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Cities and climate change: combining bibliometric trends and city-level evidence to understand the connections between urban resilience and adaptive capacity

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ABSTRACT

Climate change poses escalating challenges to urban systems, intensifying risks from extreme temperatures, flooding, sea-level rise, and socio-environmental inequalities. Cities are increasingly recognised as critical arenas for climate adaptation, where resilience and adaptive capacity shape the capacity to anticipate, absorb, and respond to climate-related impacts. This study maps research on urban resilience and adaptive capacity through a bibliometric analysis of Web of Science publications (2010–2023), identifying dominant thematic clusters via keyword co-occurrence and collaboration patterns via co-authorship networks. To connect research trends with practice, this study also reports on a qualitative meta-synthesis of twelve published city case studies from diverse geographic and socio-economic contexts. Explicitly linking bibliometric themes with city-level adaptation evidence, this study identifies areas of convergence (e.g., governance, nature-based solutions, and risk assessment) and persistent gaps, particularly in the operationalisation of social equity, participation, and maladaptation risks. The findings provide an integrated evidence base that may help inform future urban climate adaptation research and policy.

1. Introduction: How climate change impacts cities

Urban areas are increasingly vulnerable to extreme weather events, which are being exacerbated by climate change. This includes heavy rainfall, hurricanes, and other storms (Leal Filho et al., 2026). These extreme events can lead to flooding, infrastructure damage, and disruptions in urban life (Consalo, 2022; Mishra et al., 2015). They are also associated with infrastructure strain, as increased temperatures can strain transportation systems, energy grids, and buildings, requiring significant adaptations and reinforcements (Jing et al., 2021; Salimi and Al-Ghamdi, 2020; Leal Filho et al., 2024). There is a correlation between the success of mitigation and the necessity of adaptation. The further

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efforts to reduce global warming to pre-industrial levels fall short, the more adaptation must be integrated. This growing reliance on adaptation reflects the increasing recognition that cities function as complex socio-technical systems in which climate-related risks interact with infrastructure, governance, and social vulnerability, thereby requiring integrated and context-sensitive responses rather than isolated sectoral interventions.

Cities often experience the urban heat island effect, where concrete and asphalt absorb and re-radiate heat more than natural landscapes, leading to higher temperatures. Climate change exacerbates this effect, resulting in more frequent and severe heat waves that can affect public health, increase cooling energy demands, and worsen air pollution (Halder et al., 2021; Karimi et al., 2023). Recent research further emphasizes that urban morphology, land-cover composition, and building characteristics play a critical role in shaping heat exposure and energy demand patterns, reinforcing the need to integrate urban design considerations into climate adaptation strategies (Karimi et al., 2025). Alinasab et al. (2025), for example, demonstrate that street orientation and width are the determining architectural factors for mitigating urban heat stress. Thus, the strategic configuration of these elements enables the regulation of solar radiation and ventilation, directly improving thermal comfort across various urban morphologies.

Depending on the context, particularly in developing countries, changing climate patterns can affect the availability and quality of water (Padrón et al., 2020). Water shortages in cities may become more common in some regions (He et al., 2021), while in other areas, increased precipitation can lead to flooding and water contamination (Mishra et al., 2021). These contrasting hydrological pressures highlight the uneven distribution of climate risks across cities and regions, underscoring the importance of adaptive capacity in mediating local responses to both water scarcity and excess (Padrón et al., 2020; He et al., 2021; Mishra et al., 2021).

A further point worth mentioning is that climate change can lead to increased air pollution in cities. Higher temperatures can increase the formation of ground-level ozone, a key component of smog that poses serious health risks, especially for older people, children, and those with respiratory conditions (Hassan et al., 2016). The interaction between climate change, air quality, and public health further complicates urban adaptation efforts, as climate-driven environmental stressors disproportionately affect vulnerable populations and place additional pressure on urban health systems.

A particular set of problems affects coastal cities, which face increasing pressures from rising sea levels, leading to more flooding and erosion. This poses risks to infrastructure, housing, and the overall habitability of these areas (Griggs and Reguero, 2021; Laino and Iglesias, 2023). Urban biodiversity is also influenced by climate change, which may potentially lead to biodiversity losses among the species that inhabit urban areas and green spaces (Xie et al., 2022). This loss can impact ecosystem services, such as air and water purification, that are crucial for urban environments (Xie et al., 2022; Malhi et al., 2020). Together, these impacts demonstrate that climate change affects not only the physical fabric of cities but also the ecological systems that support urban life, reinforcing the need to consider resilience and adaptation within a broader socio-ecological framework (Griggs and Reguero, 2021; Laino and Iglesias, 2023; Xie et al., 2022; Malhi et al., 2020).

Climate change also poses socio-economic problems in urban areas, since its impacts often exacerbate social inequalities. Vulnerable populations may face greater risks from extreme weather events and have fewer resources to adapt to changing conditions. Economic activities can also be disrupted, affecting livelihoods and the urban economy (Gasper et al., 2011). Finally, the cumulative effects of climate change in urban areas can have widespread impacts on public health, from heat-related illnesses to diseases transmitted through contaminated water or increased populations of disease-carrying pests such as mosquitoes (Bouchard et al., 2019; Ludwig et al., 2019; Vicedo-Cabrera et al., 2021; Leal Filho et al., 2022). Fig. 1 contextualises the influences of climate change on cities, considering the issues outlined above.

Against this background, this study has two integrated aims: (i) to map how urban resilience and adaptive capacity to climate change have been conceptualised and studied in the peer-reviewed literature (2010–2023) through bibliometric analysis; and (ii) to synthesise evidence from published city case studies to examine how dominant research themes are reflected (or not) in reported adaptation practices. This combined design enables this study to move beyond a descriptive mapping of topics by explicitly interrogating points of alignment, tension, and under-representation between research agendas and city-level implementation.

Whereas a substantial body of literature has examined climate change impacts, urban resilience frameworks, and adaptive capacity indicators (Economist Impact, 2023; Meerow et al., 2016; Sachs et al., 2023; Leal Filho et al., 2019), existing reviews and bibliometric analyses have largely addressed these dimensions separately. Bibliometric studies tend to map research trends without systematically linking them to city-level adaptation practices. In contrast, case-based studies often remain context-specific and disconnected from broader patterns in the literature. This fragmentation limits the ability to assess how dominant research themes are reflected in real-world urban adaptation efforts. To address this gap, the present study integrates bibliometric mapping with a qualitative synthesis of published urban case studies, explicitly linking dominant research clusters with observed adaptation practices across cities. By doing so, the study advances existing reviews by providing a cross-city, evidence-informed perspective on how urban resilience and adaptive capacity are conceptualised and operationalised in practice.

This study also addresses the need to handle contemporary critical debates that shape urban adaptation outcomes and the issues associated with them. First, adaptation can generate maladaptation, i.e., actions that inadvertently increase vulnerability or redistribute risks, particularly when equity and long-term dynamics are not considered (Barnett and O'Neill, 2010). Second, climate justice and political economy perspectives highlight how governance, finance, and uneven power relations affect who benefits from resilience investments and who bears residual risk (Ziervogel et al., 2017; Chu and Cannon, 2021; Shi et al., 2016). These debates provide a lens to interpret why certain themes, e.g., social equity and participation, remain persistently under-represented in practice, even when frequently acknowledged in the literature.

2. Concepts and analytical framing

2.1. Urban resilience

Cities are populous hubs, often with a high percentage of built-up area and booming economic activity. Given the multiple climatic threats to cities, urban citizens and governing bodies need to build resilience. Urban resilience is the ability of the system, inclusive of its social, institutional, technical, and ecological components, to sustain and recover from shocks (Economist Impact, 2023; Meerow et al., 2016). This definition highlights the systemic nature of urban resilience, emphasizing that responses to climate change must address not only physical infrastructure but also governance arrangements, social dynamics, and institutional capacity.

As making cities resilient is one of the Sustainable Development Goals (SDGs), i.e., SDG 11, there has been growing interest in improving urban resilience worldwide. However, few countries have achieved this SDG, as it is a complex task that involves major common challenges, such as poor living conditions, transport, and air and water pollution in urban settings (Sachs et al., 2023). The difficulty in achieving Sustainable Development Goal 11 reflects the multifaceted and context-dependent nature of urban resilience, demanding coordinated action across sectors and scales rather than isolated interventions. Cities in the global south have been observed to have lower levels of urban

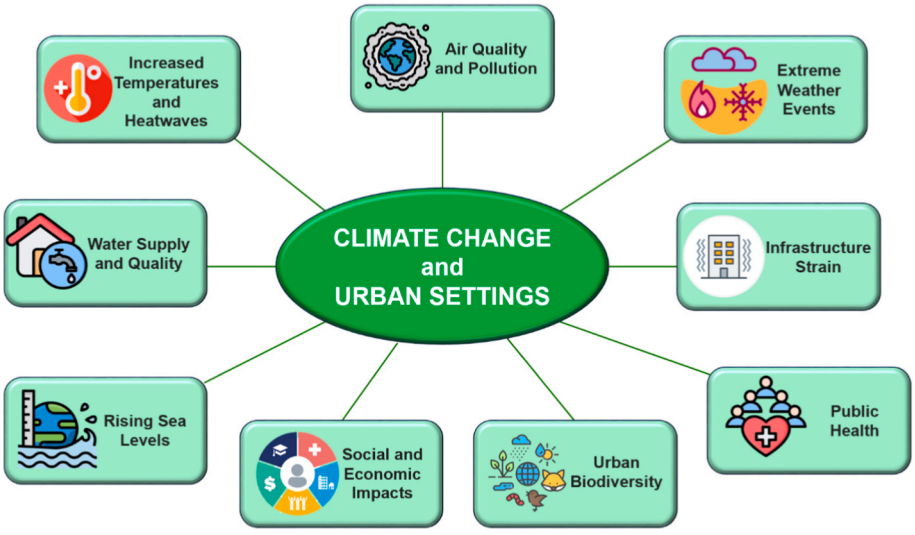

Fig. 1. – Major climate change hazards and their impacts on urban systems (Source: authors' elaboration).

resilience than other regions worldwide. This is largely due to a lack of adaptive capacity, stemming from insufficient infrastructure, funding, and climate-relevant policies (Leal Filho et al., 2019). These disparities underscore the importance of adaptive capacity as a central component of resilience, particularly in cities facing structural constraints related to governance, resources, and socio-economic inequality.

