providing drinking water and a pleasant temperature.

For the proposal of a system of shelters for daily use, the spaces were separated into four subsystems:

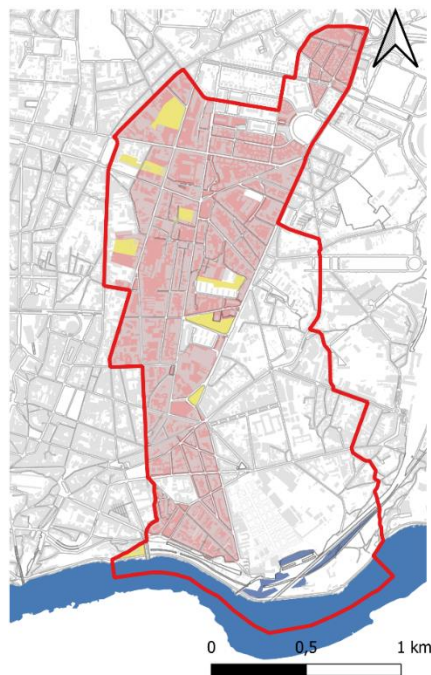
- **Outdoor Shelters:** These include parks and squares where people can mitigate the effects of heat waves. They must provide shade, air circulation, seating, and free drinking water. The presence of water features is beneficial for reducing temperatures, or even allowing people to use the water to cool down. To be more accommodating and allow longer stays, these shelters can also offer restrooms.

- **Indoor Shelters:** These provide protection from heat waves, cold waves, rain, and floods. Using the values of the shelters network proposed in Barcelona (Ajuntament de Barcelona, n.d.) as reference, it is recommended to maintain indoor temperatures above 19°C during winter, with or without mechanical heating, and below 27°C during summer. These shelters often have cultural, commercial, or religious regular uses and typically have set opening hours. An agreement with the municipality would be necessary to extend their hours during extreme events and to allow free public access.
- **Institutions to shelter vulnerable groups on a daily basis:** These are indoor shelters intended for vulnerable populations who may need to use spaces other than their homes. They must provide conditions for longer stays during extreme events but are not meant for use in the case of catastrophes. These shelters are typically community centres or have institutional regular uses.
- **Shelters for catastrophes:** Indoor shelters designed to utilise larger spaces, such as schools and sports centres, capable of accommodating more people for extended periods. These shelters are intended for use in extreme situations, such as flooding that causes significant damage and displacement, leaving people without a place to go.

Outdoor Shelter

The first subsystem presented is the outdoor shelters, to be used only for heat waves (Fig. 37 and Fig. 38). It is interesting to mention that even though these shelters do not cover the entire area in a 5 minutes-walk, they are mostly present in the areas of greater risk to heat waves. As a guideline of the proposal, some examples of how shelters can implement the criteria were designed, which were made considering the criteria developed in the methodology (Fig. 11 in chapter 4.1.1) considering outdoor shelters for daily use and all public (Fig. 39).

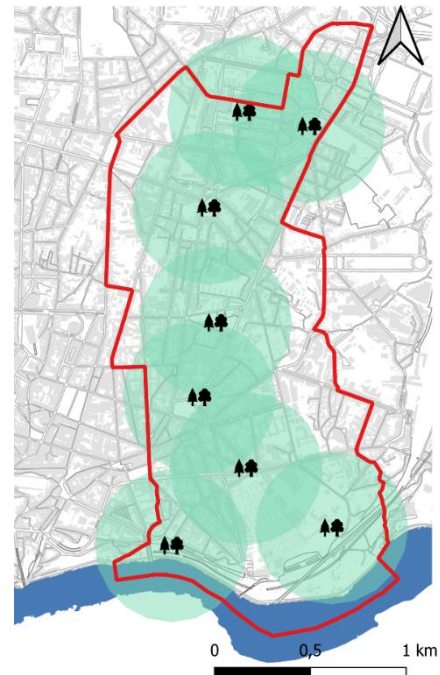
Outdoor Shelters



Legend:

 Parish of Bonfim	Environmental Qualification Priority
 Blocks	 High Priority (cold)
 Douro River	 High Priority (heat)
 Buildings	 High Priority (heat and cold)

Fig. 37 – Map of Environmental Qualification Priority, showing the predominance of need for qualification regarding heat. Source: Monteiro et al, 2022.



Legend:

 Parish of Bonfim	Regular Use
 Douro River	 Park
 Buildings	Coverage Radius
 Blocks	 Outdoor for all public (Heat)

Fig. 38 – Map of Outdoor shelters with a coverage radius of 400m (5 min walking). Author's own elaboration, 2024.

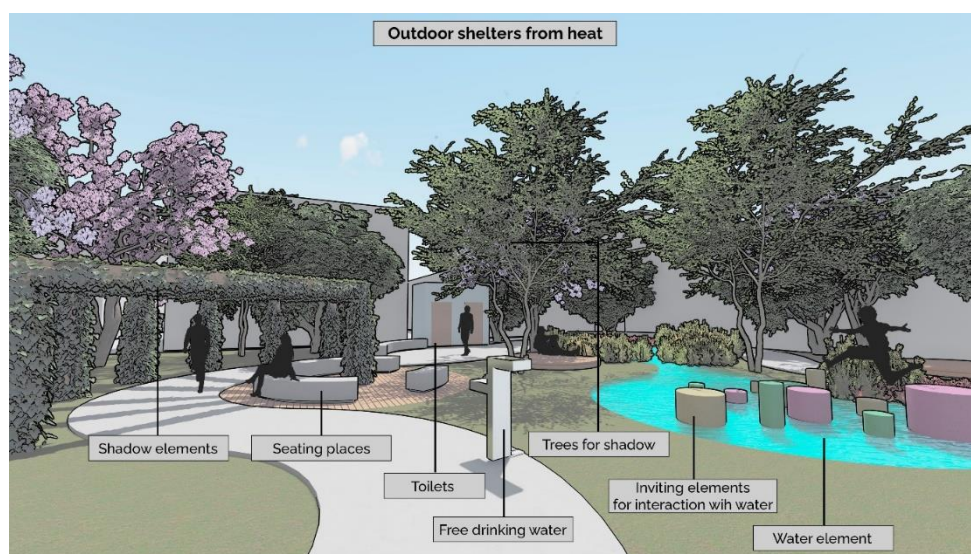


Fig. 39 - Scheme of Outdoor shelters, for heat waves. Author's own elaboration, 2024.

Indoor Shelters

The subsystem of Indoor Shelters is designed to protect the general public from heat, cold, and rain/flood events (Fig. 40 and Fig. 41). This subsystem includes commercial centres, certain religious buildings, cultural centres, and a library, which can partner with the municipality to provide shelter. These spaces have regular operating hours, but in cases of extreme events, the municipality can alert them in advance to extend their hours, particularly during the evening or night in winter. The criteria outlined in the shelter scheme ensure these spaces can serve as efficient shelters for various types of risks (Fig. 42).

Indoor Shelters

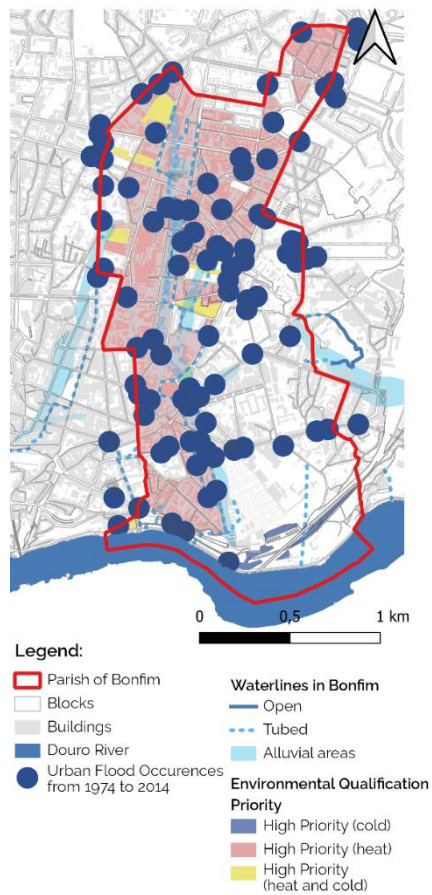


Fig. 40 - Map of Environmental Qualification Priority, flood spots and alluvial areas, showing the predominance of need of qualification regarding heat. Source: Águas do Porto, n.d; Monteiro et al, 2022, PDM, 2021.

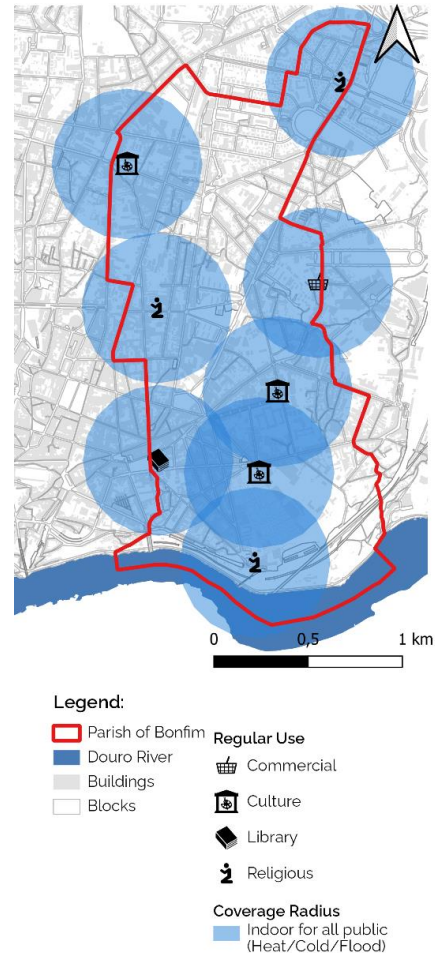


Fig. 41 - Map of Indoor shelters with a coverage radius of 400m (5 min walking). Author's own elaboration, 2024.



Fig. 42 - Scheme of Indoor shelters, for heat/cold waves, and rain/flood. Author's own elaboration, 2024.

Institutions to shelter vulnerable groups on a daily basis

This shelter subsystem consists of indoor institutional facilities (Fig. 43 and Fig. 44), primarily social centres that already serve vulnerable groups and engage in social actions to support them. While not all institutions are listed here, all have the potential to partner with the municipality to provide aid to these groups. These institutions are located near areas where vulnerable people reside, such as "ilhas," socioeconomically deprived neighbourhoods, and areas with a high population of elderly individuals. In locations where no institutions are mapped but vulnerable groups are present, alternative solutions must be identified. Some individuals can walk a longer distance, but in case of mobility difficulties, nearby religious facilities might be a solution whenever there is previous agreement. These shelters must meet the same criteria as regular indoor shelters (Fig. 42).

