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Learning from Spanish Urban Climate Adaptation: Opportunities and Challenges for Strengthening Climate Governance in Brazilian Cities †

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Abstract

Climate change increasingly impacts urban areas, particularly in developing countries. Although some Brazilian cities have advanced climate adaptation policies, these initiatives remain concentrated in a limited number of municipalities. In this context, the objective of this study is to analyze climate adaptation strategies implemented in Spanish cities and evaluate their potential applicability to the Brazilian urban context. The study adopts a qualitative comparative approach combining bibliographic and documentary research, analysis of climate policies, and technical field visits to fourteen Spanish cities. The comparative analysis focused on identifying adaptation measures with the greatest potential for transfer to Brazil while considering differences in governance capacity, financial resources, urban infrastructure, and climatic conditions. The results indicate that climate shelters, sustainable urban drainage systems (SUDS), infiltration gardens, public drinking-water fountains, urban shading structures, and green infrastructure constitute feasible strategies for many Brazilian municipalities. The study concludes that international cooperation and the exchange of successful urban experiences can support the development of more resilient Brazilian cities, provided that adaptation policies are tailored to regional climatic diversity, institutional capacities, and local socioeconomic conditions.

Keywords: climate change; climate governance; goal 13: climate action

1. Introduction

Climate change has become one of the greatest challenges facing contemporary cities, intensifying the frequency and severity of extreme weather events such as heat waves, droughts, floods, and storms. According to the Intergovernmental Panel on Climate Change (IPCC), urban areas are increasingly exposed to climate-related hazards due to the combined effects of global warming, rapid urbanization, demographic growth, and inadequate land-use planning [1].

Beyond environmental impacts, these processes threaten public health, economic development, critical infrastructure, water security, and social well-being, particularly in developing countries where institutional and financial capacities remain limited [2,3].

In response to these challenges, urban climate action has progressively incorporated two complementary approaches: mitigation, aimed at reducing greenhouse gas emissions, and adaptation, focused on reducing vulnerability and increasing the resilience of communities, ecosystems, and infrastructure [4]. While mitigation contributes to limiting future

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climate change, adaptation has become an urgent priority, as many climate impacts are already unavoidable and are expected to intensify over the coming decades [5]. Consequently, strengthening local climate governance has become a strategic component of sustainable urban development, requiring integrated planning, institutional coordination, adequate financing, scientific evidence, and active public participation [6].

Several cities worldwide have developed innovative adaptation policies that have become international references for climate-resilient urban planning. Spain stands out in this context due to the continuity of its climate policies over the last three decades and the implementation of adaptation measures at national, regional, and municipal levels. Cities such as Barcelona, Seville, Vitoria-Gasteiz, Valencia, Zaragoza, and Madrid have implemented strategies combining nature-based solutions, sustainable urban drainage systems, climate shelters, green infrastructure, urban greening, and public health measures to reduce vulnerability to increasing temperatures and extreme weather events [7–9].

Brazil has also made important progress in climate governance during recent decades. Large metropolitan areas such as São Paulo, Rio de Janeiro, and Curitiba [10–12] have developed climate policies and adaptation strategies addressing issues including urban flooding, heat islands, green infrastructure, risk management, and greenhouse gas mitigation. However, these experiences remain concentrated in a relatively small number of municipalities and do not represent the reality of most Brazilian cities. The scientific literature consistently highlights substantial inequalities in institutional capacity, technical expertise, financial resources, and governance arrangements among Brazilian municipalities, particularly affecting small and medium-sized cities that often lack the conditions necessary to formulate and implement comprehensive climate adaptation policies [13–15].

This heterogeneity represents one of the greatest challenges for climate adaptation in Brazil. The country's continental dimensions encompass highly diverse climatic regions, ranging from the humid Amazon to the semi-arid Northeast and the subtropical South, requiring adaptation strategies that are sensitive to local environmental, socioeconomic, and institutional conditions. Therefore, international experiences cannot simply be replicated; instead, they must be critically analyzed and adapted to local realities, governance capacities, and territorial specificities.

Within this context, the present study addresses the following research question: To what extent can climate adaptation strategies implemented in Spanish cities contribute to strengthening climate governance and supporting the implementation of adaptation policies in Brazilian cities?