Urban resilience has been measured using a variety of indicators across the literature. However, one noteworthy framework for its measurement is the City Resilience Index Assessment from the Rockefeller Foundation (Rockefeller Foundation, 2018). According to the framework, four dimensions contribute to a city's resilience. They are health and well-being, economy and society, infrastructure and environment, and leadership and strategy. It is a data-intensive framework for identifying a city's strengths and challenges to become more resilient and improve its adaptive capacity. Indicator-based frameworks, such as the City Resilience Index Assessment, provide structured tools for assessing resilience; however, their application often depends on data availability and institutional capacity, which can vary significantly across cities and regions.

2.2. Adaptive capacity

Adaptive capacity is a key component of urban resilience, referring to a city's ability to prepare for or cope with changing conditions (Leal Filho et al., 2019). Improving the adaptive capacity of cities to reduce disaster risk, e.g., by installing early warning systems, educating citizens to respond to warnings, and developing disaster-proof infrastructure, can help cities improve their resilience (Hofmann, 2021). Adaptive capacity encompasses both tangible elements, such as infrastructure and technology, and intangible elements, including knowledge, social capital, and institutional learning, which together shape how cities anticipate and respond to climate-related risks (Leal Filho et al., 2019; Hofmann, 2021). The use of advanced Information and Communication Technology (ICT) and smart technologies enables real-time monitoring, early warning systems, and efficient communication, contributing to adaptive capacity during crises. Green infrastructure and thoughtful urban planning contribute to a city's adaptive capacity. Well-designed green spaces can mitigate the impact of extreme weather events, improve air quality, and enhance overall urban resilience. Technological solutions and nature-based approaches are increasingly viewed as complementary strategies, as their effectiveness depends on integration within broader planning frameworks and alignment with local socio-environmental conditions (Rockefeller Foundation, 2018; Hofmann, 2021). Introducing flexible and adaptable infrastructure, such as having built-in solar panels in buildings that can help reduce reliance on the grid and withstand power outages (e.g., during disasters), can improve resilience. Community action and social capital are also crucial dimensions of urban resilience (Archer et al., 2020; Prashar et al., 2013) that can determine adaptive capacity. They play an important role in maintaining public infrastructure and collaborative efforts necessary to recover from disasters and crises. An inclusive governance system that emphasizes community participation and ensures that the challenges faced by its diverse citizens are addressed is also crucial for developing a city's resilience. This highlights that urban resilience is not solely a technical or infrastructural challenge but also a social and institutional one, in which the quality of governance and community engagement strongly influence adaptive outcomes.

2.3. Linking the concepts: from capacities to outcomes

In this review-based study, adaptive capacity is perceived as a core enabling component of urban resilience: it shapes the ability of urban systems to plan, learn, mobilise resources, and implement responses, while resilience captures the broader capacity to absorb, recover, and, where necessary, transform in the face of climate-related shocks and stresses. This framing supports the integrative analysis presented in Section 4.4, where the study examines whether the research clusters identified through bibliometric analysis correspond to capacities and practices reported in the city case literature, and where gaps, e.g., justice, participation, and maladaptation, may reflect persistent institutional and political constraints.

National governments across the world are designing policies and programs to make their cities more resilient to climate change. Further, there have been various global initiatives. For example, the United Nations Office for Disaster Risk Reduction (UNDRR) is coordinating the Making Cities Resilient 2030 (MCR2030) initiative (UNDRR, 2020). It is a unique platform that enables city stakeholders to engage in advocacy and knowledge sharing and form city-to-city learning networks. The emergence of such initiatives highlights that governments and organizations have realized the need to act on making cities resilient. Such multi-level initiatives demonstrate the growing recognition that urban resilience requires coordination between local, national, and international actors, as well as mechanisms for learning and knowledge exchange across cities.

In expanding the knowledge on urban resilience, it is important to investigate novel ideas that go beyond standard paradigms. Ecosystem-based resilience, for instance, emphasizes incorporating natural systems into urban development. The maintenance and restoration of urban

ecosystems, such as wetlands and green belts, not only increase biodiversity but also serve as a natural barrier to climatic extremes (Pickett et al., 2004; Wessels et al., 2024). The integration of various ecosystems reduces flooding, moderates temperatures, and improves overall environmental health, providing a comprehensive strategy for urban resilience (Gómez-Baggethun et al., 2013; Pandey and Ghosh, 2023). Furthermore, urban biodiversity conservation is an important component of resilience, as different ecosystems contribute significantly to ecological balance and the prevention of catastrophes (Bush and Doyon, 2019). Well-designed urban green spaces, together with actions to maintain and enhance biodiversity, positively influence city resilience by providing diverse ecosystem services critical to urban well-being (Bush and Doyon, 2019; Enssle and Kabisch, 2020). Ecosystem-based approaches, therefore, offer co-benefits for climate adaptation, biodiversity conservation, and human well-being, making them particularly attractive to cities seeking integrated, multifunctional resilience strategies (Pickett et al., 2004; Wessels et al., 2024; Gómez-Baggethun et al., 2013; Pandey and Ghosh, 2023; Bush and Doyon, 2019; Enssle and Kabisch, 2020).

Beyond ecological considerations, the preservation of cultural assets adds an important dimension to the discussion about urban resilience. Integrating historical structures, traditional knowledge, and cultural practices into resilience measures protects cultural heritage while also fostering a feeling of community and belonging (Fabbricatti et al., 2020; Tavares et al., 2021). This symbiotic relationship emphasizes the importance of cultural preservation in sustaining social cohesiveness amid crises and disasters (Wardekker et al., 2023). Complementing these cultural characteristics, resilience education programs are the foundation for providing urban residents with the information and skills they need to manage urban difficulties (Fu and Zhang, 2024; Ruiz-Mallén et al., 2022) effectively. Particularly in developing countries, these initiatives, which range from disaster preparedness to sustainable living practices, foster a culture of proactive resilience among city residents, making a substantial contribution to the development of a resilient urban fabric (Ruiz-Mallén et al., 2022; Ma et al., 2023). Cultural heritage and education thus contribute to resilience by strengthening social cohesion and collective capacity, which are critical for coping with and recovering from climate-related disturbances (Fabbricatti et al., 2020; Tavares et al., 2021; Wardekker et al., 2023; Fu and Zhang, 2024; Ruiz-Mallén et al., 2022; Ma et al., 2023).

Circular urban design, which focuses on urban planning, represents a paradigm change by re-evaluating old models of resource use and waste creation (Kirchherr et al., 2023). Recycling, reusing, and minimizing waste are all part of circular economies, which promote regenerative systems that align with sustainability goals (Barros et al., 2021; Puntillo et al., 2021; Ren et al., 2023). This method not only strengthens a city's adaptive potential but also enables it to respond effectively to environmental changes (Barros et al., 2021; Williams, 2023). By reducing resource dependency and enhancing system flexibility, circular design principles can support adaptive capacity and long-term resilience in the face of climate uncertainty (Kirchherr et al., 2023; Barros et al., 2021; Puntillo et al., 2021; Ren et al., 2023; Williams, 2023).

Social innovation hubs in urban areas act as catalysts, bringing together residents, entrepreneurs, and researchers to discover new solutions to urban difficulties. Encouraging entrepreneurship and social innovation creates a dynamic environment that can adapt swiftly to new risks and possibilities (Grilo and Moreira, 2022; Somwethee et al., 2023). These centres play an important role in increasing urban resilience. Such hubs illustrate how innovation ecosystems can facilitate experimentation and learning, which are increasingly recognised as key components of urban adaptive capacity.

Access to affordable and resilient housing is critical for the development of metropolitan areas amid rising climate-related threats (Li and Spidalieri, 2021). Integrating sustainable and disaster-resilient design concepts into affordable housing efforts increases community resilience (Li and Spidalieri, 2021; Li et al., 2024). This is consistent with the overall objective of constructing resilient, inclusive, and environmentally sustainable urban areas. Housing resilience is therefore closely linked to social equity, as secure and affordable housing reduces vulnerability and enhances communities' capacity to cope with climate-related hazards.

The concept of urban resilience has emerged as a potential solution to enhance cities' capacity to absorb and address risks, contributing valuable insights to sustainable development. Despite this, a gap remains in understanding the impact of climate change on regional urban resilience. Considering adaptive capacity as a key component of urban resilience, this study aims to address the following question: What are the most recent advances in the literature on urban resilience and adaptive capacity? What are the adaptive strategies adopted by cities to boost urban resilience against climate pressures? These questions provide the conceptual foundation for the subsequent bibliometric analysis and the synthesis of city-level case studies presented in the following sections.

3. Methods

Given the need for research into the extent to which climate change affects urban environments, this paper outlines recent advances in the literature and evidence on urban resilience and adaptive capacity in cities. The analysis used hybrid methods, drawing on previous observations by Boulanger (2023) and others (Zheng et al., 2020; Van Eck and Waltman, 2011; Carvalho et al., 2013), and employed two main methods. The first method adopted was a bibliometric analysis to conduct two different focused literature reviews and explore connections between terms related to urban resilience, adaptive capacity, and climate change. The second method deployed was a set of case studies from 12 cities to evaluate practices in urban resilience and adaptive capacity. Together, these two methods constitute a mixed-method review design, combining bibliometric mapping of the scientific literature with a qualitative synthesis of published urban case studies, rather than a primary empirical investigation.