Institutions to shelter vulnerable groups daily

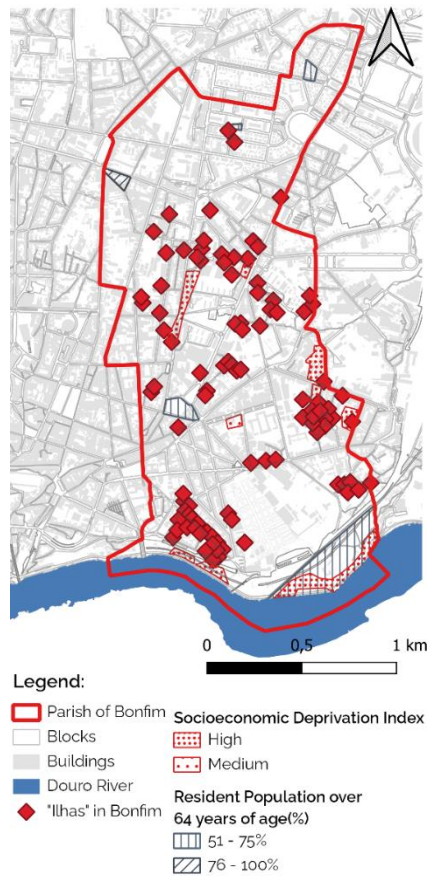


Fig. 43 - Map of main vulnerabilities in the territory.
Source: Monteiro et al, 2022.

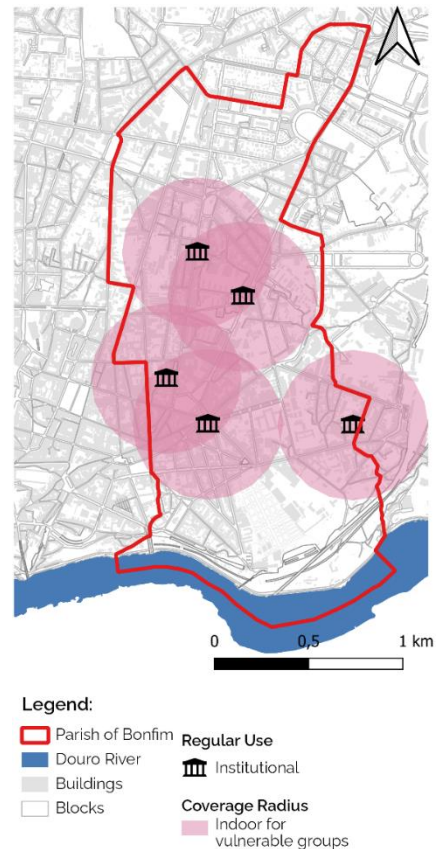


Fig. 44 - Map of Indoor shelters for vulnerable groups with a coverage radius of 400m (5 min walking).
Author's own elaboration, 2024.

Shelters for catastrophes

This category of shelter is crucially located in areas of socioeconomic deprivation and heightened climatic risks. Therefore, schools and social centres are often selected as they provide infrastructure for people to stay for extended periods, such as throughout the day or night, especially when their homes lack ideal infrastructure for thermal comfort or are lost or damaged due to flooding.

To identify suitable locations for these shelters, areas, where climate risks intersect with social vulnerabilities, were mapped to understand the areas with the greatest need for implementing these shelters (Fig. 45).

Taking into account the priority areas, schools were mapped within a coverage radius of 500 metres, considering their larger capacity to serve as shelters (Fig. 46). Additionally, a sports centre was identified to be utilised in case of necessity.

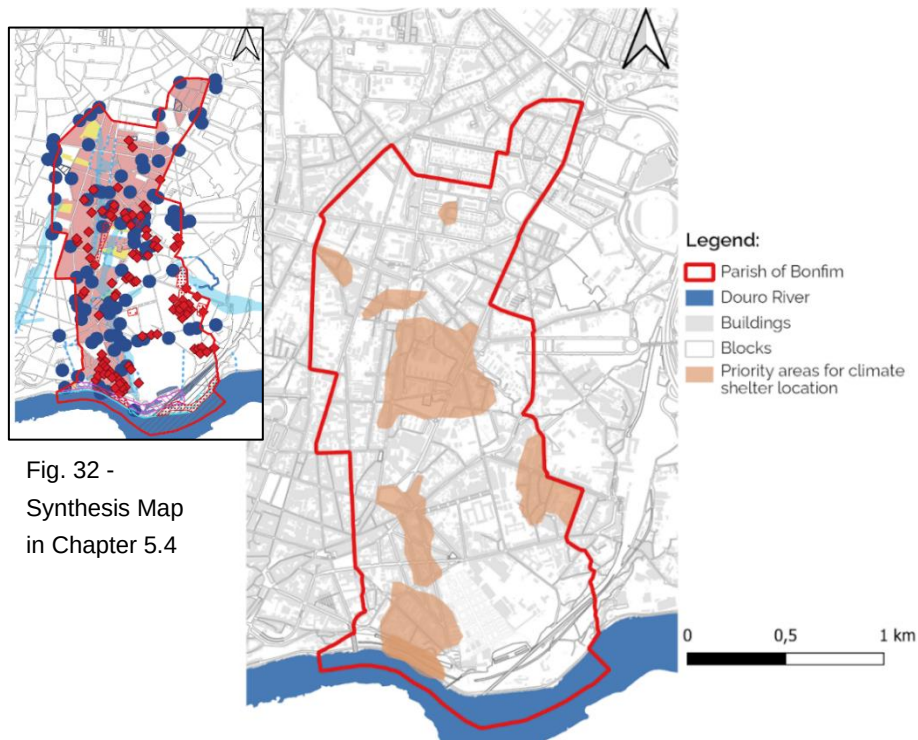
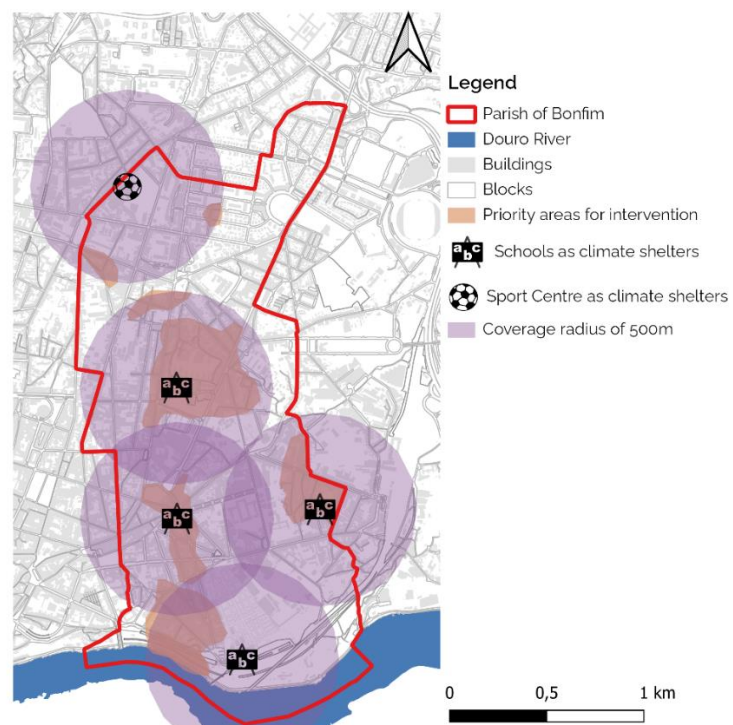


Fig. 45 - Identification of vulnerable areas according to the synthesis map - risks and vulnerabilities. Author's own elaboration, 2024.



Finally, in the scheme below (Fig. 47), it is possible to see the criteria that shelters for catastrophes must meet. These criteria were defined by combining the requirements for indoor shelters from the reference cases (Fig. 11 in Chapter 4.4.1) and incorporating infrastructure for longer stays, such as sleeping and eating facilities. It is important to note that these shelters, located in schools or sports centres, are intended for use only in emergency situations involving significant loss and damage. They must be supported by early warning systems to enable faster community responses.

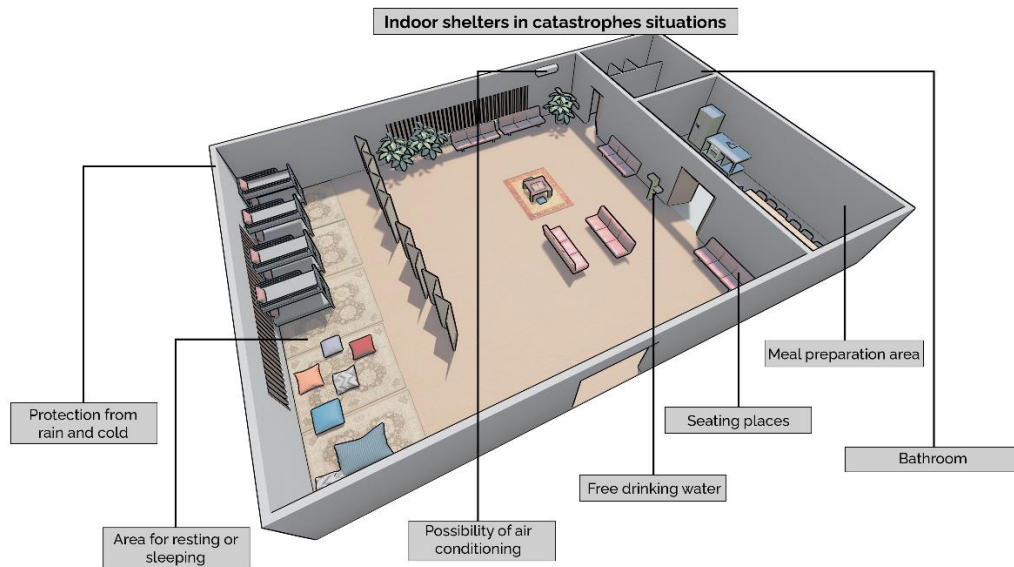


Fig. 47 - Scheme of shelters from catastrophes. Author's own elaboration, 2024.

Complete System

Finally, all shelters were drawn on a map with a code for each type of risk they respond to.

O – Outdoor shelters responding to the risk of heat.

I – Indoor shelters responding to the risk of heat, cold and rain/flood.

V – Indoor shelters for vulnerable populations, responding to the risk of heat, cold and rain/flood.

C – Indoor shelters for situations of catastrophes.

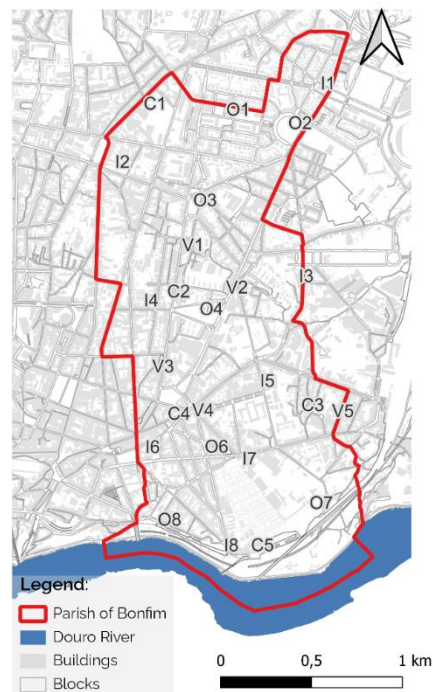


Fig. 48 - Map of location of all shelters by ID. Author's own elaboration.