The objective of this study is to analyze climate adaptation strategies implemented in Spanish cities and evaluate their potential applicability to the Brazilian urban context, considering the institutional, environmental, socioeconomic, and climatic differences between the two countries. Rather than proposing the direct transfer of urban solutions, this study seeks to identify strategies capable of informing climate planning and supporting decision-making processes adapted to Brazilian realities.

The relevance of this research lies in its contribution to international climate governance by promoting the exchange of knowledge and experiences between Spain and Brazil. The study also contributes to the growing debate on policy transfer in climate adaptation, demonstrating that successful urban practices depend not only on technological solutions but also on governance capacity, institutional coordination, long-term planning, and social participation. By combining empirical observations obtained during the postdoctoral research with a comparative analysis of adaptation strategies, this study seeks to provide evidence that may support more resilient, inclusive, and climate-responsive urban policies in Brazilian municipalities.

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2. Materials and Methods

This study adopts a qualitative comparative research design based on documentary analysis, bibliographic review, and field observations undertaken during a postdoctoral research fellowship at the University of Barcelona (Spain). Comparative research has been widely employed in climate governance studies because it enables the identification of institutional arrangements, policy instruments, and adaptation practices that may inform climate action in different territorial contexts while acknowledging socioeconomic and environmental differences.

Rather than proposing the direct replication of international experiences, the study adopts a policy-transfer perspective, seeking to identify adaptation strategies whose underlying principles may be adapted to Brazilian municipalities according to their climatic, institutional, financial, and governance characteristics.

Methodological Procedures

The first phase consisted of a bibliographic and documentary review of scientific publications, technical reports, and institutional documents addressing climate adaptation and climate governance in Spain and Brazil. The documentary sources included national, regional, and municipal climate policies, adaptation plans, technical guidelines, and reports produced by governmental institutions and international organizations, particularly the Intergovernmental Panel on Climate Change (IPCC). This review also included academic studies on nature-based solutions, sustainable urban planning, urban resilience, and local climate governance.

The second phase involved field observations and technical visits conducted between September 2024 and August 2025 to fourteen Spanish cities: Barcelona, Madrid, Seville, Córdoba, Granada, Málaga, Jaén, Salamanca, Valladolid, Santander, Bilbao, Vitoria-Gasteiz, Zaragoza, Valencia, and Palma de Mallorca. These cities were selected because they represent different climatic conditions, urban morphologies, and levels of implementation of climate adaptation policies, thereby providing a diverse empirical basis for comparative analysis.

The technical visits sought to identify urban adaptation measures implemented in public spaces and municipal infrastructure, emphasizing strategies that could potentially be transferred to Brazilian cities. During the visits, direct observations were carried out, complemented by photographic records and consultations of local planning documents and institutional information available through municipal governments.

Rather than evaluating engineering performance or quantitative effectiveness, the comparative analysis focused on governance arrangements, implementation feasibility, scalability, and institutional transferability. This approach recognizes that climate adaptation depends not only on technical effectiveness but also on political commitment, administrative capacity, long-term planning, and multilevel coordination.

3. Climate Adaptation Strategies in Spanish Cities and Their Applicability to Brazil

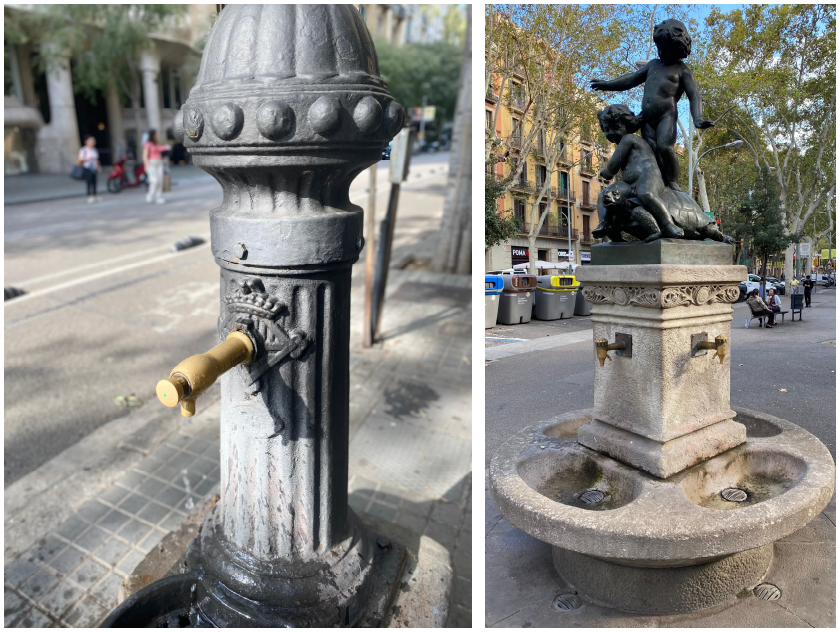
Based on the methodological procedures described in Section 2, including the documentary review of climate policies and the field observations conducted in fourteen Spanish cities during the postdoctoral research at the University of Barcelona, this section presents the main research findings. The comparative analysis focused on identifying urban climate adaptation strategies and evaluating their potential applicability to Brazilian municipalities according to four analytical dimensions: technical feasibility, compatibility with Brazilian climatic and urban conditions, institutional and governance requirements, and expected environmental and social co-benefits.