In the literature review, a bibliometric analysis was conducted on the Web of Science database, using search strings to identify peer-reviewed publications. The first analysis covered studies on urban resilience to climate change, using the search string: TS ("urban resilience" AND "climate change"), published between 2010 and 2023, with document types limited to articles, review articles, early access articles, or editorial material. The search on February 8, 2024, resulted in 589 publications. The second focused analysis, with a more restricted aim, covered studies on the adaptive capacity of cities to climate change, using this search string: TS ("urban" AND "adaptive capacity" AND "climate change"), published between 2010 and 2023, document types: article or review article or early access or editorial material, resulting in 468 publications on February 9, 2024. Both bibliometric analyses were based on term co-occurrence, using the VOSviewer software (VOSviewer, 2024), version 1.6.20, which is designed to construct and visualize bibliometric networks. Bubble size represents term frequency. Stronger connections between the bubbles mean a higher probability of terms co-occurring and forming thematic clusters, as indicated by colours (Van Eck and Waltman, 2011). The intensity of relationships between keywords is reflected in the strength of the ties connecting the nodes (Carvalho et al., 2013). The use of keyword co-occurrence analysis enabled the identification of dominant thematic structures and conceptual linkages within the literature, providing an overview of how research on climate change, urban resilience, and adaptive capacity has evolved. Furthermore, a co-authorship analysis was conducted using network visualization of jointly authored publications. This approach enabled the identification of collaborative groups among authors and countries, as well as the key nodes that organize international research. This study intentionally used focused, reproducible topic-search strings centered on the expressions "urban resilience" and "adaptive capacity" in combination with "climate change", because these terms directly operationalise the two core

constructs examined in this manuscript.

Following the bibliometric analysis, case studies from 12 diverse cities were used to illustrate exemplary urban resilience and adaptive capacity practices. The methodology for selecting case studies on urban resilience and adaptive capacity across 12 cities follows a systematic, robust approach. Initially, the study's objectives focused on identifying and illustrating best practices in urban resilience and adaptive capacity. The scope encompasses various dimensions, including climate change, natural disasters, socioeconomic factors, and community engagement. The previous comprehensive literature review guided this approach, providing insights into existing frameworks and methodologies. This review identified gaps in the literature, shaping the criteria for city selection. To ensure relevance and diversity, clear selection criteria were developed, including wide-scoped geographic representation, city size, socio-economic factors, and susceptibility to specific risks. The preliminary screening phase involved an initial assessment of potential cities based on the above-detailed criteria. A balance between developed and developing cities was sought to present a comprehensive view. This approach aims to showcase examples of good practice in urban resilience and adaptive capacity across diverse urban contexts, enriching our understanding of each city's context. In this study, the case studies should be understood as a systematic review and qualitative meta-synthesis of previously published empirical studies, rather than as newly generated primary case research. Thus, and in accordance with the Yin (2018) framework, the cases were classified as type I, involving a thorough analysis of each case as a cohesive entity. This comprehensive evaluation showcased the effective strategies employed in addressing challenges related to urban resilience and adaptive capacity. The chosen approach enabled a holistic examination, allowing a nuanced comparison of results and significantly enriching the overall understanding of the investigated cities. Comparability across cases was achieved through thematic coding aligned with the bibliometric clusters identified in the literature review, allowing insights derived from studies employing different methods, e.g., indicator-based assessments, policy analyses, or qualitative case narratives, to be interpreted within a common analytical framework.

The cases are treated as illustrative evidence for thematic synthesis, rather than a statistically representative sample of global urban adaptation practice. Selecting the 12 case-study cities based on prior studies ensured relevance and diversity. High vulnerability to climate change impacts like flooding, extreme temperatures, and sea-level rise; geographic representation to reflect both developed and developing urban contexts; established urban resilience and climate adaptation strategies; and significant visibility in the bibliometric dataset, indicating prominence in scholarly research, determined the cities. These criteria enable relevant comparisons of urban resilience and climate change adaptation capabilities, making the analysis more sound and rigorous.

4. Results and discussion

The bibliometric outputs and the case-study evidence are presented in this section. Sections 4.1 and 4.2 report the bibliometric results, i.e., mapping, co-occurrence, and co-authorship patterns, and Section 4.3 summarises the selected city case evidence. Interpretive integration is then consolidated in Section 4.4, which serves as the main discussion by critically linking the bibliometric themes to the city-level findings and identifying explanatory gaps and tensions. This structure maintains a clear separation between reporting results and interpreting their implications, while avoiding duplication across sections.

4.1. Urban resilience and climate change

The first literature review handled studies of urban resilience and climate change. Fig. 2 presents publications categorized by Web of Science classification in a tree map, highlighting the 10 most relevant categories. Larger rectangles represent a higher proportion of publications in the Web of Science category, with size indicating the total number of publications by discipline. The categories Environmental Sciences, Environmental Studies, Green Sustainable Science Technology, and Urban Studies stand out. Most of the documents are published in the United States of America (19.5%), China (16.0%), and England (10.7%). This distribution highlights the disciplinary concentration and geographical focus of research on urban resilience, indicating where

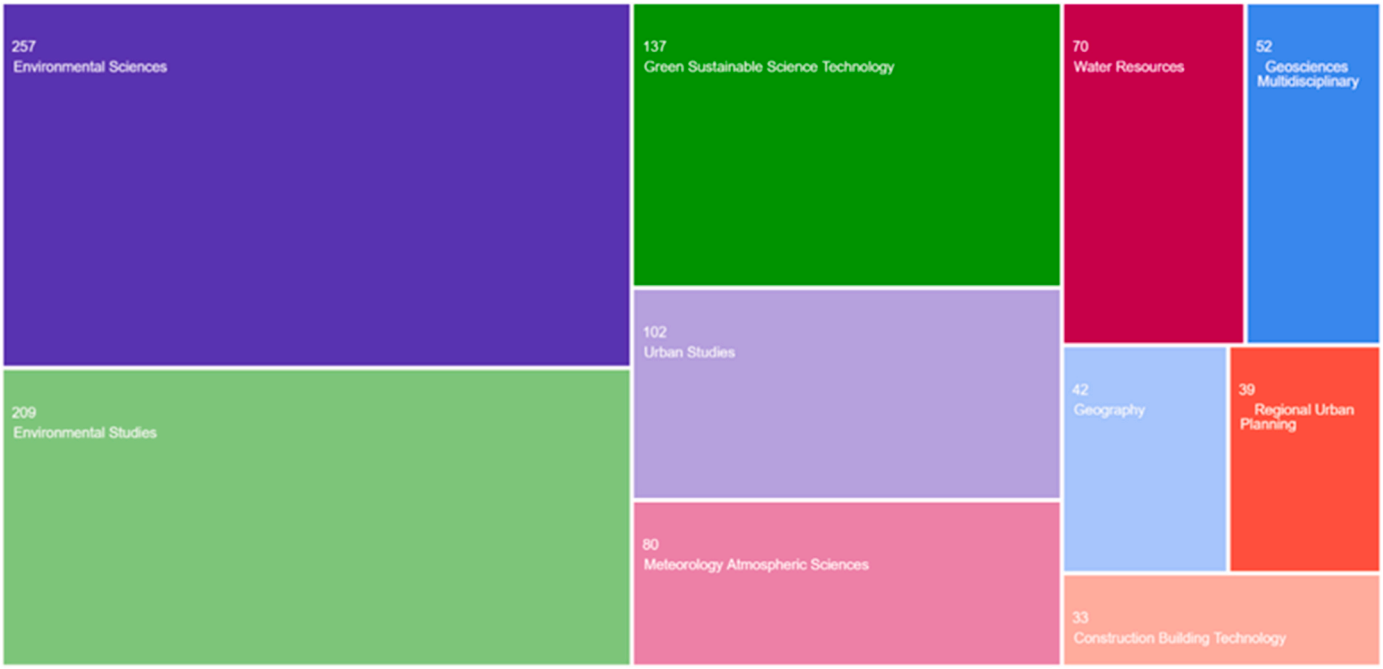

Fig. 2. Tree map chart of Web of Science categories of the publications on urban resilience and climate change. The size of each rectangle represents the relative proportion of publications within each Web of Science category. At the same time, the numerical values indicate the total number of publications associated with each discipline. (Source: authors' elaboration).

scientific production on this topic has been most prominent.

The results of the bibliometric analysis of urban resilience and climate change based on term co-occurrence are presented in Fig. 3, using keywords with at least 10 occurrences, yielding 96 items. Six thematic clusters are associated with each colour. These thematic clusters indicate the main conceptual groupings within the literature on urban resilience and climate change, reflecting how research topics are organised and interconnected.