The mapping reveals that all shelters are distributed within the territory of Bonfim parish. In total, there are 26 selected shelters: 8 outdoor shelters (parks), 8 indoor shelters regularly used for religious, commercial, and cultural purposes, 5 indoor shelters designated for vulnerable populations, and 5 catastrophe shelters. The selection process aimed to utilise existing locations that would require minimal or no intervention to function as shelters. Table 5 demonstrates that only spaces needing low, very low, or no intervention were chosen to streamline the implementation of this strategy. Indoor shelters were selected to vary in their regular use, ensuring that people feel comfortable entering these spaces and can engage in different activities while being protected from climate events.

Table 5 - Final Climate Shelters System, with Id for location in map, type of risk they respond to, equipment, regular use, and need for requalification level. Author's own elaboration.

Id	Type of Risk	Equipment	Regular Use	Need for Req.
O1	Outdoor (Heat)	Alameda Eça de Queiroz and Parque Infantil Do Jardim Do Conhecimento	Park	Low
O2	Outdoor (Heat)	Praça do Dr. Francisco Sá Carneiro	Park	Low
O3	Outdoor (Heat)	Jardim da Praça Rainha Dona Amélia	Park	Low
O4	Outdoor (Heat)	Parque Paulo Vallada	Park	None
O5	Outdoor (Heat)	Jardim do Campo 24 de Agosto	Park	Very low
O6	Outdoor (Heat)	Parque Infantil no Largo de Doares dos Reis	Park	Very low
O7	Outdoor (Heat)	Parque das Águas	Park	Low
O8	Outdoor (Heat)	Alameda das Fontaínhas	Park	Low

I1	Indoor (Heat/Cold/Flood)	Igreja de Santo Antônio das Antas	Religious	Very low
I2	Indoor (Heat/Cold/Flood)	Fundação Instituto Marques da Silva	Culture	Very low
I3	Indoor (Heat/Cold/Flood)	Centro Comercial Fontenário	Commercial Centre	Low
I4	Indoor (Heat/Cold/Flood)	2a Igreja Baptista do Porto	Religious	Very low
I5	Indoor (Heat/Cold/Flood)	Casa Oficina Antonio Carneiro	Culture	Very low
I6	Indoor (Heat/Cold/Flood)	Biblioteca Pública Municipal do Porto	Library	Very low
I7	Indoor (Heat/Cold/Flood)	Museu Militar do Porto	Culture	Very low
I8	Indoor (Heat/Cold/Flood)	Capela de Nossa Senhora da Graça	Religious	Very low
V1	Indoor (for vulnerable)	Qualificar para Incluir, Associação de Solidariedade Social	Institutional	Very low
V2	Indoor (for vulnerable)	Pele - Associação Social e Cultural	Institutional	Very low
V3	Indoor (for vulnerable)	Centro Social da Legião da Boa Vontade	Institutional	Very low
V4	Indoor (for vulnerable)	Junta de Freguesia do Bonfim	Institutional	Very low
V5	Indoor (for vulnerable)	Senhor Do Bonfim - Associação de Solidariedade Social	Institutional	Very low
C1	For catastrophes	Acadêmico Futebol Club	Sport Centre	Low
C2	For catastrophes	EB1 Fernão de Magalhães - Agrupamento Aurelia de Sousa	Educational	Low
C3	For catastrophes	Escola Básica do 1o Ciclo com Jardim de Infância da Lomba	Educational	Low
C4	For catastrophes	Escola Básica No1 do Campo 24 de Agosto	Educational	Low
C5	For catastrophes	Escola Salesianos do Porto	Educational	Low

Once the mapping and selection of the aforementioned shelters have been completed, the subsequent stage of the implementation process involves the analysis of their capacity, as well as the formulation of a communication strategy for users, which should include information on thermal comfort and the facilities available at each location. In addition to informing the population, these aspects should also be monitored to ensure that the shelters are functioning properly.

6.3. DISCUSSION OF RESULTS

This proposal approaches two dimensions of adaptation planning. Firstly, it serves as a strategy to protect people from the impacts of extreme climate events, which are becoming more frequent, unpredictable, and intense, particularly affecting vulnerable populations. Secondly, it leverages social infrastructures to enhance resilience. This way, it is possible to approach current risks, as well as prepare the community to approach future challenges.

The initial identification process yielded a substantial number of mapped equipment, which enabled a comprehensive analysis of potential locations that could serve as shelters. To ensure an effective and efficient system, the equipment selected was that which already provided the majority of facilities, as well as that which provided the best coverage of the territory, taking into account the risks and vulnerabilities. Consequently, the system of selected shelters is comprised of four subsystems, which will provide a more comprehensive and systemic solution to the risks and vulnerabilities.

During the selection process, it was observed that the proposed shelter system is intended for public use. However, there may be vulnerable groups that require longer-term accommodation during the day. In such instances, social institutions may be instrumental in providing activities and ensuring the needs of these individuals are met. The institutions selected for potential shelters are those that already function as day centres and have sufficient space to accommodate additional individuals. Moreover, it is essential that the institutions in question demonstrate a commitment to fulfilling the role of shelters in order for the initiative to be effective. Furthermore, in the event of a catastrophe, the authority may impose this function on the selected institutions.

Although not all institutions have been integrated into the daily climate shelter system for vulnerable groups, they can still participate in this climate adaptation strategy. This can be achieved through partnerships aimed at raising awareness in schools or by conducting workshops within their own communities.

A total of twenty-six spaces were selected to be part of the climate shelter system. However, eight of these (outdoor shelters) are parks that are already in public use and require the implementation of toilets and drinking fountains. In contrast, thirteen (indoor shelters and shelters for vulnerable people) would continue to be used, allowing greater access for the population and offering free water. The five shelters for catastrophic events require greater structural preparation to ensure readiness for catastrophe situations and to facilitate appropriate responses from the population and site staff. In terms of governance, the system is relatively straightforward to manage, firstly because it makes use of existing spaces and secondly because the population is already familiar with them. However, should the network require expansion, it is possible to revert to the selection phase, reanalyse the spaces, and select those that are more readily convertible to climate shelters. Furthermore, all the selected spaces have regular functions as **social infrastructures**, which are important for **enhancing social capital and building community resilience**.

It is therefore essential that planners address vulnerabilities through processes that engage and empower the population, especially those who are vulnerable. The proposed process for planning a climate shelter system was informed by the principles of climate justice, including recognition, procedure and distribution. The recognition principle involved the identification of geographical conditions and the most vulnerable populations, with the use of schools and sports centres in the parish for catastrophe shelters representing a primary application.

While the interviews were designed to address the procedural principle, it is evident that effective justice would require broader participation. This could be achieved through the implementation of strategies such as focus groups and workshops with the population and stakeholders. Due to time and resource constraints, this project serves as a guideline for planners. Future endeavours should include the preparation of the population for participation through the dissemination of information and the provision of educational resources.

The overarching objective of this proposal is to develop an equally distributed network of climate shelters, thereby ensuring that all members of society can benefit from climate change responses. The

planning of climate action with the objective of reducing vulnerabilities is of the utmost importance for the realisation of a just transition and the generation of resilience.

In their literature review, Malloy & Ashcraft (2020) observed that adaptation studies tend to focus on the outcomes of adaptation rather than the processes involved. Furthermore, they noted that such studies often fail to address the underlying causes of injustice. Consequently, further studies must endeavour to gain a more comprehensive understanding of the target population in order to inform the design of effective interventions.

Furthermore, community-based adaptation empowers the population by fostering self-organisation through community governance systems. The implementation of an alert system and communication plan can enhance the community's ability to anticipate, respond to, and recover from extreme climate events, thereby building adaptive capacity and increasing the acceptance of the proposal. Such a system also enables the population to assist one another during critical moments by helping neighbours and the elderly seeking refuge in designated places.

Effective climate action necessitates multilevel governance and partnerships with civil society organisations, academic and scientific institutions, and local small businesses. This involves integrating both top-down and bottom-up approaches, ensuring a comprehensive and inclusive process. By involving multiple stakeholders and levels of governance, the strategy can be more robust and responsive to the diverse needs and capacities of the community.

The construction of outdoor shelters also serves to mitigate the impacts of climate change through the implementation of strategies to renaturalise spaces, as outlined in the municipality's climate adaptation strategy and the "Plano de Valorização das Ribeiras do Porto" (Porto's Riverbanks Valorisation Plan). The development of high-quality green spaces fosters more effective climate shelters from heat while promoting greater integration of green and blue infrastructure within urban environments.

Moreover, the interviews conducted revealed that climate shelters serve not only to protect from climate events but also to provide respite from air pollution, whether through parks or indoor spaces. In essence, these shelters play a pivotal role in enhancing the population's quality of life, fostering greater use and ownership of the city's amenities for all residents.

In summary, climate shelters, seen as components of social infrastructure, serve as a robust strategy for climate change adaptation while also functioning as spaces for strengthening social capital and community resilience. They have the potential to become everyday spaces that contribute to local identity and cohesion, fostering resilience, which is vital for reducing vulnerabilities. Implementing a system of climate shelters provides the population with a diverse array of spaces not only for protection but also for fostering connections between individuals. With knowledge of these spaces, people can make informed decisions and take independent action, thereby **enhancing overall community resilience**. This proposal is a step forward for adaptation planning, however, only the selection process is not enough to achieve a fair climate action, it must be done together with other strategies aiming to engage and to promote climate resilience and literacy in the population.

6.4. OTHER RECOMMENDATIONS

Establishing an effective network of climate shelters requires the implementation of strategies to ensure their functionality and efficiency. Key steps include clear communication with the public regarding shelter availability and access, dissemination of information through various media platforms, and the development of guidelines for the design and location of new shelters. Additionally, implementing a robust monitoring and evaluation system is essential to assess the effectiveness of shelters in fulfilling

their intended functions, including usage rates, satisfaction levels, and following of safety protocols. Through proactive measures and continuous improvement, it is possible to ensure that climate shelters serve their purpose in safeguarding the population during extreme climate events.

6.4.1. COMMUNICATION PLAN

The communication strategy for climate shelters is not only about their locations but also about when to seek them out. While civil protection in the municipality of Porto already assumes responsibility for certain vulnerable groups, such as homeless individuals during extreme cold, by making metro stops available, the proposed use of climate shelters in this work aims to cater to the entire population in a straightforward manner. Therefore, it is important to establish mechanisms to ensure that this information reaches everyone.

One strategy is to identify establishments with signage on their facades indicating that they can be used as shelters, thereby enabling passers-by to ascertain that they can access the premises freely. Another strategy is to disseminate information to the population about the thermal comfort in these spaces and which facilities are available in each shelter.