Among the most relevant initiatives are climate shelters, green roofs, ecological corridors, infiltration gardens, and sustainable urban drainage systems, which have transformed Barcelona into an international reference in urban sustainability. Likewise, the Superblock model has been recognized by the United Nations Environment Programme as an innovative approach to improving urban environmental quality while reducing traffic-related impacts [15,16].

The strategies identified in Barcelona and other Spanish cities provide valuable insights for Brazil. However, their transferability should not be understood as a simple process of policy replication. Differences in governance structures, financial resources, urban infrastructure, and institutional capacity require careful adaptation to local realities. Therefore, the following discussion not only presents the initiatives observed in Spain but also evaluates their potential applicability within the Brazilian context.

3.1. Public Drinking-Water Fountains

Since the Middle Ages, many European cities have maintained public drinking-water fountains as a basic urban service. In addition to supplying water, these structures contribute to reducing the health risks associated with extreme heat. Barcelona, for example, has a network of more than two thousand public drinking-water fountains, some of which also possess historical and ornamental value (Figure 1).



(**a**) (**b**)

Figure 1. Public drinking-water fountains in Seville (**a**) and Barcelona (**b**). Source: author (2024).

Beyond their aesthetic contribution to urban landscapes, these fountains help protect public health during periods of extreme temperatures, when thermal stress increases the risks of dehydration, cardiovascular disease, and heat-related mortality, particularly among elderly populations and individuals with chronic illnesses.

To facilitate public access, the Barcelona City Council developed the Fonts BCN mobile application, which provides the location, description, and images of public fountains. Similarly, the Municipality of Zaragoza maintains an interactive platform that allows users to identify fountain locations through computers and mobile devices.

From a Brazilian perspective, the implementation of public drinking-water fountains represents one of the most feasible and cost-effective adaptation measures identified during the technical visits. Many Brazilian cities already possess water supply infrastructure that

could support the expansion of public fountains in parks, squares, transportation terminals, and commercial areas.

Nevertheless, maintenance, vandalism prevention, and water quality monitoring would require coordination between municipal agencies and water utilities. Given their relatively low cost and direct public health benefits, public fountains could be rapidly incorporated into local climate adaptation plans, particularly in cities increasingly affected by heat waves and low relative humidity.

3.2. Climate Shelters

Another significant Spanish initiative is the development of climate shelters, which have been described as key instruments of bioclimatic urbanism [17] and as genuine urban oases [18].

Climate shelters consist of indoor or outdoor spaces that are clearly identified, freely accessible, and designed to provide thermal comfort, hydration, and protection during periods of extreme temperatures. Since 2019, Barcelona has pioneered this strategy, establishing more than 400 climate shelters and ensuring that approximately 90% of its population can access one within a ten-minute walk [19].

Currently, approximately 2122 climate shelters have been identified across Spain, concentrated mainly in Barcelona but also present in cities such as Tarragona, Girona, Lleida, Bilbao, Vitoria-Gasteiz, Zaragoza, Seville, Valencia, Málaga, Murcia, and Madrid [19]. Figure 2 illustrates an example of a climate shelter located in the inner courtyard of the Barcelona Centre for Contemporary Culture (CCCB).