In Fig. 3, the **green** cluster is related to urban resilience in cities, conceptualizing it (Meerow et al., 2016) and considering the management, strategies, and challenges involved in these efforts (Chelleri et al., 2015; Jabareen, 2013), as well as indicators, policies, and politics for addressing climate change at the community level (Béné et al., 2018). The **red** cluster is closely related to climate change and its impacts in urban contexts (Leichenko, 2011), including urban planning and design, temperature, energy, and urbanization. The third cluster, in **blue**, covers studies related to resilience (Ernstson et al., 2010), including governance, infrastructure, and ecosystem services, with perspectives on climate adaptation (Anguelovski et al., 2014; Yu et al., 2017) and adaptive capacity (McPhearson et al., 2015). The **yellow** cluster involves studies on cities' vulnerability to climate change, including natural hazards, disasters, floods, and rising sea levels, as well as city-level mitigation strategies (Elmqvist et al., 2019; Fratini et al., 2012). The **purple** cluster is associated with adaptation practices and risk reduction, including those related to climatic justice (McClymont et al., 2020; Meerow and Newell, 2019; Rosenzweig et al., 2018). The last one, the **light blue** cluster, relates to lessons for a resilient city (Frantzeskaki, 2019), focusing on ecological resilience (Bush and Doyon, 2019; Ribeiro and Pena Jardim Gonçalves, 2019; Wamsler et al., 2013), including socio-ecological systems analysis (Chang et al., 2021; Thonicke et al., 2020). Together, these clusters illustrate the thematic breadth of research on urban resilience and climate change, spanning conceptual frameworks, governance, infrastructure, vulnerability, adaptation practices, and socio-ecological perspectives.

The co-authorship analysis (Fig. 4) shows a relatively concentrated field, with some authors serving as central nodes in the collaboration network on urban resilience and climate change. The author Sharifi stands out for the highest density of connections, primarily partnering with Asian researchers, while Serre and Heinzlef form another relevant core. Smaller clusters around authors such as Velasco, Russo, and Meerow indicate more specialized or emerging groups, contributing to the diversification of the research agenda. This configuration reveals several major international networks, supported by surrounding groups that gradually enhance the knowledge base on urban resilience and climate change.

Fig. 5 illustrates the international co-authorship network for studies on urban resilience and climate change, organized into clusters that represent groups of countries with stronger collaboration patterns. The first cluster, centered on the USA, includes Canada, South Africa, Singapore, Sweden, and New Zealand. This cluster serves as a hub for

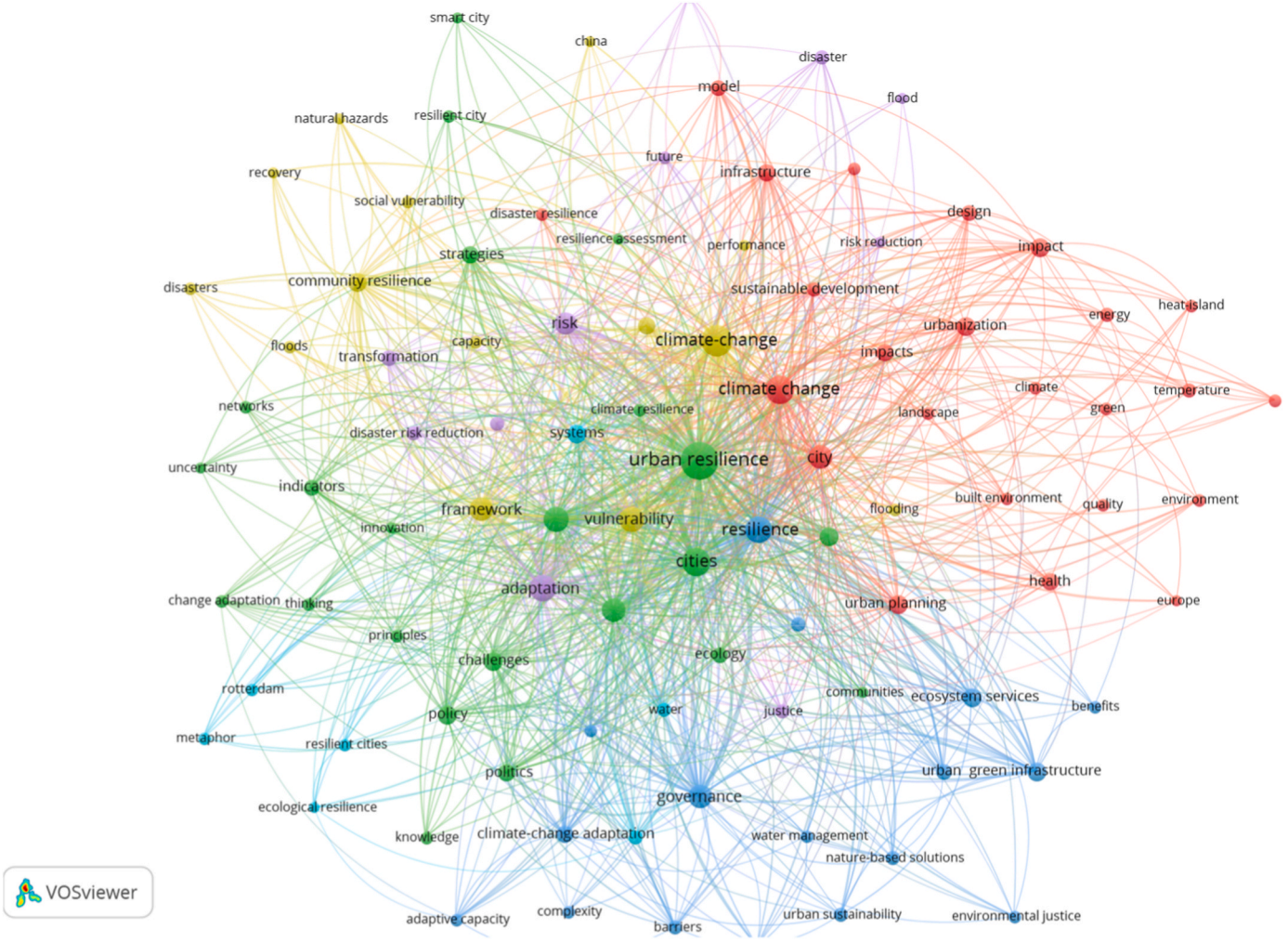

Fig. 3. Co-occurrence of terms related to urban resilience and climate change based on VOSviewer analysis. Node size reflects the frequency of keyword occurrence, link strength represents the intensity of co-occurrence between terms, and colours denote distinct thematic clusters identified through the analysis. (Source: authors' elaboration).

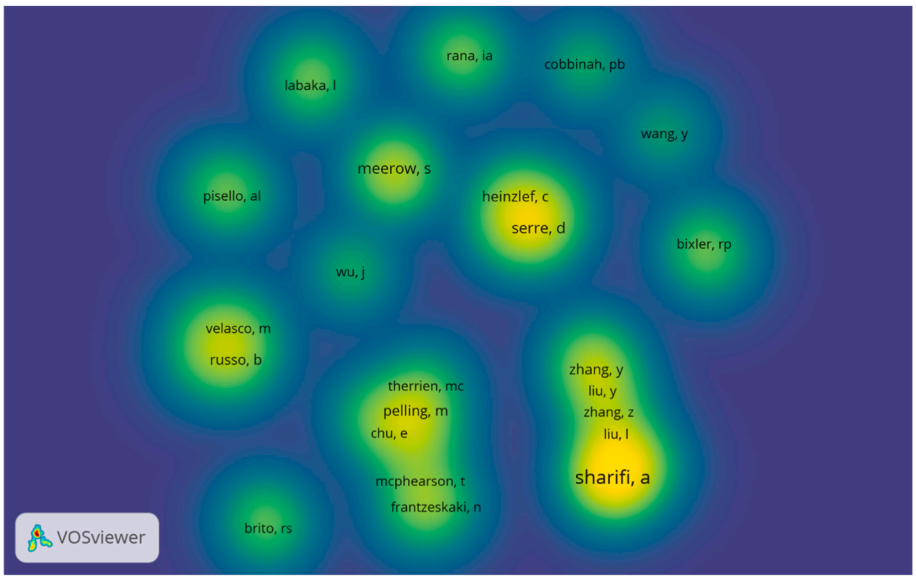

Fig. 4. – Co-authorship network of leading authors on urban resilience and climate change based on VOSviewer analysis. (Source: authors' elaboration).

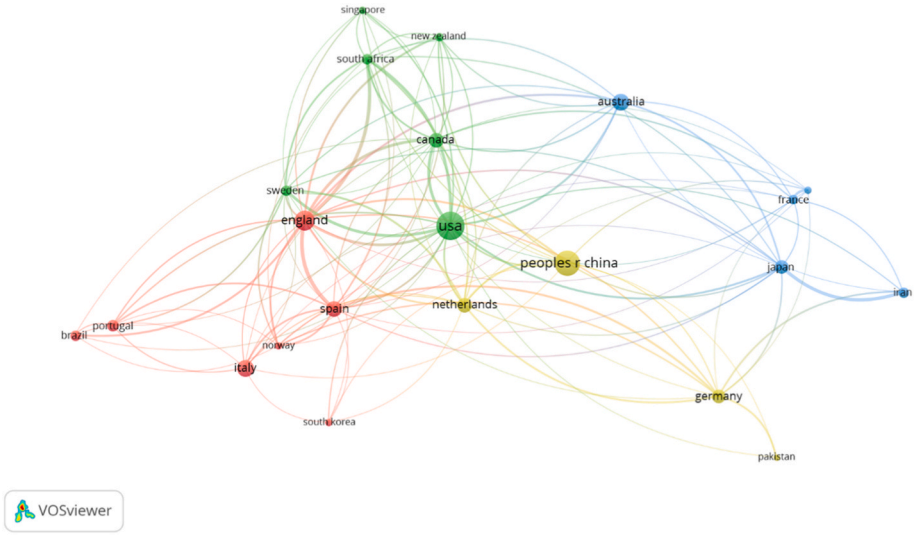

Fig. 5. – Co-authorship network of leading countries on urban resilience and climate change based on VOSviewer analysis. (Source: authors' elaboration).

collaborations between North America, Africa, and parts of Europe and Oceania. A second cluster involves England, Spain, Italy, Portugal, Norway, and South Korea, highlighting a dense European core with connections extending to Asia and Latin America, particularly through Brazil. Another cluster, comprising Japan, France, Iran, and Australia, indicates a cooperative network linking Asia and Oceania with European partners. Lastly, the cluster led by the People's Republic of China, the Netherlands, and Germany connects Asian and Western European research fronts while also maintaining ties with countries such as Pakistan.