Another effective approach is to utilise various media channels (municipality website, newspapers, television, social networks) to provide advance warnings of weather events, along with a list of available shelters based on the imminent risk.

Not only communication with the population but maintaining open communication between the municipality and indoor equipment with set opening hours is crucial for ensuring the effectiveness of climate shelters. Implementing a system of prior alerts can help notify these establishments in advance of extreme weather events, prompting them to extend their opening hours to accommodate more people. This proactive approach ensures that adequate shelter is available to the community when needed most.

Moreover, developing a mobile application or a plugin for existing ones (such as Google Maps, or applications of the municipality) can assist people in finding the nearest shelter to their location and accessing weather event alerts. This application would serve not only the general public but also tourists, who frequently use GPS technologies while travelling. It would be particularly relevant for providing climate event alerts, enabling people to prepare in advance and seek these places when needed. Functioning as part of an early warning system, the application could categorise shelters by colour according to the type of risk and indicate which ones are currently open for use. A scheme of how the application might look is shown below in Fig. 49.

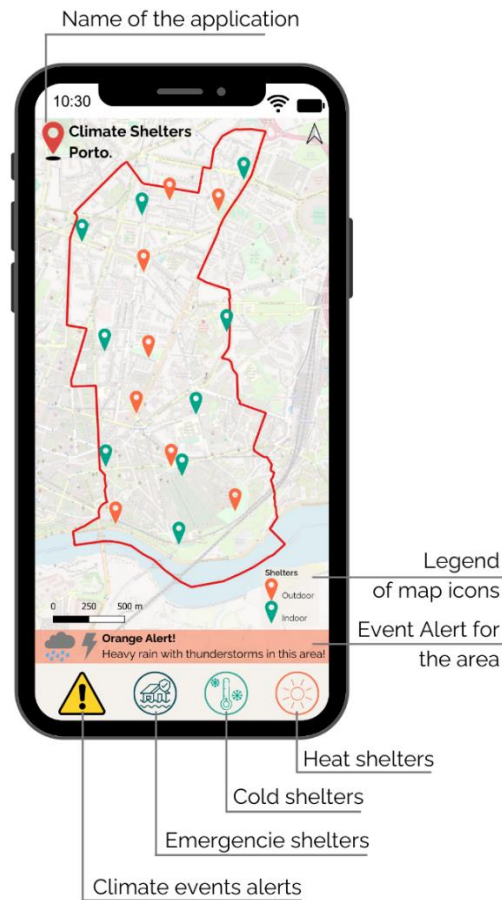


Fig. 49 - Suggestion of application for the location of climate shelters and climate event alerts. Author's own elaboration, 2024.

6.4.2. MONITORING

Monitoring the users and functioning of spaces is essential to ascertain their effectiveness as shelters. It provides insights into the awareness, usage, and satisfaction levels of the users regarding these spaces. Furthermore, monitoring facilitates understanding of emerging needs and informs strategies for enhancing the spaces to better fulfil those requirements.

This process can be conducted by the City Council independently or in collaboration with universities, employing both objective and subjective analyses. Objective assessments involve evaluating whether the spaces meet shelter requirements, while subjective evaluations entail engaging with the population/users for feedback. Similar to the approach used in developing the shelter network, the monitoring process should adopt a combination of top-down and bottom-up approaches, actively involving the community throughout the process.

Many identified places/sites necessitate interventions to render them usable, underscoring the importance of proactive monitoring. Climate shelters must remain adaptable to emerging vulnerabilities, risks, and changing locations, requiring ongoing adjustments.

Additionally, the implementation of new equipment must align with the process of monitoring and the evolving needs of the population. Effective monitoring enables timely identification of shelters that are

not meeting their functions or becoming overwhelmed, prompting necessary adaptations or the creation of new shelters. As such, it is imperative for municipal climate adaptation plans to incorporate design guidelines for shelters, outlining the necessary infrastructure in accordance with the selection criteria outlined in the methodology (Chapter 4). This ensures that shelters remain responsive to the needs of the community and effectively mitigate climate-related risks.

6.4.3. LITERACY AND AWARENESS

Another important aspect of raising resilience is to promote awareness campaigns and instruct the population on how to prevent and act during extreme events. In the context of the climate shelters system designed for catastrophes, it would be beneficial for institutions to visit schools designated as shelters to train professors and staff on how to protect themselves and the people who may need to use these spaces. This training is crucial in case institutions or the government are unable to reach the location in time, making it a vital tool in enhancing overall resilience.

Additionally, these spaces can provide information on preventive and adaptive measures for extreme events, such as the importance of drinking water during heat waves or protecting oneself during cold spells. These instructions should be displayed alongside the identification of the climate shelter at the entrance to ensure they are associated with the shelter system project.

6.4.4. GOVERNANCE

For the system to be effective and efficient, it is crucial for the municipality to clearly establish the management and monitoring responsibilities for each type of shelter. Given the involvement of both private and public institutions, each must understand their specific duties regarding their respective spaces. The responsibilities should be articulated among the municipality, civil protection and the institutions themselves but, to ensure this occurs efficiently, the municipality should delineate responsibilities and provide clear, detailed information to each institution.

6.4.5. SHARING KNOWLEDGE AND EXPERIENCES

Finally, another interesting strategy for the implementation of climate shelters systems (and other climate adaptation planning strategies) is to maintain contact with other cities to understand the results and feedback of their initiatives. By sharing methods and results, cities intending to implement climate shelter systems can use these insights as references for their own implementation. This open and collaborative approach allows cities to share ideas and support each other in improving the planning and execution process.

7

CONCLUSIONS

The studies on climate shelters are still emerging in the literature. The concept of climate shelters is primarily discussed in the context of critical infrastructure designed to protect populations during extreme weather events, such as floods that cause significant loss and damage. However, climate shelters should not only be functional during extreme events but also provide thermal comfort for everyday use.

During extreme events, it is beneficial to prepare these shelters to function for longer periods. However, it is equally important that people can use these spaces in other situations. While there is limited literature on using climate shelters for everyday use, some cities are beginning to adopt these strategies as part of their climate change adaptation efforts. These strategies are relatively new, with only a few cities proposing climate shelters as a comprehensive network. Many others are considering them as sporadic implementations or suggestions from political parties.

The first conclusion of this thesis is that **climate shelters need to address the multiple risks** in the territory. Most of the proposed shelters for daily use primarily address the risk of heat waves. However, given Portugal's context of significant energy poverty, it is justified to create conditions for vulnerable groups to cope with cold waves as well. This underlines the importance of creating a subsystem of indoor shelters for vulnerable groups, allowing those without adequate housing to use these spaces for protection during cold temperatures.

Secondly, by **using social infrastructures to build the climate shelters system, its potential to strengthen social capital and community resilience increases**, highlighting the importance of this strategy in climate-responsive planning. Even though this methodology has only been applied in one parish, its replicability was validated through this process becoming a guideline for urban planners to follow in proposing climate shelters in other cities.

Thirdly, **the bottom-up approach, when articulated with the top-down approach, is crucial to ensure the effectiveness and efficiency of proposals aimed at community resilience**. Although it was not possible to effectively apply the bottom-up steps proposed in the methodology, their importance for fair and equitable planning continues to be reinforced through community and stakeholders involvement. Municipalities have a wider reach within civil society, facilitating communication with the population and stakeholders, and organising workshops and focus groups. They can also be coupled to knowledge sharing among cities, implementing climate protection systems, which is essential for the success of the initiative.

Fourth, the **management and articulation of responsibilities by different entities and institutions is crucial for an effective and efficient governance** as climate shelters compose a dynamic system, which must keep pace with societal and climate change. A limited number of studies were identified that examined the implementation of climate shelters. This fact underscores the need to establish robust **monitoring** mechanisms to understand how to continuously improve these spaces for all residents.

Furthermore, **literacy and awareness** of the population are also fundamental for the system's overall functioning and for improving the adaptive capacity of the population.

In summary, this dissertation, while focusing on vulnerable groups within the territory, also provides a solution for enhancing urban life to all residents. The climate shelter system should not only aim to protect the population during extreme events, although this is its primary focus, but also strive to offer quality spaces within the city, build adaptive capacity, and ultimately pave the way for a more resilient urban environment.

Ultimately, the main challenge and effort in designing a climate shelter system is not so much in the selection and adaptation of spaces to become shelters, but in their governance, communication, monitoring and its potential for promoting climate literacy, so that the system can be effective and efficient and achieve its goal of building community resilience.

Limitations and Further Research

This study intended to conduct several interviews not only with the population, but also with stakeholders (representatives of different institutions and entities) to highlight the importance of collaborative approaches in the planning process. However, due to time constraints, there were few questions in the interview and the sample size was not large enough to provide statistically significant results. Therefore, it is crucial for further research to develop a comprehensive survey that correlates awareness of climate change, knowledge of how to respond to it, and socio-economic profiles and locations in order to create a more precise and effective education and awareness campaign and an effective proposal.

Final notes

Finally, while this dissertation was being written (September 2023 to June 2024), several extreme climate events occurred worldwide. As the author is from Rio Grande do Sul, Brazil, it is imperative to mention the severe flooding affecting the entire region., which impacts the population will be felt for years to come. To date, 172 people have lost their lives, more than 575,000 lost their homes, more than 2,390,000 were affected (Defesa Civil RS, 2024) and the cost of recovery is estimated by R\$19,000,000,000 (nineteen billion reais) (G1, 2024), or 3.32 billion euros. If current trends continue, such events will persist, resulting in further loss of life. Therefore, it is imperative for governments to promote adaptation and mitigation strategies to better prevent and respond to these impacts. This Master's Thesis studied and provided one tool for climate adaptation, but, most importantly, presented the urgency of this debate. It is hoped that this work, alongside numerous other studies in this field, is valuable for urban planners and motivates researchers to prioritise climate change adaptation in urban development.