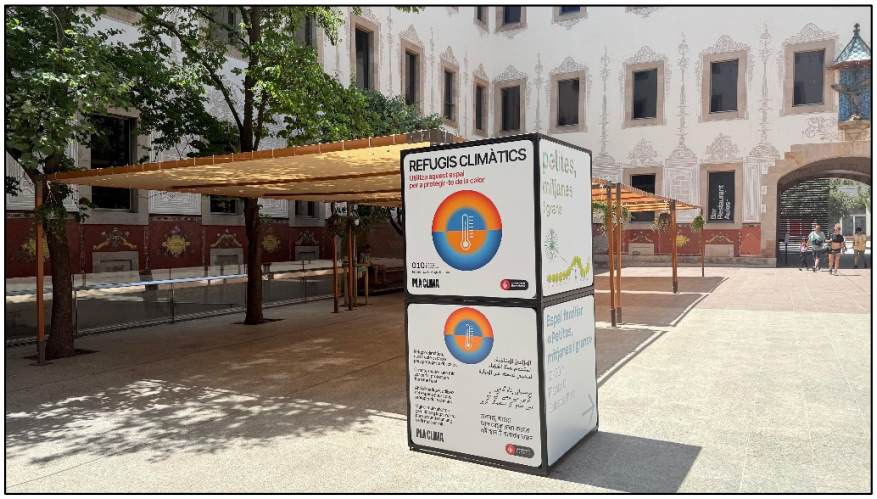


Figure 2. Outdoor climate shelter in Barcelona. Source: author (2024). Note: The Catalan term "refugis climàtics" refers to climate shelters.

The growing relevance of climate shelters is associated with increasing heat-related mortality across Europe [20–23]. Their benefits extend beyond local residents and support tourists during periods of extreme heat [17,23].

However, several limitations have been identified. Some facilities offer restricted opening hours, particularly on weekends, reducing their effectiveness during critical periods [18]. Furthermore, studies indicate that many indoor shelters are not fully inclusive, as socially vulnerable populations may feel uncomfortable accessing certain facilities [24].

In Brazil, climate shelters present significant adaptation potential because they can often be implemented using existing public infrastructure, including schools, libraries, cultural centers, health facilities, and community centers. This characteristic substantially reduces implementation costs.

Nevertheless, their success would depend on broader governance arrangements involving municipal governments, public health agencies, civil defense institutions, and local communities. Additional challenges include security concerns, limited maintenance of public spaces, and uneven access to urban amenities, particularly in peripheral neighborhoods. Consequently, the Brazilian adaptation of this strategy should prioritize accessibility, social inclusion, and community participation rather than merely reproducing the physical infrastructure observed in Spain.

3.3. Urban Shading Structures

Urban shading structures represent another important adaptation strategy observed in Spanish cities. Some interventions have become iconic examples of climate-responsive urban design, such as the Metropol Parasol in Seville (Figure 3).