When it comes to ensuring the sustainability and general well-being of cities, urban resilience and adaptive capacity are increasingly important factors. Hence, numerous authors have asserted that the need to build resilience is increasingly recognised by cities as a means of addressing the growing problems posed by climate change and other threats (Birchall et al., 2023; Ji et al., 2022; Zeng et al., 2022). The capacity to endure and recover from shocks and pressures, as well as the ability to adapt to and thrive amid ongoing change, is included in those studies. Thus, urban resilience entails not only the maintenance of basic activities and infrastructure but also the guarantee of the preservation of urban identity, as mentioned by Shao et al. (2021). Yet the same authors examined the idea that urban resilience is a city's ability to adapt to different situations and maintain its vitality when faced with multiple challenges and crises, and how this concept has evolved in the context of major catastrophes. Hence, the concept of urban resilience encompasses not only metropolitan areas but also rural communities with community infrastructure. On the contrary, a resilient urban environment encompasses not only the city system's capacity to adapt and react to a multitude of adverse uncertainties and abrupt assaults but also the capability to convert favourable circumstances into financial gains (Berkes et al., 2008) efficiently. Likewise, Araya-Muñoz et al. (2016) observed that the ability of cities to absorb and recover from unanticipated shocks or stressors, while continuously improving their capacity to adapt, must be prepared for. To accomplish this, there must be strong governance and leadership, dependable infrastructures, and collective capacity and readiness. According to Lomba-Fernández's 2020 research, urban areas are required to establish resilience strategies that take into account the ongoing dynamics of threats and uncertainties. This body of

work reinforces the view that urban resilience is a dynamic and evolving concept, encompassing both the ability to withstand disturbances and the capacity to adapt and transform in response to changing conditions.

To date, ideas of urban resilience have been largely conceptualised based on the experience and practices of cities in the global North. It highlights the challenge to bring a resilience lens to urban risk management in the context of the global South, and what role normative concepts such as rights and justice should play in such management (Ziervogel et al., 2017). Also, the importance of empirical rigor and appropriate policy responses across the full range of urban activities and livelihood strategies was not well estimated, particularly for the most vulnerable social groups in the most vulnerable locations, in order to distill comparative insights and lessons (Simon and Leck, 2015). Yet, national governments' commitments to implementing urban resilience strategies have not been encouraging despite being signatories to all transnational climate treaties. To enable this global response, particularly in Africa, there is a need to intensify and quicken action on climate change according to the UN. Targeted investment in urban resilience strategies will not only enhance urban living but also improve adaptation, minimize climate change-related impacts, and support other infrastructure development across growing African conurbations (Cobbinah, 2021). These observations point to persistent geographical and socio-economic imbalances in the application of urban resilience concepts, underscoring the need for context-sensitive approaches and greater attention to cities in the global South.

In the complex, interdependent social and ecological systems in which we live, resilience also includes the capacity for transformation when systems cross thresholds (Chirisa et al., 2016). It becomes apparent that there are, in fact, two sets of interventions to build urban resilience but that they are mixed up. The first concerns physical and environmental matters; the second, institutional concerns (McGill, 2020). Resilience strategies should also be able to capitalise on stakeholder community involvement and appropriate local knowledge in the design and implementation of resilient infrastructure projects (Bahadur et al., 2010). This distinction emphasizes that effective urban resilience strategies require the integration of physical interventions with institutional and participatory processes.

4.2. Adaptive capacity and climate change

The second literature review processes studies of adaptive capacity and climate change in an urban context. Fig. 6 is presented in a tree map chart, categorizing publications by WoS classification for the top 10 relevant categories, where Environmental Sciences and Environmental Studies are emphasized here. Most of the studies are published in the United States of America (32.3%), China (11.5%), and Australia (10.7%). Among the publication titles, the journals Sustainability (6.8%), Science of the Total Environment (3.2%), and Urban Climate (3.0%) are highlighted. This distribution illustrates both the disciplinary focus and the geographical concentration of research on adaptive capacity and climate change in urban contexts.

Fig. 7 presents the findings of a bibliometric analysis that focuses on the co-occurrence of terms associated with adaptive capacity and climate change. The analysis considered keywords that occurred at least 8 times, resulting in a total of 121 items. The results are presented through **five** thematic clusters, each identified by a specific colour. The identification of multiple thematic clusters reflects the conceptual diversity of research addressing adaptive capacity in relation to climate change.

The **red** cluster focuses on the adaptive capacity for vulnerability analysis (Lankao and Qin, 2011), including management, governance, and urban planning (Carter et al., 2015). It also addresses challenges and barriers in building resilient cities (Albers et al., 2015; Romero-Lankao, 2012). The **green** cluster refers to studies addressing adaptation to the impacts of climate change and exposure to rising temperatures (Oleson et al., 2015; Wilhelmi and Hayden, 2010), including urban heat islands (Huang et al., 2019) and public health effects (Harlan and Ruddell, 2011; Hess et al., 2012). The **blue** cluster covers publications that include the adaptation and vulnerability to floods, hazards, and disasters (Ajibade and McBean, 2014; Tapia et al., 2017), with analyses of vulnerability indexes (Abdrabo et al., 2023). The **yellow** cluster represents studies that assess the impact of climate change from a perspective of the development of indicators and frameworks for those impacts (Tyler and Moench, 2012), including strategies for adaptation (Klein and Juhola, 2014). The **purple** cluster addresses the impact of climate change and the adaptation process in urban areas (Aguiar et al., 2018;

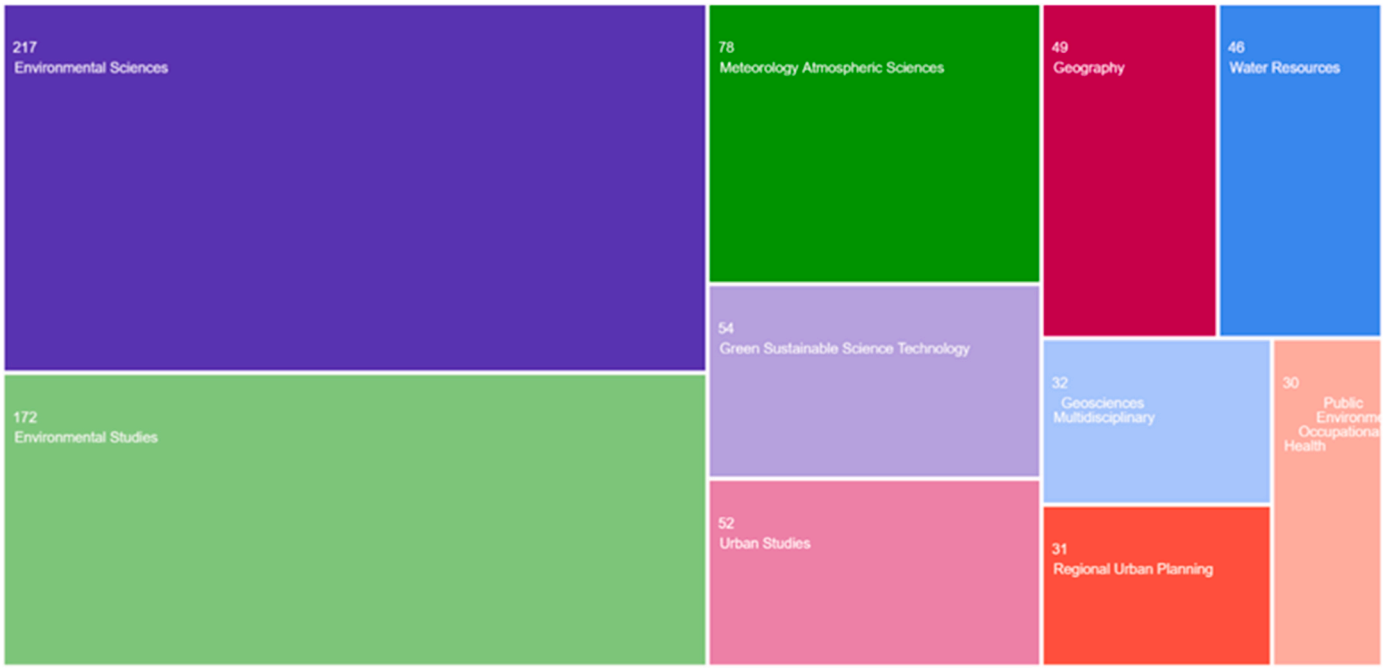

Fig. 6. Tree map chart of Web of Science categories of the publications on adaptive capacity and climate change. Larger rectangles correspond to higher proportions of publications within each category, illustrating the disciplinary distribution of research on adaptive capacity in urban contexts. (Source: authors' elaboration).