8

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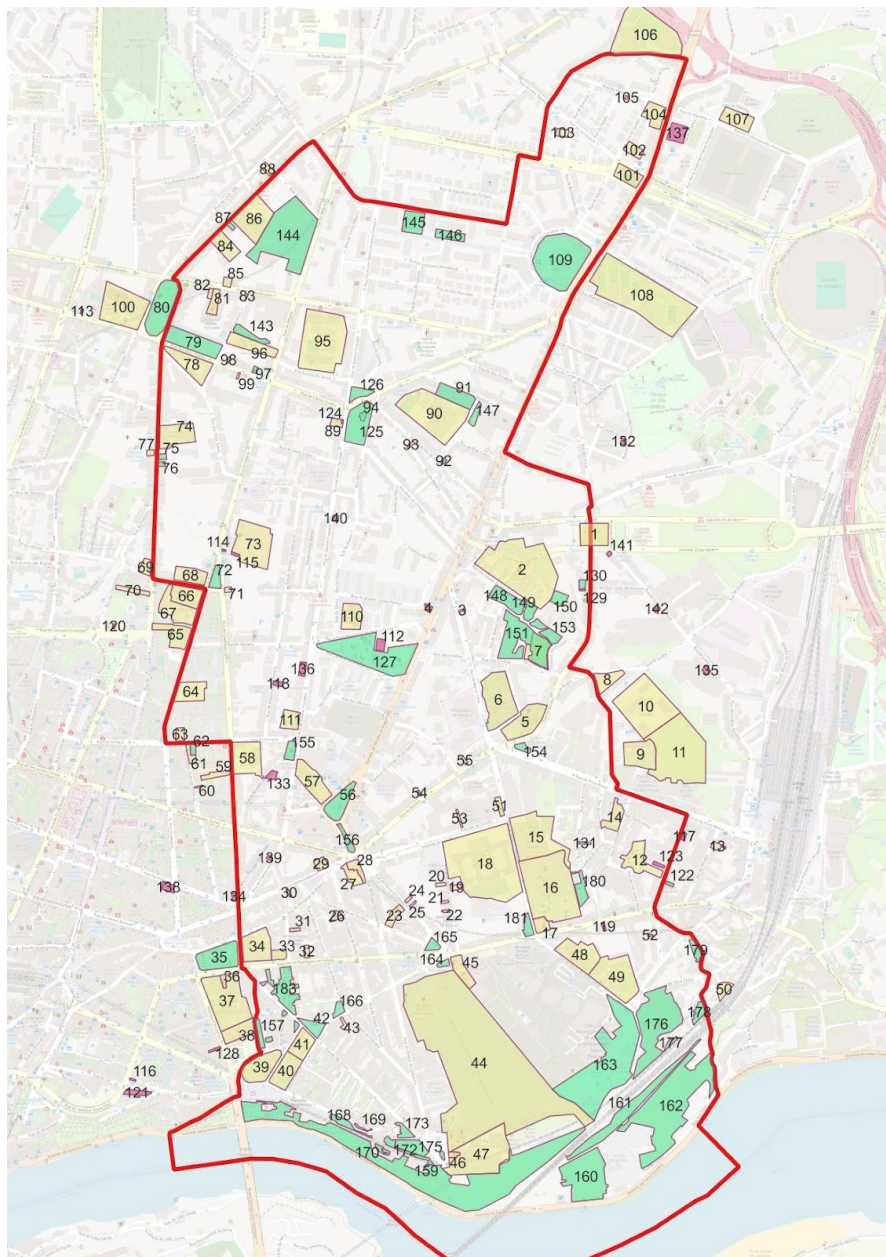
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9

APPENDIX

9.1. MAP OF IDENTIFIED INFRASTRUCTURES



9.2. TABLE WITH POTENTIAL CLIMATE SHELTERS

Id	Source	Type of risk	Equipment	General Use	Outdoor or indoor	Status	Thermal Comfort				Accessibility		Safety		Facilities		Obs
							Protection from wind (for cold and flood)	Verification for heat in outdoor spaces	Water elements (for heat in outdoor spaces)	Trees or other structures (shadow for heat)	Spatial Accessibility	Public Access	Safety from Crimes	Safety from extreme events	Bathroom	Seating places	Free Drinking water
1	PDM, 2021	Heat	Praça das Flores	Leisure	Outdoor	Existent	No	Yes	No	No	Yes	Yes		No	No	Yes	No
2	PDM, 2021	Heat/Cold/Flood	Hospital Joaquim Urbano	Health	Indoor	Existent	Yes		No								
3	PDM, 2021	Heat/Cold/Flood	Unknown	-	Indoor	Existent	Yes		No								Unknown
4	Rede Social Porto	Heat/Cold/Flood	Pale. Associação Social e Cultural Igreja do Senhor do Bonfim	Culture	Indoor	Existent	Yes	-	No	Yes	?	No	Yes	Yes	Yes	?	
5	PDM, 2021	Heat/Cold/Flood		Religious	Indoor	Existent	Yes		No	No	No	No	Yes	Yes	?	Yes	?
6	PDM, 2021	Heat	Cemitério do Bonfim	Cemetery	Outdoor	Existent	No	Yes	No	No	No	No	No	No	No	No	No
7	PDM, 2021	Heat	Centro Infantil Justino	Leisure	Outdoor	Proposed	No		No	Yes	No	No	No	No	No	No	Maybe, still a proposal
8	PDM, 2021	Heat/Cold/Flood	Fábrica Cretico, Jardim Infância e ATL	Education	Indoor	Existent	Yes	-	No	Yes	Yes	No	Yes	Yes	Yes	Yes	?
9	PDM, 2021	Heat/Cold/Flood	Piscina de Campainhã	Leisure	Indoor	Existent	Yes		No	Yes	Yes	No	Yes	Yes	Yes	Yes	Open hour
10	PDM, 2021	Heat/Cold/Flood	Escola EB2/3 de Ramalho Ortigão	Education	Indoor	Existent	Yes	-	No	Yes	Yes	No	Yes	Yes	Yes	Yes	Open hour
11	PDM, 2021	Heat	Park	Leisure	Outdoor	Proposed	No	Yes	No	No	No	No	No	No	No	No	Maybe, still a proposal
12	PDM, 2021	Heat/Cold/Flood	Escola Básica do 1o Ciclo da Lomba	Education	Indoor	Existent	Yes		No	Yes	Yes	No	Yes	Yes	Yes	Yes	Open hour
13	PDM, 2021	Heat/Cold/Flood	Mira Forum	Culture	Indoor	Existent	Yes		No	Yes	Yes	No	Yes	Yes	Yes	Yes	
14	PDM, 2021	Heat/Cold/Flood	Fundação Atila - Adriego	Health	Indoor	Existent	Yes										
15	PDM, 2021	Heat/Cold/Flood	Escola Básica 2o e 3o Ciclo Doutor Augusto Pires	Education	Indoor	Existent	Yes		No	Yes	Yes	No	Yes	Yes	Yes	Yes	Open hour
16	PDM, 2021	Heat/Cold/Flood	Divisão de Trânsito do Porto	Institutional	Indoor	Existent	Yes		No	Yes	Yes	No	Yes	Yes	Yes	Yes	
17	PDM, 2021	Heat/Cold/Flood	3a Esquadra Bonfim	Institutional	Indoor	Existent	Yes		No	Yes	Yes	No	Yes	Yes	Yes	Yes	
18	PDM, 2021	Heat/Cold/Flood	Escola Alexandre Herculano	Education	Indoor	Existent	Yes		No	Yes	Yes	No	Yes	Yes	Yes	Yes	
19	PDM, 2021	Heat/Cold/Flood	Lar de Acolhida	Education	Indoor	Existent	Yes		No								Open hour
20	PDM, 2021	Heat/Cold/Flood	Lar de Acolhida	Education	Indoor	Existent	Yes		No								Not recognisable in the street
21	PDM, 2021	Heat/Cold/Flood	Lar Sol Nascente	Institutional	Indoor	Existent	Yes		No	Yes	Yes	No	Yes	Yes	Yes	Yes	
22	PDM, 2021	Heat/Cold/Flood	Igreja Massilândia	Religious	Indoor	Existent	Yes		No	Yes	Yes	No	Yes	Yes	?	Yes	Open hour
23	PDM, 2021	Heat/Cold/Flood	Templo Adventista do Século Da	Religious	Indoor	Existent	Yes		No	Yes	Yes	No	Yes	Yes	?	Yes	Open hour
24	PDM, 2021	Heat/Cold/Flood	Tribunal Administrativo	Institutional	Indoor	Existent	Yes		No								Abandoned Building
25	PDM, 2021	Heat/Cold/Flood	Escola EB1 do Campo	Education	Indoor	Existent	Yes		No								Abandoned Building
26	PDM, 2021	Heat/Cold/Flood	Escola EB1 do Campo	Education	Indoor	Existent	Yes		No								
27	PDM, 2021	Heat/Cold/Flood	Junta de Freguesia do Bonfim	Education	Indoor	Existent	Yes		No	Yes	Yes	No	Yes	Yes	Yes	Yes	Open hour
28	PDM, 2021	Heat/Cold/Flood	Tribunal Central	Institutional	Indoor	Existent	Yes		No	Yes	Yes	No	Yes	Yes	Yes	Yes	
29	PDM, 2021	Heat/Cold/Flood	Tribunal Central	Institutional	Indoor	Existent	Yes		No	Yes	?	No	Yes	Yes	Yes	Yes	
30	PDM, 2021	Heat/Cold/Flood	Carta Pre Escolar	Education	Indoor	Existent	Yes		No	Yes	?	No	Yes	Yes	Yes	Yes	Open hour
31	PDM, 2021	Heat/Cold/Flood	Igreja Lusitana do Cristo Redentor	Religious	Indoor	Existent	Yes		No	Yes	No	No	Yes	Yes	?	Yes	Open hour
32	PDM, 2021	Heat/Cold/Flood	Associação dos Comerciantes do Porto	Community Cent	Indoor	Existent	Yes		No	Yes	No	No	Yes	Yes	Yes	Yes	
33	PDM, 2021	Heat	Park	Leisure	Outdoor	Proposed	No	Yes	No	No	No	No	?	?	No	No	No
34	PDM, 2021	Heat/Cold/Flood	Biblioteca Pública Municipal do Porto	Library	Indoor	Existent	Yes		No	No	Yes	No	Yes	Yes	Yes	Yes	?
35	Author	Heat	Jardim de São Lázaro	Leisure	Outdoor	Proposed	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No	Open hour
36	PDM, 2021	Heat/Cold/Flood	Igreja de Nossa Senhora da Esperança	Religious	Indoor	Existent	Yes		No	Yes	Yes	No	Yes	Yes	?	Yes	Open hour
37	PDM, 2021	Heat/Cold/Flood	Colégio de Nossa Senhora da Esperança	Education	Indoor	Existent	Yes		No	Yes	Yes	No	Yes	Yes	Yes	Yes	Open hour
38	PDM, 2021	Heat/Cold/Flood	Lar de Idosos de São Lázaro	Institutional	Indoor	Existent	No		No	Yes	Yes	No	Yes	Yes	Yes	Yes	?
39	PDM, 2021	Heat/Cold/Flood	Arraio Asilo da Mendicância	Institutional	Indoor	Existent	No		No	No	Yes	No	Yes	Yes	Yes	Yes	Open hour
							No		No	No							Abandoned Building