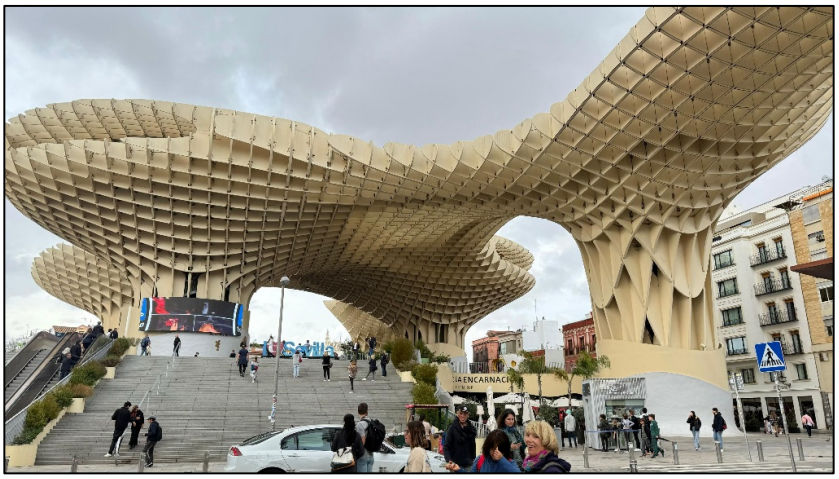
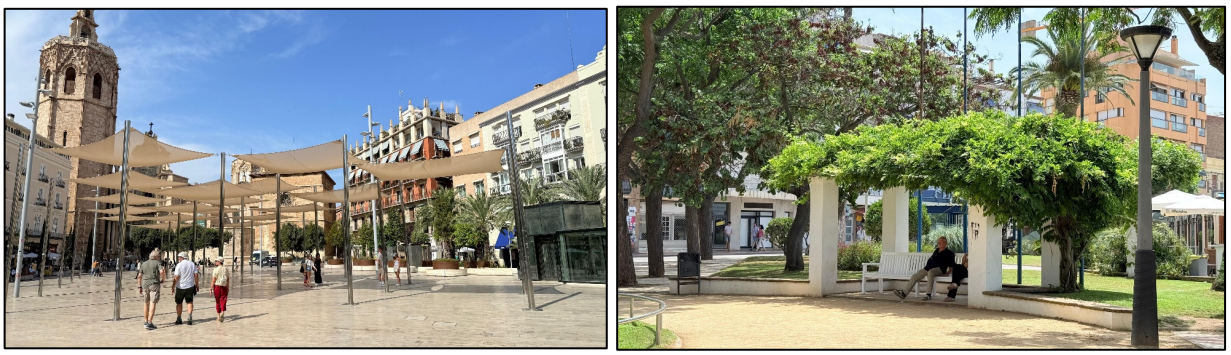


Figure 3. Metropol Parasol in Seville. Source: author (2024).

Although highly effective from a microclimatic perspective, large-scale projects of this nature require careful consideration of construction and maintenance costs, landscape impacts, and potential effects on urban land valorization. These factors are particularly relevant when evaluating their transferability to Brazilian cities, where financial resources are often limited.

More affordable alternatives were also observed, including temporary fabric canopies installed over streets and public squares, a common feature in several Spanish cities. Examples include shading systems in Valencia's *Plaza de la Reina* and pergola structures combined with green roofs in Jaén and Palamós, as illustrated in Figure 4.



(**a**) (**b**)

Figure 4. Examples of urban shading strategies: shading canopy in a public square in Valencia (**a**) and concrete shading structure in Palamós (**b**). Source: author (2025).

For Brazil, these lower-cost solutions may be especially attractive because they can be gradually implemented in commercial districts, public squares, pedestrian areas, and transportation corridors. Their effectiveness is particularly relevant in cities located in tropical and subtropical climates, where increasing temperatures and prolonged heat waves are becoming more frequent. Compared with large engineering projects, these interventions offer a favorable balance between cost, scalability, and thermal benefits.

3.4. Green Infrastructure and Ecological Corridors

In cities such as Barcelona, Vitoria-Gasteiz, and Santander, green roofs, living walls, green façades, and urban green belts are widely integrated into broader ecological networks—as shown in Figure 5. These interventions contribute to shading, thermal regulation, stormwater infiltration, and biodiversity conservation.

(**a**) (**b**)

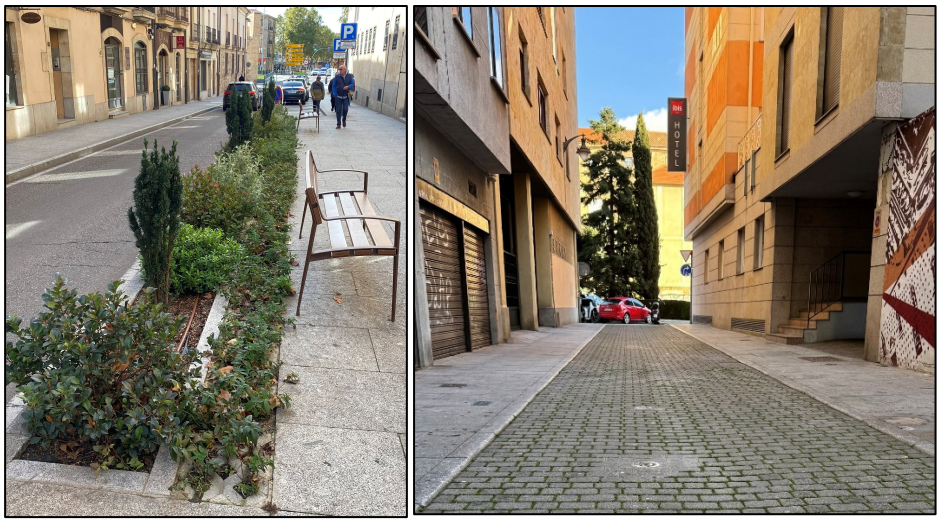
Figure 5. Green wall in Barcelona (**a**) and green belt along a roadway in Vitoria-Gasteiz (**b**). Source: author (2025).