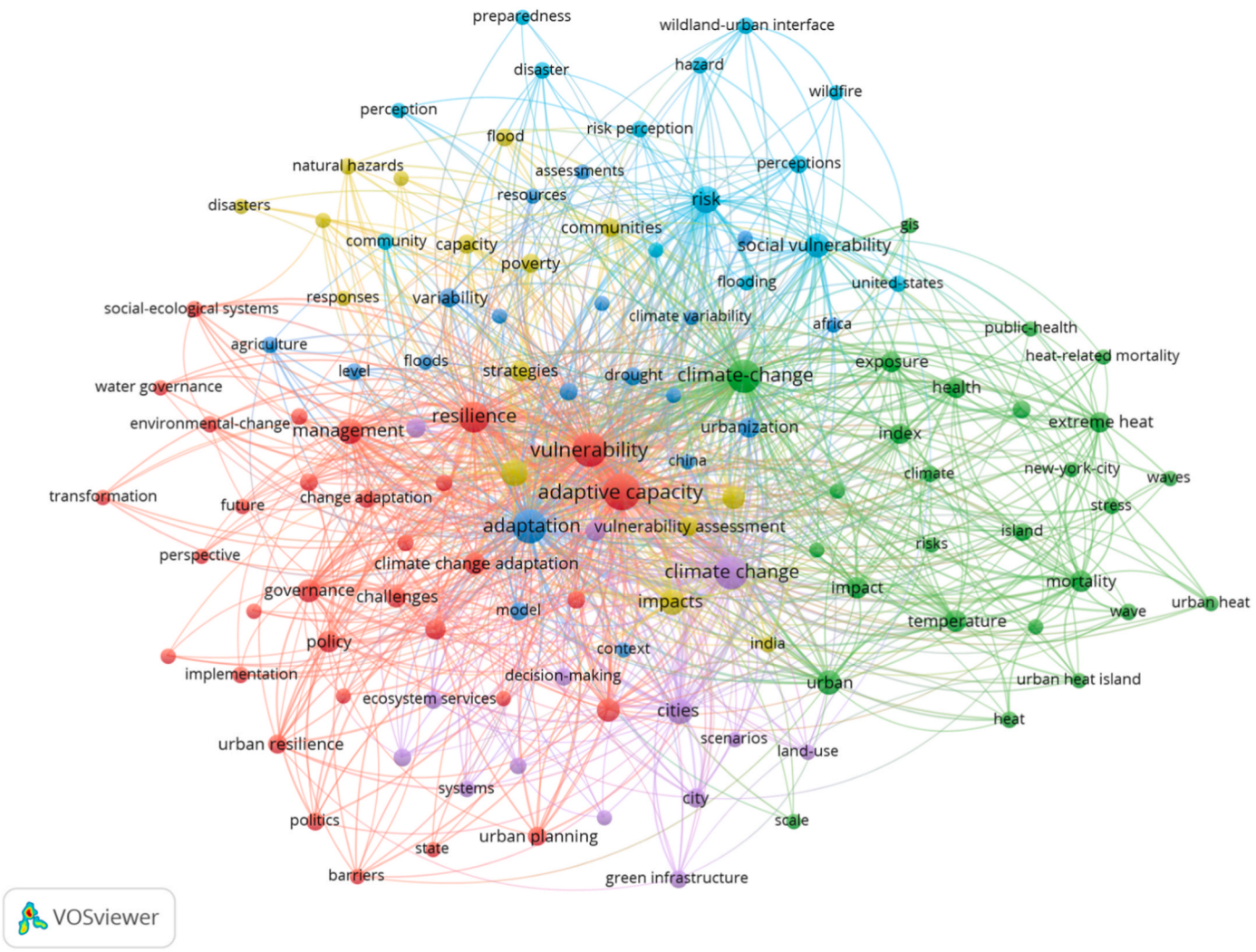

Fig. 7. Co-occurrence of terms related to adaptive capacity and climate change derived from VOSviewer analysis. The network visualization displays thematic clusters based on keyword co-occurrence, where node size indicates keyword frequency and colours represent different thematic groupings. (Source: authors' elaboration).

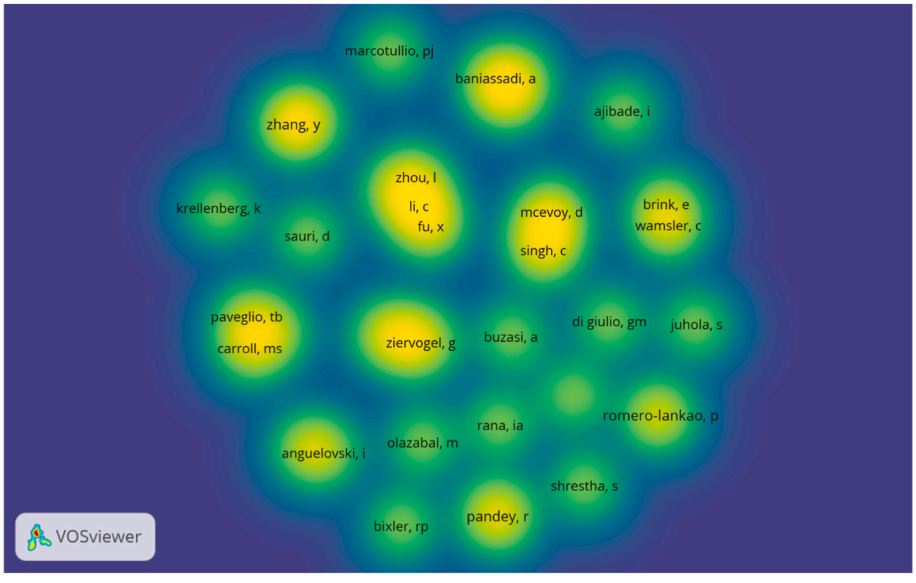

Fig. 8. – Co-authorship network of leading authors on adaptive capacity and climate change based on VOSviewer analysis. (Source: authors' elaboration).

Leal Filho et al., 2019), for example, with land use (Hung et al., 2016), green infrastructure (Roe and Mell, 2013), and ecosystem services analysis, including the decision-making perspective (Chu and Cannon, 2021; Pandey et al., 2018). The last cluster, in **light blue**, covers publications focusing on risk analysis and social vulnerability in the urbanization process. It involves studies related to the adaptation to climate change related to the risks (Eakin et al., 2010; Solecki et al., 2011) and vulnerability in climate and social perspectives (Kotzee and Reyers, 2016). Taken together, these clusters highlight the breadth of adaptive capacity research, encompassing governance, exposure to climate hazards, vulnerability assessment, indicator development, and decision-making processes.

The co-authorship network for studies on adaptive capacity and climate change shows a relatively dense structure, according to Fig. 8, in which some groups of core authors concentrate the main collaborative ties. Central nodes of collaboration such as Zhou, Li, and Fu; McEvoy and Singh; Brink and Wamsler; Paveglio and Carrol, are highlighted. Surrounding these hubs, authors including Baniassadi, Romero-Lankao, Ziervogel, Zhang, Pandey, and Anguelovski form specialized clusters that broaden the thematic and geographical scope of the literature on adaptive capacity.

Fig. 9 illustrates the international co-authorship network for studies on adaptive capacity and climate change. The network is organized into clusters that represent groups of countries with stronger collaboration patterns. A cluster centered around the USA, including Canada, the Netherlands, Australia, and the People's Republic of China, forming a core axis of joint publications. A second cluster encompasses England, India, Bangladesh, South Africa, and Sweden, indicating strong collaboration among European, Asian, and African institutions. The third cluster, which consists primarily of Japan, Spain, Italy, and France, emphasizes a collaborative effort between European and Asian nations. Led by Germany and including Brazil and Chile, the last cluster highlights a developing partnership that connects European and Latin American research on adaptive capacity in urban settings.

As cities grapple with issues such as climate change, rapid urbanization, and socio-economic disparities, the concept of adaptive capacity has emerged as a crucial aspect of urban resilience. As explained by Araya-Muñoz et al. (2016), Carter et al. (2015), and Acosta et al. (2013), adaptive capacity is a concept that is relative in nature, with its impacts varying across different locations and its response differing in various scenarios. Adaptive capacity can be elucidated by considering a set of influencing factors and processes that influence the ability of a region, territory, or community to adapt (Masud et al., 2017; Henríquez et al., 2006) and a composite state that can be elucidated by several influential circumstances and activities. Leichenko (2011) and Smit & Pilifosova (Smit and Wandel, 2006) state that the Third Assessment Report of the Intergovernmental Panel on Climate Change was the first to establish a list of factors that determine climate change. The elements encompass economic resources, technology, information and skills, infrastructure, institutions, and equity. Since then, other studies have been done with the aim of expanding and improving this list. Scientific research has also focused on different facets such as social, human, and political capital, health, social status, perception of society, and mechanisms of dissemination (Eakin et al., 2010; Armitage and Johnson, 2006; Tol and Yohe, 2007). Thus, the measurement and evaluation of adaptive capacity in urban areas pose a difficult challenge due to its multifaceted nature as scientists have created multiple frameworks and metrics to assess the ability to adapt at different levels (Smit and Wandel, 2006; Engle, 2011). These frameworks frequently incorporate both quantitative and qualitative data to depict the intricate interplay among social, economic, and environmental issues. Nevertheless, there is still a requirement for standardized procedures and instruments to enable uniform measurement and comparison across diverse urban environments (Leal Filho et al., 2019; Wamsler et al., 2013). This diversity of approaches underscores the ongoing challenge of translating adaptive capacity concepts into comparable and operational measures across different urban contexts.