Id	Source	Type of risk	Equipment	General Use	Outdoor or Indoor	Status	Thermal Comfort				Accessibility		Safety		Facilities			Obs
							Protection from wind (for cold) (for heat in outdoor spaces)	Ventilation (for heat in outdoor spaces)	Walls or structures (for heat in outdoor spaces)	Trees or structures (shadow for heat)	Other	Spatial Accessibility	Public Access	Safety from Crimes	Safety from extreme events	Bathroom	Seating places	
40	PDM, 2021	Heat/Cold/Flood	Antiga Creche Abargo dos Pequenos	Education	Indoor	Existent	No		No									Abandoned Buiding
41	PDM, 2021	Heat/Cold/Flood	Escola Primária da Alegria	Education	Indoor	Existent	Yes		No	Yes		Yes	Yes	Yes	Yes	Yes	?	Requalification for museum
42	Author	Heat	Praça da Alegria	Leisure	Outdoor	Proposed	No	Yes	No		Yes	Yes	No	No	No	No	?	Impenetrable soil
43	PDM, 2021	Heat/Cold/Flood	Escola Folhosa	Education	Indoor	Existent	Yes		No				Yes	Yes	Yes	Yes	?	Open hour
44	PDM, 2021	Heat	Cemitério Privativo da Glória do Torço	Cemetery	Outdoor	Existent	No			Yes								Verify
45	PDM, 2021	Heat/Cold/Flood	Museu Militar do Porto	Culture	Indoor	Existent	Yes		No	Yes		Yes	Yes	Yes	Yes	Yes		
46	PDM, 2021	Heat/Cold/Flood	Capela de Nossa Senhora da Graça	Religious	Indoor	Existent			No	Yes		Yes	Yes	Yes	Yes	?	?	Open hour
47	PDM, 2021	Heat/Cold/Flood	Colégio das Salesianas do Póvo	Education	Indoor	Existent	Yes		No			Yes	No	Yes	Yes	Yes	?	Open hour
48	PDM, 2021	Heat/Cold/Flood	Colégio Barão de Nova Santa Rita	Education	Indoor	Existent	Yes		No	Yes			Yes	Yes	Yes	Yes	?	Open hour
49	PDM, 2021	Heat/Cold/Flood	Centro de Saúde do Bonfim	Health	Indoor	Existent	Yes		No									Isolated
50	PDM, 2021	Heat/Cold/Flood	Centro de Saúde do Bonfim	-	Indoor	Existent	No		No									
51	PDM, 2021	Heat/Cold/Flood	Casa Oficina Antonio Carneiro	Culture	Indoor	Existent	Yes		No	Yes		Yes	Yes	Yes	Yes	Yes	?	Rehabilitation
52	Author	Heat/Cold/Flood	Teatro de Ferro	Culture	Indoor	Proposed	Yes		No	Yes		Yes	Yes	Yes	Yes	Yes	?	
53	PDM, 2021	Heat/Cold/Flood	O Pequeno Chocó	Education	Indoor	Existent	Yes		No	Yes			Yes	Yes	Yes	Yes	?	Open hour
54	Rede Social Porto	Heat/Cold/Flood	Criche, Jardim Infantil E Salas De Estudo,	Education	Indoor	Existent	Yes		No				Yes	Yes	Yes	Yes	?	
55	PDM, 2021	Heat/Cold/Flood	Casa dos Acores do Norte	Culture	Indoor	Existent	Yes		No									No indication at the floor
56	Author	Heat	Lar de Missões - Zezino Machado Pereira	Institutional	Indoor	Existent	Yes		No									
57	PDM, 2021	Heat/Cold/Flood	Jardim do Campo 24 de Agosto	Leisure	Outdoor	Proposed	No	Yes	Yes	Yes		Yes	Yes	Yes	?	Yes	?	
58	PDM, 2021	Heat/Cold/Flood	Lar de Nossa Senhora do Livramento, Externato e Turismo do Porto	Institutional	Indoor	Existent	Yes		No	Yes		Yes	Yes	Yes	Yes	Yes	?	
59	PDM, 2021	Heat/Cold/Flood	Extensão de Saúde Dom João IV (CS Bonfim/Estafeta - Unidade Batalha)	Education	Indoor	Existent	Yes		No	Yes		Yes	Yes	Yes	Yes	Yes	?	Open hour
60	PDM, 2021	Heat/Cold/Flood	Casa de Repouso Serequidade Unip. Lda	Health	Indoor	Existent	Yes		No									
61	PDM, 2021	Heat/Cold/Flood	Seminário dos Salesianos de Nossa Senhora do Carmo	Religious	Indoor	Existent	Yes		No	Yes		Yes	Yes	Yes	Yes	Yes	?	
62	Author	Heat/Cold/Flood	Senhora do Perpétuo Socorro	Religious	Indoor	Proposed	Yes		No	Yes		Yes	Yes	Yes	Yes	Yes	?	
63	PDM, 2021	Heat/Cold/Flood	Escola Superior de Saúde	-	Indoor	Existent	Yes		No									Does not exist
64	PDM, 2021	Heat/Cold/Flood	Lar Associação Prolebra do Internato de São João	Institutional	Indoor	Existent	Yes		No									Looks closed
65	PDM, 2021	Heat/Cold/Flood	Escola ES 2/3 Augusto Costa	Education	Indoor	Existent	Yes		No	Yes		Yes	Yes	Yes	Yes	Yes	?	Open hour
66	PDM, 2021	Heat/Cold/Flood	Teatro Helena Sá e Costa	Culture	Indoor	Existent	Yes		No	Yes		Yes	Yes	Yes	Yes	Yes	?	Open hour
67	PDM, 2021	Heat/Cold/Flood	Escola Superior de Música de Artes do Espetáculo	Education	Indoor	Existent	Yes		No	Yes		No	Yes	Yes	Yes	Yes	?	Open hour
68	PDM, 2021	Heat/Cold/Flood	Escola Básica das Fiumhas	Education	Indoor	Existent	Yes		No	Yes		Yes	Yes	Yes	Yes	Yes	?	Open hour
69	PDM, 2021	Heat/Cold/Flood	Direção de Infraestruturas de Porto	Institutional	Indoor	Existent	Yes		No	Yes		Yes	Yes	Yes	Yes	Yes	?	Open hour
70	PDM, 2021	Heat/Cold/Flood	Associação de Ecologistas - Campo Aberto - Associação de	Institutional	Indoor	Existent	Yes		No									Verify existence

Id	Source	Type of risk	Equipment	General Use	Outdoor or indoor	Status	Thermal Comfort					Accessibility		Safety		Facilities			Obs
							Protection from wind (for cold and flood)	Ventilation for heat in outdoor spaces	Water elements (for heat in outdoor spaces)	Trees or other structures (shadow for heat)	Other	Spatial Accessibility	Public Access	Safety from Crimes	Safety from extreme events	Bathroom	Seating places	Free Drinking water	
71	PDM, 2021	Heat/Cold/Flood	ACISUF - Associação Católica Internacional ao Serviço da Juventude da Comunidade do Porto	Religious	Indoor	Existent	Yes		No										Does not exist
72	Author	Heat	Jardim do Lopo de José Moreira da Silva	Leisure	Outdoor	Proposed	No		No	Yes		Yes	Yes	-	Yes	No	Yes		
73	PDM, 2021	Heat/Cold/Flood	Cooperativa dos Pedreiros	Institutional	Indoor	Existent	Yes		No	Yes		Yes	No	Yes	Yes	Yes	Yes	?	Open hour
74	PDM, 2021	Heat/Cold/Flood	Externato Ribauro	Education	Indoor	Existent	Yes		No	Yes		Yes	No	Yes	Yes	Yes	Yes	?	Open hour
75	Author	Heat/Cold/Flood	APRSN - Administração Regional De Saúde Do Norte LP	Health	Indoor	Proposed	Yes		No										
76	Author	Heat/Cold/Flood	Igreja Paroquial Deus é Amor	Religious	Indoor	Proposed	Yes		No	Yes		Yes	No	Yes	Yes	Yes	Yes	?	Open hour
77	PDM, 2021	Heat/Cold/Flood		-	Indoor	Existent	Yes		No										Does not exist
78	PDM, 2021	Heat/Cold/Flood	Colégio de Nossa Senhora da Paz	Education	Indoor	Existent	Yes		No	Yes		Yes	No	Yes	Yes	Yes	Yes	?	Open hour
79	Author	Heat/Cold/Flood	Fundação Instituto Marques da Silva	Culture	Indoor	Proposed	Yes		No	Yes		No	No	Yes	Yes	?	?	?	
80	Author	Heat	Praca do Marquês de Pombal	Leisure	Outdoor	Existent	No		Yes	Yes		Yes	Yes	-	Yes	Yes	Yes	No	
81	PDM, 2021	Heat/Cold/Flood	Capela Paroquial de São Paroquia APIMA - Associação Portuguesa das Indústrias de mobiliário e outros	Religious	Indoor	Existent	Yes		No	Yes		Yes	No	Yes	Yes	Yes	Yes	?	Verify
82	PDM, 2021	Heat/Cold/Flood		Institutional	Indoor	Existent	Yes		No	Yes		Yes	No	Yes	Yes	Yes	Yes	?	
83	PDM, 2021	Heat/Cold/Flood	Grécio/Pré-escola Nossa Senhora do Perpêso Socorro	Education	Indoor	Existent	Yes		No	Yes		Yes	No	Yes	Yes	Yes	Yes	?	Verify
84	PDM, 2021	Heat/Cold/Flood	Habitação - Funders	Education	Indoor	Existent	Yes		No	Yes		Yes	No	Yes	Yes	Yes	Yes	?	Verify
85	PDM, 2021	Heat/Cold/Flood	Complexo Desportivo do Académico Futebol Clube	Sports	Indoor	Existent	Yes		No	Yes		No	No	Yes	Yes	?	?	?	
86	PDM, 2021	Heat/Cold/Flood	Igreja Evangélica Miranilha	Religious	Indoor	Proposed	Yes		No	Yes		?	No	Yes	Yes	Yes	?	?	
87	Author	Heat/Cold/Flood	Dancetera Julo Dreniz	Commercial	Indoor	Existent	Yes		No	Yes		Yes	No	Yes	Yes	Yes	Yes	?	Verify
88	PDM, 2021	Heat/Cold/Flood	Capela de São Crispim e São Crispiano	Religious	Indoor	Existent	Yes		No	Yes		Yes	No	Yes	Yes	Yes	Yes	No	
89	PDM, 2021	Heat/Cold/Flood	Escola Artística de Soares dos Reis	Education	Indoor	Existent	Yes		No	Yes		Yes	No	Yes	Yes	Yes	Yes	?	Verify
90	PDM, 2021	Heat/Cold/Flood	Igreja Evangélica Batista das Anias	Religious	Indoor	Proposed	Yes		No	Yes		Yes	No	Yes	Yes	Yes	Yes	?	Verify
91	Author	Heat/Cold/Flood	CRP Porto Oriental	Health	Indoor	Proposed	Yes		No	Yes		Yes	No	Yes	Yes	Yes	Yes	?	Does not exist
92	Author	Heat/Cold/Flood	Escola Secundária Aurélio de Sousa	Education	Indoor	Existent	Yes		No	Yes		Yes	No	Yes	Yes	Yes	Yes	?	Verify
93	PDM, 2021	Heat/Cold/Flood	Escola Superior de Educação da Paula Frassinetti	Education	Indoor	Existent	Yes		No	Yes		Yes	No	Yes	Yes	Yes	Yes	?	Unknown
94	PDM, 2021	Heat/Cold/Flood	Igreja Paroquial das Missões	Religious	Indoor	Proposed	Yes		No	Yes		Yes	No	Yes	Yes	?	?	?	Verify
95	PDM, 2021	Heat/Cold/Flood	Assistência Social - Caritas Diocesana do Porto	Institutional	Indoor	Existent	Yes		No	Yes		Yes	No	Yes	Yes	?	?	?	Open hour
96	PDM, 2021	Heat/Cold/Flood	Centro de Segurança Social Porto - Centro de Dia Larino Coelho	Institutional	Indoor	Existent	Yes		No	Yes		No	No	Yes	Yes	?	?	?	Open hour
97	Author	Heat/Cold/Flood	Instituto Profissional do Terço	Religious	Indoor	Existent	Yes		No	Yes		Yes	No	Yes	Yes	?	Yes	?	
98	PDM, 2021	Heat/Cold/Flood	Igreja do Santo António das Anias	Religious	Indoor	Existent	Yes		No	Yes		Yes	No	Yes	Yes	Yes	Yes	?	Verify
99	PDM, 2021	Heat/Cold/Flood	6a Esquadra Anias	Institutional	Indoor	Existent	Yes		No	Yes		Yes	Yes	Yes	Yes	Yes	Yes	?	
100	PDM, 2021	Heat/Cold/Flood																	
101	PDM, 2021	Heat/Cold/Flood																	
102	PDM, 2021	Heat/Cold/Flood																	