Scientific studies demonstrate that green roofs contribute to reducing urban heat islands through shading and evapotranspiration processes [18,25]. Urban parks also play a significant role in thermal regulation. In Barcelona, temperature differences of up to 5.2 °C have been recorded between the *Parc de la Ciutadella* and its surrounding urban environment [26]. Similar cooling effects have been documented in Brazilian cities, including the Areião Park in Goiânia (Brazil) [27].

The Spanish experience demonstrates that green infrastructure should not be understood merely as an environmental amenity but as a core component of urban climate adaptation. For Brazilian cities, particularly those undergoing rapid urban expansion, ecological corridors and urban greening projects offer a relatively low-cost adaptation pathway capable of simultaneously addressing heat stress, biodiversity loss, and environmental degradation.

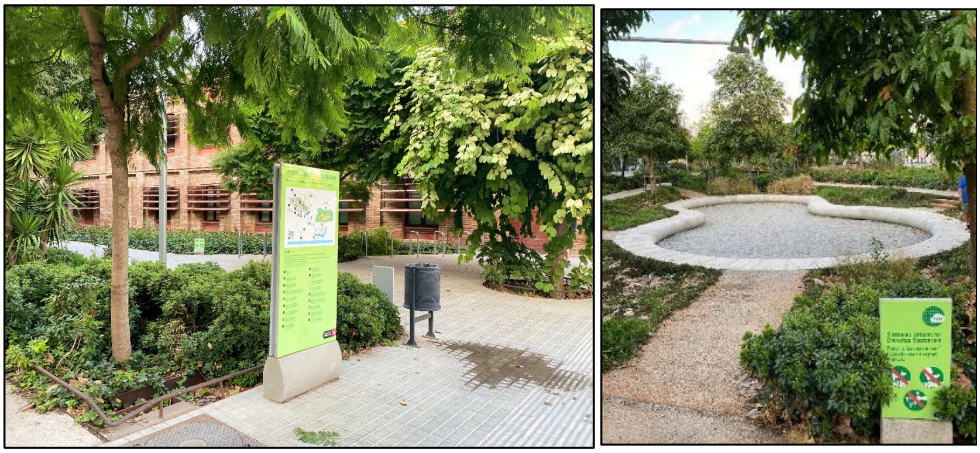
3.5. Infiltration Solutions and Sustainable Urban Drainage Systems

Another important ecological function of urban green areas is their contribution to rainwater infiltration. In Spanish cities, infiltration wells and permeable surfaces or materials are commonly integrated into sidewalks, streets, squares, and public spaces (Figure 6), representing low-cost interventions that effectively reduce flooding and stormwater accumulation [18]. Barcelona also provides examples of larger-scale Sustainable Urban Drainage Systems (SUDS), which combine permeable pavements, vegetated surfaces, infiltration basins, and underground storage structures to promote the natural water cycle (Figure 7).



(**a**) (**b**)

Figure 6. Infiltration wells in a sidewalk in Salamanca (**a**) and a street in Valladolid paved with permeable cobblestones (**b**). Source: author (2025).



(**a**) (**b**)

Figure 7. Sustainable Urban Drainage System (SUDS) in Barcelona (**a**,**b**). Source: author (2024).

From a Brazilian perspective, these measures offer some of the greatest adaptation potential among all strategies observed. Flooding and urban waterlogging constitute recurrent problems in many Brazilian cities due to extensive soil sealing, inadequate drainage infrastructure, and uncontrolled urban expansion.

Infiltration gardens, permeable pavements, and SUDS can often be incorporated into existing urban renewal programs at relatively low cost. Nevertheless, successful implementation requires coordination among urban planning, environmental management, sanitation, and public works agencies—highlighting once again the central role of governance in climate adaptation.