4.3. Case studies

As urban areas worldwide grapple with the escalating challenges posed by climate change, understanding and showcasing effective strategies for urban resilience and adaptive capacity become paramount. In this section, case examples that address practical approaches adopted by different cities to fortify their resilience in the face of climate-related adversities are presented and discussed. Each case serves as a microcosm, revealing how urban centres have successfully navigated the complexities of climate change impacts. By examining these real-world instances, is intended to draw insights and lessons that contribute to a nuanced understanding of best practices in enhancing urban resilience

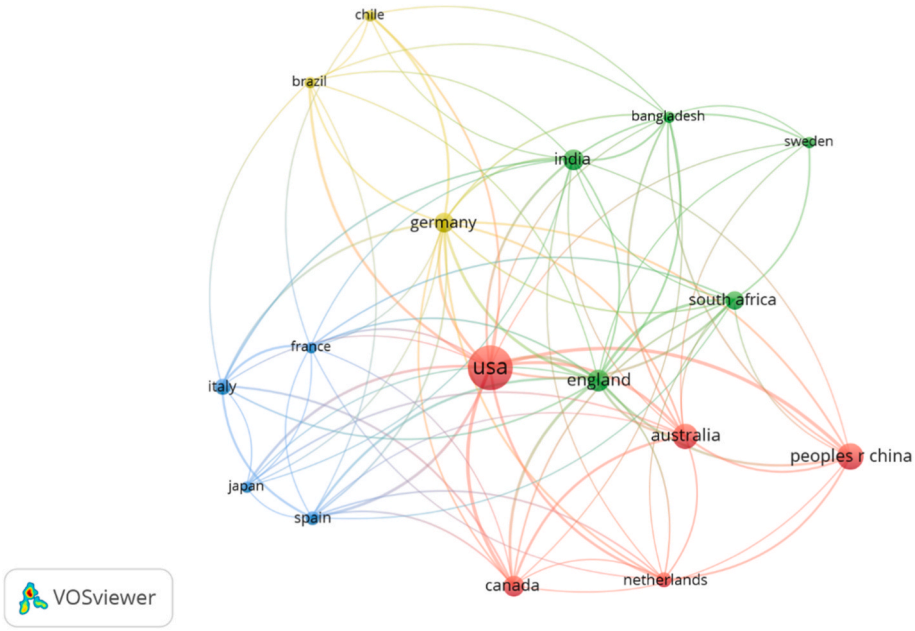

Fig. 9. – Co-authorship network of leading countries on adaptive capacity and climate change based on VOSviewer analysis. (Source: authors' elaboration).

and adaptive capacity. The case study entails a set of cities, which are displayed in Fig. 10. The case studies are drawn from diverse geographical and socio-economic contexts, allowing for the illustration of multiple pathways through which cities address climate change-related challenges.

The details from each city are provided in Table 1, which showcase the intricate interplay of socio-economic, environmental, and governance factors, evident, providing valuable insights for urban planners, policymakers, and researchers seeking actionable strategies in the context of climate change resilience. Table 1 summarises key characteristics and adaptation measures across the selected cities, providing a structured basis for cross-case interpretation in subsequent sections.

There is a substantial volume of research that examines case studies demonstrating how cities have undertaken efforts to enhance their adaptation ability to climate change. Metropolitan areas such as China (Hu and He, 2018), Singapore (He et al., 2022; Islam and An, 2014; Bhullar, 2013), and Rotterdam (Groot et al., 2015) have successfully embraced forward-thinking policies and practices to improve their ability to withstand and adapt to climate change challenges. These cities have implemented effective strategies such as sustainable urban planning, investments in green infrastructure, active community involvement, and platforms for exchanging knowledge. These case studies provide useful insights and exemplary methods that might serve as a reference for other metropolitan regions in their endeavours to develop adaptive capability.

Liu et al. (2022) evaluated the changes in urban resilience within the Beijing-Tianjin-Hebei (BTH) region for a specific period. Econometric models were employed to explore the contributions of climate factors, including temperature, precipitation, and wind speed, to urban resilience. The study reveals significant spatial heterogeneity in urban resilience across the BTH region, with Beijing and Tianjin exhibiting better and more stable resilience than Hebei Province. Climate change factors exhibit both static and dynamic impacts on urban resilience, with temperature and precipitation positively influencing resilience while wind speed has a negative effect. Over the observation period, the BTH region's overall urban resilience increases, narrowing the differences between cities. Beijing consistently maintains higher resilience levels, while Hebei Province and Tianjin City demonstrate substantial growth. The research offers critical policy recommendations for improving urban resilience in the BTH region, emphasizing the importance of coordinated efforts between urban authorities, communities, civil society, and donors.

Globally, the fastest-growing urban areas are often smaller settlements, facing significant limitations in adaptive capacity yet increasingly tasked with bolstering local urban resilience. Paterson et al. (2017) study contrasts data from three smaller coastal cities, Broward County, Florida, USA; Selsey, West Sussex, UK; Santos, Sao Paulo State, Brazil, alongside their broader regional governance systems. Examining the impact of scale and sector on city adaptive capacity, the Adaptive Capacity Index approach was used, rooted in structuration theory, offering an alternative to the conventional social-ecological systems framework for adaptation analysis. The structuration theory highlights the interplay of agency, structure, and institutional influence on information flow, shaping adaptive capacity and outcomes. The examined cases illustrate the replication of disparities in adaptive capacity across different scales. These inequalities are perpetuated by the actions of both local and non-local actors, becoming institutionalized in administrative responsibilities and standardized behaviours at both local and non-local levels. Inequality has been primarily driven by actors outside the immediate local context. The findings unveil greater disparities in adaptive capacity across scales than among government, private, and civil society sectors within each study area, underscoring the importance of scale in adaptation research and showcasing structuration theory's value in comprehending the social dynamics influencing adaptive capacity. Policy implications include a call for redistributing decision-making power across scales and implementing compensatory mechanisms, especially for smaller-scale actors who bear increasing costs for resilience planning in cities.

Twinomuhangi et al. (2021) investigated the impact of climate change on the urban poor in Kampala, Uganda, emphasizing heightened vulnerability due to limited adaptive capacity. Data from respondents residing in informal settlements were collected, along with focus group discussions and informant interviews. The results indicate that 96.6% of households are aware of climate change, primarily perceiving it as rising temperatures and reduced rainfall. Floods (53.4%) and droughts (27%) are the most prevalent climate risks, with flooding perceived as more frequent and severe. Vulnerability varies based on socio-economic factors, including income, education, marital status, occupation, housing conditions, and duration of stay. Individuals with lower wealth and education, engaged in informal businesses, and lacking secure housing

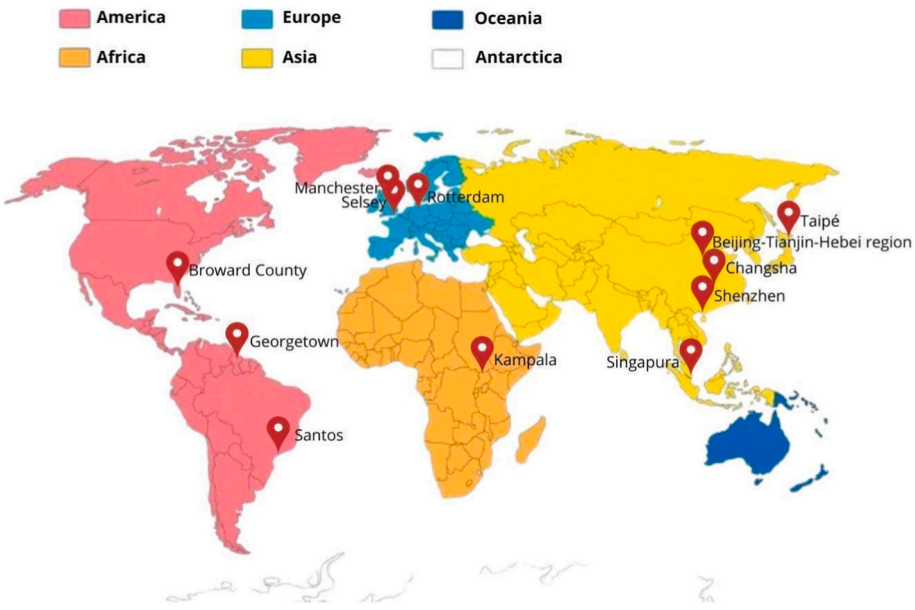

Fig. 10. Schematic map showing the geographical distribution of the sampled cities included in the case study analysis. The map illustrates the spatial diversity of the selected cities across different regions and socio-economic contexts. (Source: authors' elaboration).

Table 1
Examples of urban resilience and adaptive capacity towards climate change.

City, case study, and country	Approach	Reference
Beijing-Tianjin-Hebei region, change in urban resilience, **China**	Utilizing urban resilience evaluation indicators as a quantifiable and data-driven approach to characterize urban resilience in the context of climate change.	Liu et al., 2022
Broward County; Selsey; and Santos, the influence of scale and sector on adaptive capacity, **United States, United Kingdom, and Brazil**, respectively.	Adaptive Capacity Index (ACI) methodology, grounded in structuration theory, offers an alternative perspective to the conventional analysis framework of adaptation found in social-ecological systems.	Paterson et al., 2017
Changsha, adaptation plan to climate change, **China**	Development of an evaluation index system of urban adaptive capacity (UAC) based on the driver–pressure–state–impact–response model (DPSIR), and adopted grey relational analysis (GRA), with suggestions for adaptive capacity building and sustainable development in other urban areas.	Hu and He, 2018
Georgetown, adaptation plan, **Guyana**	The study analyses the susceptibility, climate change adaptation strategies, and adaptation policies. It also suggests using transformative approaches to support their investments in low-carbon and climate-resilient infrastructure.	Leal Filho et al., 2019
Kampala, perception and vulnerability to climate change, **Uganda**	Questionnaire evaluation of climate change perception and Vulnerability	Twinomuhangi et al., 2021
Manchester, United Kingdom	The development of a framework and associated activities to analyze and understand climate risk in the city. In addition, drafting a resilience and adaptation plan for the city.	MacKillop, 2012; Manchester Climate Ready, 2024
Rotterdam, Integration in urban climate adaptation-integration between scientific disciplines and integration between scientific and stakeholder knowledge, **The Netherlands**	The use of several integration methods to improve scientific discipline and stakeholder knowledge integration.	Groot et al., 2015
Shenzhen City, a resilience strategy is proposed for the city to assist it in dealing with the possibility of flooding in the future, **China**.	This report proposes a resilience strategy for the city to prepare for future flooding. A sophisticated water management system and sponge city development are part of this method. Developing a flood insurance scheme is also necessary to shift risk. To some extent, this matters.	Shao et al., 2021
Singapore city, the stakeholders urban resilience and adaptation plan, **Singapore**	Singapore's strategy for the report emphasizes establishing a resilience framework that places significant emphasis on building research and development partnerships with both local and international research institutes.	Islam and An, 2014
Taipei, citizen engagement to climate change, **Taiwan**	Semi-structured interview methodology to establish a framework for assessing respondents' perceptions and knowledge regarding flood mitigation.	Ling et al., 2022

tenure are more susceptible to flooding than drought. Urban poor communities face heightened sensitivity due to ecosystem degradation, and limited access to infrastructure, utilities, and services. To address vulnerabilities, a comprehensive approach is recommended, involving collaboration between urban authorities, communities, civil society, and donors. It includes enhancing housing and livelihoods in slum settlements, co-producing climate information services, raising climate change awareness, restoring critical ecosystems, and fostering inclusive adaptation planning for resilient urban poor communities.