Id	Source	Type of risk	Equipment	General Use	Outdoor or Indoor	Status	Thermal Comfort				Accessibility		Safety		Facilities			Obs
							Protection from wind (for cold and flood)	Ventilation (for heat in outdoor spaces)	Water elements (for heat in outdoor spaces)	Trees or other structures (shadow for heat)	Other	Spatial Accessibility	Public Access	Safety from Crimes	Safety from extreme events	Bathroom	Seating places	
103	PDM, 2021	Heat/Cold/Flood	Lar de idosos - Lar Luminoso Lda	Institutional	Indoor	Existent	Yes		No	Yes		Yes	No	Yes	Yes	Yes	?	Open hour
104	PDM, 2021	Heat/Cold/Flood	Centro Paroquial Santo António das Anas	Religious	Indoor	Existent	Yes		No	Yes		Yes	No	Yes	Yes	Yes	?	Verify
105	PDM, 2021	Heat/Cold/Flood	Centro Médico - Paz Das Lda	Health	Indoor	Existent	Yes		No	Yes		Yes						Does not exist
106	PDM, 2021	Heat/Cold/Flood	Escola e Vigorosa Sport	Sport	Indoor	Existent	Yes		No	Yes		Yes	No	Yes	Yes	Yes	?	
107	PDM, 2021	Heat/Cold/Flood	Agrupamento de Escolas das Anas	Education	Indoor	Existent	Yes		No	Yes		Yes	No	Yes	Yes	Yes	?	Verify
108	PDM, 2021	Heat/Cold/Flood	Complexo Desportivo de Monte Aventura	Sport	Indoor	Existent	Yes		No	Yes		Yes	No	Yes	Yes	Yes	?	
109	Author	Heat	Park Escola Básica do 1o Ciclo Feriada de Marafães	Leisure	Outdoor	Proposed	No	Yes	No	Yes		Yes	Yes	-	No	Yes	No	
110	PDM, 2021	Heat/Cold/Flood	Escola Básica do 1o Ciclo Feriada de Marafães	Education	Indoor	Existent	Yes		No	Yes		Yes	No	Yes	Yes	Yes	?	Verify
111	PDM, 2021	Heat/Cold/Flood	Casa para idosos - Sara Costa & Álvaro Costa Lda	Institutional	Indoor	Existent	Yes		No									Recuperation Clinic - Health use
112	Rede Social Porto	Heat/Cold/Flood	A.A.D.I.D. - Centro Educacional Ana Sullivan	Education	Indoor	Existent	Yes		No	Yes		Yes	No	Yes	Yes	Yes	?	Verify
113	Rede Social Porto	Heat/Cold/Flood	MAJURE - Associação de Apoio à Juventude de Marafães	Institutional	Indoor	Existent	Yes		No	Yes		Yes	No	Yes	Yes	Yes	?	Verify - does not exist (?)
114	Rede Social Porto	Heat/Cold/Flood	Academia José Moreira Da Silva - Coop. Estudos Economia Social, Cri	Institutional	Indoor	Existent	Yes		No	Yes		?	No	Yes	Yes	?	?	
115	Rede Social Porto	Heat/Cold/Flood	AVIMAS - Associação Portuguesa para a intervenção com Animas de Ajuda social	Institutional	Indoor	Existent												Not found
116	Rede Social Porto	Heat/Cold/Flood	APN - Associação Portuguesa de Neuromusculares	Institutional	Indoor	Existent	Yes		No	Yes		Yes	No	Yes	Yes	?	?	
117	Rede Social Porto	Heat/Cold/Flood	Armo - Organização Cooperativa para o Desenvolvimento Social e Comunitário, CRL	Institutional	Indoor	Existent	Yes		No	Yes		Yes	No	Yes	Yes	Yes	?	
118	Rede Social Porto	Heat/Cold/Flood	Departamento de Saúde Saúde Pública de Marafães	Health	Indoor	Existent	Yes		No									
119	Rede Social Porto	Heat/Cold/Flood	Fine e Desafios - Associação de Apoio Integrado à Família	Institutional	Indoor	Existent	Yes		No	Yes		Yes	No	Yes	Yes	Yes	?	
120	Rede Social Porto	Heat/Cold/Flood	Creche, Jardim de Infância, CATL - O Sol	Education	Indoor	Existent	No	No	No	No	No	No	No	No	No	No	No	Abandoned building
121	Rede Social Porto	Heat/Cold/Flood	ASZ Fontainhas CATL	Education	Indoor	Existent												Verify - not found
122	Author	Heat/Cold/Flood	Mira - Artes Performativas	Culture	Indoor	Proposed												Not indicated in the façade
123	Rede Social Porto	Heat/Cold/Flood	Senhor Do Bonfim - Associação Social Solidária Social RE-FOOD 4 GOOD - Bonfim	Institutional	Indoor	Existent	Yes		No	Yes		Yes	No	Yes	Yes	Yes	?	Entrance for cars - verify the indoor space
124	Rede Social Porto	Heat/Cold/Flood	Associação Núcleo do Bonfim	Institutional	Indoor	Existent	Yes		No									
125	Author	Heat	Park	Leisure	Outdoor	Proposed	No	Yes	No	Yes		Yes	Yes		Yes	No	No	
126	Author	Heat	Park	Leisure	Outdoor	Proposed	No	Yes	No	Yes		Yes	Yes		Yes	No	No	
127	Author	Heat	Park	Leisure	Outdoor	Proposed	No	Yes	No	Yes		Yes	Yes		Yes	No	Yes	
128	Rede Social Porto	Heat/Cold/Flood	Associação Dos Parafidistas Do Marafães	Institutional	Indoor	Existent	Yes		No									Not found
129	Rede Social Porto	Heat/Cold/Flood	Associação Intercultural Lusó Sacromense	Culture	Indoor	Existent	Yes		No	Yes		Yes	No	Yes	Yes	Yes	?	Not intuitive to find