The analysis demonstrates that Spanish cities have progressively incorporated climate adaptation into urban planning through a combination of nature-based solutions, climate-responsive urban design, and governance instruments supported by long-term public policies. Although the observed initiatives differ in scale, investment requirements, and implementation complexity, they collectively illustrate how integrated climate governance can strengthen urban resilience while simultaneously improving environmental quality, public health, and citizens' well-being.

Among the adaptation measures identified during the field observations, five strategies stood out because of their potential applicability to the Brazilian context: (i) public drinking-water fountains; (ii) climate shelters; (iii) urban shading structures; (iv) green infrastructure and ecological corridors; and (v) sustainable urban drainage systems (SUDS) and infiltration solutions. While their implementation in Brazil requires adjustments to local climatic, socioeconomic, and institutional conditions, these measures present different levels of technical complexity and financial demand, allowing their adoption by municipalities with distinct governance capacities.

The following subsections discuss each strategy individually, emphasizing not only its functioning and contribution to climate adaptation in Spanish cities but also its implementation requirements, potential limitations, and opportunities for application within the diverse territorial and institutional realities of Brazilian municipalities.

4. Conclusions

This study analyzed climate adaptation strategies implemented in Spanish cities and assessed their potential applicability to Brazilian municipalities from a comparative climate governance perspective. Motivated by a postdoctoral research fellowship conducted at the University of Barcelona, the study sought to examine how internationally recognized urban adaptation experiences can contribute to strengthening climate adaptation policies in Brazil while acknowledging the country's institutional, socioeconomic, and climatic diversity.

The findings demonstrate that several strategies adopted in Spanish cities—including climate shelters, sustainable urban drainage systems (SUDS), infiltration gardens, public drinking-water fountains, urban shading structures, and green infrastructure—present considerable potential for application in Brazilian municipalities. However, the analysis also indicates that their successful implementation depends less on the simple replication of physical interventions than on the existence of adequate governance arrangements, long-term planning, institutional coordination, financial resources, and community engagement. In this sense, the Spanish experience should be understood as a source of policy learning rather than as a universal model to be directly transferred to other territorial contexts.

The comparative analysis also highlights that climate adaptation in Brazil has progressed unevenly. Although cities such as São Paulo, Rio de Janeiro, and Curitiba have developed important climate policies and adaptation initiatives, these experiences remain concentrated in a limited number of municipalities and do not represent the institutional reality of most Brazilian cities. Consequently, strengthening local adaptive capacity requires not only investments in urban infrastructure but also the consolidation of municipal climate governance, technical capacity building, interinstitutional cooperation, and stable financing mechanisms capable of supporting long-term adaptation policies.

From a scientific perspective, this study contributes to the literature by integrating field observations, documentary analysis, and comparative assessment within a climate governance framework. Rather than focusing exclusively on technological solutions, the research demonstrates that the transferability of adaptation strategies depends on the interaction between environmental conditions, governance capacity, institutional maturity, and local socioeconomic characteristics. By emphasizing these dimensions, the study expands the discussion on policy transfer and urban climate adaptation in developing countries.

Some limitations should nevertheless be acknowledged. The analysis is based on qualitative field observations and documentary evidence collected during technical visits to Spanish cities and therefore does not include quantitative evaluations of the environmental performance or cost-effectiveness of the adaptation measures. Furthermore, the study

focuses on a selected group of Spanish experiences and does not intend to represent the full diversity of international urban adaptation practices.

Future research could expand this comparative approach by incorporating adaptation experiences from other countries and by developing quantitative assessments of the environmental, economic, and social performance of individual adaptation measures. Comparative studies involving Brazilian municipalities with different climatic conditions, population sizes, and governance capacities would also contribute to identifying context-specific pathways for strengthening urban resilience.

In conclusion, the study demonstrates that international cooperation can play a strategic role in accelerating climate adaptation by promoting institutional learning and the exchange of successful experiences. The lessons derived from Spanish cities provide valuable insights for Brazilian municipalities, not as ready-made solutions, but as references that can inform the design of locally appropriate adaptation policies. In this regard, strengthening climate governance emerges as the fundamental condition for transforming adaptation strategies into effective public policies capable of increasing the resilience of Brazilian cities to the growing impacts of climate change.

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