Id	Source	Type of risk	Equipment	General Use	Outdoor or Indoor	Status	Thermal Comfort					Accessibility		Safety		Facilities			Obs
							Protection from wind (for wind outdoor spaces)	Ventilation for heat in outdoor spaces	Water elements (for heat in outdoor spaces)	Trees or other structures (shadow for heat)	Other	Spatial Accessibility	Public Access	Safety from Crimes	Safety from extreme events	Bathroom	Seating places	Free Drinking water	
130	Author	Heat/Cold/Flood	Centro Comercial Fontelario	Commercial	Indoor	Proposed	Yes		No	Yes		Yes	No	Yes	Yes	Yes	?	No	Residents association
131	Author	Heat/Cold/Flood	Associação de Moradores da Lomba Verde	Community Centre	Indoor	Proposed	Yes		No	Yes		Yes	No	Yes	Yes	Yes	Yes	?	Far away from the parish perimeter
132	Rede Social Porto	Heat/Cold/Flood	Associação de Moradores da Lomba Verde	Community Centre	Indoor	Existing	Yes		No										Open hour
133	Rede Social Porto	Heat/Cold/Flood	Centro Social da Legião da Boa Vontade	Institutional	Indoor	Existing	Yes		No	Yes		Yes	No	Yes	Yes	Yes	?	?	Verify
134	Rede Social Porto	Heat/Cold/Flood	Externato Santa Clara - Beatriz Ribeiro e Filhos	Education	Indoor	Existing	Yes		No	Yes		Yes	No	Yes	Yes	Yes	Yes	?	Verify
135	Rede Social Porto	Heat/Cold/Flood	Hissong Portugal - Associação de Moradores da Lomba Verde	Religious	Indoor	Existing	Yes		No	Yes									Inside a building with offices
136	Rede Social Porto	Heat/Cold/Flood	Associação de Moradores da Lomba Verde	Institutional	Indoor	Existing	Yes		No	Yes		Yes	No	Yes	Yes	Yes	Yes	?	
137	Rede Social Porto	Heat/Cold/Flood	Loja do Cidadão do Porto	Institutional	Indoor	Existing	Yes		No	Yes		Yes	No	Yes	Yes	Yes	Yes	?	
138	Rede Social Porto	Heat/Cold/Flood	Núcleo do Porto da Liga dos Combatentes (NPLC)	Institutional	Indoor	Existing	Yes		No	Yes		Yes	No	Yes	Yes	Yes	Yes	?	
139	Rede Social Porto	Heat/Cold/Flood	Previdência Familiar do Porto - Associação de Moradores da Lomba Verde	Institutional	Indoor	Existing	Yes		No	Yes		Yes	No	Yes	Yes	Yes	Yes	?	
140	Rede Social Porto	Heat/Cold/Flood	Associação de Moradores da Lomba Verde	Institutional	Indoor	Existing	Yes		No	Yes		Yes	No	Yes	Yes	Yes	Yes	?	Not found
141	Rede Social Porto	Heat/Cold/Flood	Rede Indicar CRL	Institutional	Indoor	Existing	Yes		No	Yes		Yes	No	Yes	Yes	Yes	Yes	?	Not indicated in the facade - verify
142	Rede Social Porto	Heat/Cold/Flood	Visões Urais Associação	Culture	Indoor	Existing	Yes		No	Yes		Yes	No	Yes	Yes	Yes	Yes	?	Closed terrain
143	Author	Heat	Park	Leisure	Outdoor	Proposed	No	-	No	Yes		Yes	No	No	No	No	No	No	Closed terrain
144	Author	Heat	Park	Leisure	Outdoor	Proposed	No	-	No	Yes		Yes	No	No	No	No	No	No	Potential small park
145	Author	Heat	Park	Leisure	Outdoor	Proposed	No	Yes	Yes	Yes		Yes	Yes	Yes	Yes	Yes	Yes	Yes	Closed terrain
146	Author	Heat	Park	Leisure	Outdoor	Proposed	No	Yes	Yes	Yes		Yes	Yes	Yes	Yes	Yes	Yes	Yes	Closed terrain
147	Author	Heat	Park	Leisure	Outdoor	Proposed	No	Yes	Yes	Yes		Yes	Yes	Yes	Yes	Yes	Yes	Yes	Closed terrain
148	Author	Heat	Park	Leisure	Outdoor	Proposed	No	Yes	No	No		No	No	No	-	No	No	No	Closed terrain
149	Author	Heat	Park	Leisure	Outdoor	Proposed	No	Yes	No	No		No	No	No	-	No	No	No	Closed terrain
150	Author	Heat	Park	Leisure	Outdoor	Proposed	No	Yes	No	No		No	No	No	-	No	No	No	Closed terrain
151	Author	Heat	Park	Leisure	Outdoor	Proposed	No	Yes	No	No		No	No	No	-	No	No	No	Closed terrain
152	Author	Heat	Park	Leisure	Outdoor	Proposed	No	Yes	No	No		No	No	No	-	No	No	No	Closed terrain
153	Author	Heat	Park	Leisure	Outdoor	Proposed	No	Yes	No	No		No	No	No	-	No	No	No	Closed terrain
154	Author	Heat	Park	Leisure	Outdoor	Proposed	No	-	No	No		No	No	No	-	No	No	No	Closed terrain with abandoned building
155	Author	Heat	Park	Leisure	Outdoor	Proposed	No	Yes	No	Yes		Yes	Yes	Yes	Yes	No	Yes	No	High slope
156	Author	Heat	Park	Leisure	Outdoor	Proposed	No	Yes	No	Yes		Yes	Yes	Yes	Yes	No	Yes	No	High slope
157	Author	Heat	Park	Leisure	Outdoor	Proposed	No	Yes	No	Yes		Yes	Yes	Yes	Yes	No	Yes	No	High slope
158	Author	Heat	Park	Leisure	Outdoor	Proposed	No	Yes	No	No		No	Yes	Yes	Yes	No	No	No	High slope
159	Author	Heat	Park	Leisure	Outdoor	Proposed	No	Yes	No	No		No	Yes	Yes	Yes	?	Yes	?	High slope
160	Author	Heat	Park	Leisure	Outdoor	Proposed	No	Yes	Yes	Yes		Yes	?	Yes	Yes	?	Yes	?	High slope
161	Author	Heat	Park	Leisure	Outdoor	Proposed	No	Yes	Yes	Yes		Yes	No	Yes	Yes	?	Yes	?	High slope
162	Author	Heat	Park	Leisure	Outdoor	Proposed	No	Yes	Yes	Yes		Yes	No	Yes	Yes	?	Yes	?	High slope
163	Author	Heat	Parque das Águas	Leisure	Outdoor	Proposed	No	Yes	Yes	Yes		Yes	Yes	Yes	Yes	?	Yes	?	High slope
164	Author	Heat	Park	Leisure	Outdoor	Proposed	No	Yes	No	Yes		Yes	Yes	Yes	Yes	No	Yes	No	High slope
165	Author	Heat	Park	Leisure	Outdoor	Proposed	No	Yes	No	Yes		Yes	Yes	Yes	Yes	No	No	No	High slope
166	Author	Heat	Park	Leisure	Outdoor	Proposed	No	Yes	No	Yes		Yes	Yes	Yes	Yes	No	No	No	High slope
167	Author	Heat	Park	Leisure	Outdoor	Proposed	No	Yes	No	Yes		Yes	Yes	Yes	Yes	No	No	?	Verify if the fountain has water
168	Author	Heat	Park	Leisure	Outdoor	Proposed	No	Yes	No	Yes		Yes	Yes	Yes	Yes	No	No	No	High slope
169	Author	Heat	Park	Leisure	Outdoor	Proposed	No	Yes	No	No		Yes	Yes	Yes	No	No	No	No	High slope
170	Author	Heat	Park	Leisure	Outdoor	Proposed	No	Yes	No	No		Yes	Yes	Yes	No	No	No	No	High slope
171	Author	Heat	Park	Leisure	Outdoor	Proposed	No	Yes	No	No		No	No	No	No	No	No	No	High slope
172	Author	Heat	Park	Leisure	Outdoor	Proposed	No	Yes	No	No		No	No	No	No	No	No	No	High slope
173	Author	Heat	Park	Leisure	Outdoor	Proposed	No	Yes	No	No		Yes	No	No	No	No	No	No	High slope
174	Author	Heat	Park	Leisure	Outdoor	Proposed	No	Yes	No	No		Yes	No	No	No	No	No	No	High slope
175	Author	Heat	Park	Leisure	Outdoor	Proposed	No	Yes	No	No		No	No	No	No	No	No	No	High slope
176	Author	Heat	Park	Leisure	Outdoor	Proposed	No	Yes	No	No		No	No	No	No	No	No	No	High slope
177	Author	Heat	Park	Leisure	Outdoor	Proposed	No	Yes	No	No		No	No	No	No	No	No	No	High slope
178	Author	Heat	Park	Leisure	Outdoor	Proposed	No	Yes	No	No		No	No	No	No	No	No	No	High slope
179	Author	Heat	Park	Leisure	Outdoor	Proposed	No	Yes	No	No		No	No	No	No	No	No	No	High slope

Id	Source	Type of risk	Equipment	General Use	Outdoor or indoor	Status	Thermal Comfort					Accessibility		Safety		Facilities			Obs
							Protection from wind (for cold and flood)	Ventilation (for heat in outdoor spaces)	Water elements (for heat in outdoor spaces)	Trees or other structures (shadow for heat)	Other	Spatial Accessibility	Public Access	Safety from Crimes	Safety from extreme events	Bathroom	Seating places	Free Drinking water	
180	Author	Heat	Recinto Desportivo da Lomita	Leisure	Outdoor	Proposed	No	Yes	No	Yes		Yes	Yes	Yes	?	Yes	?		
181	Author	Heat	Park	Leisure	Outdoor	Proposed	No	Yes	No	No		Yes	Yes	No	-	No	No		
182	Author	Heat	Park	Leisure	Outdoor	Proposed	No	Yes	No	No		No	Yes	Yes	No	No	No		
183	Author	Heat	Park	Leisure	Outdoor	Proposed	No	Yes	?	Yes		?	No	Yes	Yes	?	?		

Legend:

Lines with places not able to become shelters

Lines with first selected shelters

9.3. TABLE OF INTERVIEW RESULTS

Id	Gender	Age	Do you feel affected by climate change (such as extreme events of heat, cold and flood)?	What do you do in these events? Do you change something in your routine?	If there were places to go to refugee from these event, would you use them?
1	Female	Adult	Yes	I use the " esplanadas " during the heat and go to warmer places in the winter	Absolutely
2	Male	Adult	Yes, too cold in Winter	We go next to the river in heat waves, and to Nortshopping when it is cold, because there are places for the baby to play.	Yes
3	Female	Adult	We used the air conditioning until May this year, last year we used until March	I enjoy going next to the river .	Yes
4	Male	Adult	I feel cold and the rain bothers me	I use the fire place at my house , and go to plazas and parks when it is hot.	I don't leave much my house
5	Male	Adult	It rains a lot.	I stay at home , or go to shoppings, and museus, and parks .	I would use.
6	Female	Elderly	Very cold winter	I usually stay at home , without heating	I would use.
7	Male	Elderly	Today it is cold, I search for places more comfortable when go out.	Usually stay at home	I prefer to stay at home.
8	Male	Adult	January is supposed to be colder, people say it was not like this.	When it is hot, I go to my balcony and gardens . When it is cold, I stay at home or go to indoor places .	I would use
9	Female	Adult	Yes	No	Yes
10	Female	Adult	A lot	The traffic changes, but usually I stay at home or go to the beach when it is hot.	Yes, there could be water features for people to get wet and cool off in.
11	Female	Adult	We don't feel extreme heat and cold in Porto. But we notice that the seasons are less defined.	We go to the " esplanadas " during heat and we go out less when it is cold.	Yes
12	Male	Adult	The climate is good	I go to the beach when it is hot	No
13	Female	Adult	It is more complicated for the work	No	Yes, it would be great to have water everywhere.
14	Female	Adult	The winter is more uncomfortable. It rains a lot. Summer is better.	I work too much, only go from home to work and from work to home. During Summer, I go to the " Ribeira " and " Jardim do Morro ".	I would definitely use them, especially in Winter.

15	Male	Adult	The climate is uncertain, it rains and it's sunny in the same day. There are many microclimates. There are humidity in coast zones and rivers. In relation to 10 years ago, the seasons were better defined.	We stay more at home during Winter, and look for beaches and airy places during Summer.	Yes
16	Male	Adult	Yes, I am from Viseu, but I feel affected.	Stay more at home during Winter.	Yes
17	Female	Elderly	The seasons are getting rougher.	We search for sunlight in Spring, and pleasant places in the parks .	Yes
18	Female	Elderly	The climate has changes, and there are more pollution.	Cool places.	Yes
19	Female	Elderly	There are more pollution in the air, and noise.	During heat - we go to the beach , parks , look for shadows .	Yes. The municipality could deviate the traffic in the city centre, and people could use more public transport. There could be more healthy places in the city, like parks.
20	Female	Elderly	Yes	I go to green places	Yes
21	Female	Elderly	Yes	Yes, I go to parks .	Yes
22	Female	Elderly	I perceive the climate change, there are more uncertainty in the climate.	I usually go out of the city, like the " Serras de Valongo ", which are very beautiful places. I also go to museums and libraries.	Yes
23	Female	Adult	The climate is good.	I go to public parks .	I would use them, it is essential to have these spaces.
24	Female	Adult	I feel affected, the climate has been more unpredictable	Green spaces , and shadow , the cities nowadays have more cement.	Yes, comfortable and convivial places, also for animals.
25	Female	Adult	I am from Caiscais, and for me the climate is nice there	Go to the beach	Yes
26	Male	Adult	The winter rains a lot, but I feel good during the rest of the year	I go to the beach and to parks when it is hot.	Of course
27	Male	Adult	Yes	I go to the beach in Gaia, and I go out less during the winter	I would use warmer closed spaces during the winter.
28	Male	Elderly	The air is heavier, saturated	To get away, gardens to rest, without the mess	Mainly Parks
29	Male	Elderly	Não	Stay more at home , and go to " Parque da Cidade "	Maybe
30	Male	Elderly	A bit	Beach , calmer zones	Probably
31	Male	Adult	Yes, everyone	I usually stay more at home or at the university	Yes
32	Female	Adult	Yes, heat island and heavy precipitation	In extreme situations, I stay at home .	Yes, spaces with thermal comfort