Singapore's urban resilience and adaptation plan refers to the case report of Islam & An (Islam and An, 2014). The study emphasizes the establishment of a resilience framework that places significant emphasis on forming research and development partnerships with both local and international research institutes. The primary objective of these partnerships is to enhance the understanding of the effects of climate change. The objective is for the research findings to inform and direct the development of its resilience framework. What is missing is the establishment of a community resilience framework inside the broader framework. Nevertheless, the report clearly indicates that the government perceives itself as actively involved with community organizations, non-governmental organizations (NGOs), and enthusiastic individuals through public consultations in order to collaboratively shape the future. Singapore is believed to have a dynamic grassroots movement focused on climate change. However, the report also mentioned that the policy makers are doubtful about the accuracy of this assertion and further unbiased research is necessary to confirm the truthfulness of these statements.

According to MacKillop (2012), urban planning is also vital in Manchester, UK, to achieve a climate city concept. From the efforts to control smoke and clear slums in the 19th century to today's race to be at the forefront of ‘green’ and ‘sustainable’ cities, climate has been a central actor in Manchester's history. The city has taken to climatic urbanism, and especially the discourse of the ‘green city’, as a way of enticing footloose capital to lay anchor in the city. Furthermore, it is possible to highlight the analysis and understanding of climate risk in the city, in the context of the development of a framework and associated activities. Furthermore, the drafting of a resilience and adaptation plan for the city is emphasized (Manchester Climate Ready, 2024).

Climate change poses a critical and urgent threat, necessitating effective flood risk communication to raise awareness and foster resilience within vulnerable communities. Ling et al. (2022) investigated local engagement practices in flood risk communication in a Taipei community, employing semi-structured interviews to explore residents' communication and resilience strategies under climate change. The findings reveal the community's role in shaping risk information dissemination through loosely formed networks and social media. Understanding local socio-environmental contexts emerges as pivotal for mutual communication and public engagement. Urban resilience, requiring collaborative efforts, benefits from interactive visual tools for effective communication and adaptive capacity. The research highlights estuarine residents' flood adaptive practices, emphasizing the influence of perceptions and knowledge on risk communication. Residents' prolonged residence in the area enhances their understanding and inclination to relay flood risk information. The study advocates for decentralized risk communication strategies, emphasizing the active involvement of residents throughout different flood phases. Social media, forming informal citizen networks, emerges as a swift and

effective tool for risk communication, influencing localized adaptive actions. Recommendations include incorporating communication into policy development, encouraging citizen engagement, and leveraging local software capacity for enhanced urban resilience, underscoring the profound impact of expectations on recovery strategies and the need for inclusive decision-making processes in building resilience against flooding risks.

Leal Filho et al. (Leal Filho et al., 2019) offered an analysis of the level of vulnerability of Georgetown, the ways in which it can deal with the effects of climate change and the policies that are being put into place to assist with adaptation. Guyana is a lower middle-income country, but its capital city, Georgetown, is prioritized in the national government's intervention to enhance its adaptation. Access to health care, repair of the road network, and efficient energy consumption are also boosting the city's resilience. The authors also advise the employment of transformative approaches to support their efforts towards investments in low-carbon and climate-resilient infrastructure. This would result in the maximization of investments in urban areas and the attempt to address the poverty concerns associated with those places. National-level Inter-agency collaboration to develop early warning systems (EWS) for flooding, public enlightening through workshops, the Green State Development Strategy Framework, and the Climate Change Adaptation Policy and Implementation Plan are examples of interventions in Georgetown to increase its adaptive capacity.

In the study from Groot et al. (2015), lessons learned thus far on science-policy interactions supporting the adaptation to climate change in the Bergpolder Zuid district, in the city of Rotterdam, The Netherlands. In this study, concerns regarding integration were divided into two categories: the integration within the scientific community, which includes disciplines, methodologies, models, and data; and the integration between the scientific community and the society of local stakeholders, which involves a synthesis of scientific and practical knowledge, linking different sectors, governance structures, and organizations. The example of Rotterdam includes a discussion on the utilization of numerous means of integration to strengthen integration between scientific disciplines as well as integration between scientific knowledge and the knowledge of stakeholders. For example, the integration amongst disciplines has been achieved by defining a consistent set of research objectives, developing a common language and understanding, use of the Effect-Vulnerability-Adaptation-Implementation Model, and developing knowledge products, such as climate effect and vulnerability maps. Regarding the integration between scientific and stakeholder knowledge, it was verified that capturing stakeholder requirements, co-designing the research agenda, and linking research to application have contributed to reaching the objectives.

The analysis of the twelve case studies provides significant insights into the challenges and responses related to climate change in urban settings. Collectively, these case studies contribute to a nuanced understanding of the intricate dynamics between climate change, urban resilience, and adaptation strategies, offering valuable insights for global policymakers and practitioners. Rather than providing a direct comparison, these case studies are intended to illustrate the diversity of urban adaptation experiences, which are synthesised and interpreted in the following section.

To facilitate a structured comparison between dominant research themes identified through the bibliometric analyses and the practices observed across the case studies, a synthesis Table 2 is introduced below. The cities listed in Table 2 are not intended to represent exhaustive or comparative cases, nor to imply a one-to-one correspondence with the cited references. Rather, they serve as illustrative examples drawn from the case studies reviewed in this section, selected to demonstrate how dominant thematic domains identified through the bibliometric analysis manifest across diverse geographic, socio-economic, and governance contexts.

Building on the comparative synthesis presented in Table 2, this section integrates the bibliometric trends with empirical evidence across the twelve cities. Rather than revisiting individual cases, the discussion focuses on cross-cutting patterns, common limitations, and structural divergences between conceptual adaptation frameworks and their operationalisation in urban contexts. This approach enables an assessment of how dominant academic narratives translate into practice across diverse institutional and geographical settings.

4.4. Synthesising the bibliometric trends and city-level adaptation practices

Sections 4.1 and 4.2 presented the results of the bibliometric analyses on urban resilience and adaptive capacity to climate change, while Section 4.3 illustrated how these concepts are addressed through city-level adaptation practices. A synthesis of these components is required to examine how dominant research themes identified in the literature are reflected in practical urban responses, as suggested by previous

Table 2
Alignment between dominant bibliometric themes and adaptation practices observed in selected urban case studies.

Dominant bibliometric theme	Key aspects highlighted in the literature	Manifestation in case studies	Example cities	References
Governance and institutional capacity	Role of governance structures, policy integration, and leadership in shaping urban resilience and adaptive capacity	Development of coordinated resilience and adaptation plans, multi-level governance arrangements, and institutional collaboration	Singapore, Manchester, Rotterdam	Shao et al., 2021; Carter et al., 2015; Groot et al., 2015
Urban heat and climate exposure	Impacts of rising temperatures, urban heat islands, and exposure-related risks	Implementation of heat adaptation measures, urban design strategies, and integration of climate considerations into planning	Singapore, Beijing	Leichenko, 2011; Oleson et al., 2015; Huang et al., 2019
Infrastructure and service resilience	Importance of robust and flexible infrastructure systems for climate adaptation	Investments in resilient infrastructure, flood protection, and energy-efficient systems	Beijing–Tianjin–Hebei region, Rotterdam	Liu et al., 2022; Groot et al., 2015
Vulnerability and social equity	Unequal distribution of climate risks and adaptive capacity across populations	Targeted adaptation strategies addressing vulnerable groups, informal settlements, and social inclusion	Kampala, Georgetown	Leal Filho et al., 2019; Twinomuhangi et al., 2021
Risk communication and participation	Role of communication, local knowledge, and stakeholder engagement in resilience-building	Community-based risk communication, use of social networks and participatory approaches	Taipei	Ling et al., 2022
Ecosystem-based and nature-based approaches	Integration of ecosystems and green infrastructure into urban resilience strategies	Use of green infrastructure, ecosystem services, and ecological resilience measures	Rotterdam, Singapore	Bush and Doyon, 2019; Ribeiro and Pena Jardim Gonçalves, 2019; Roe and Mell, 2013
Scale and multi-level adaptation	Influence of scale and cross-level interactions on adaptive capacity	Challenges faced by smaller cities and the role of actors beyond the local scale	Broward County, Selsey, Santos	Paterson et al., 2017

review studies on urban resilience and adaptation (Economist Impact, 2023; Meerow et al., 2016; Leal Filho et al., 2019).

Rather than reiterating individual bibliometric findings, the synthesis focuses on how the most prominent thematic domains identified in the literature are reflected in, or diverge from, observed adaptation practices across cities. These domains are consistently visible across the co-occurrence networks, indicating their central role in shaping contemporary research on climate change, urban resilience, and adaptive capacity. The synthesis presented in Table 2 highlights areas of convergence between these dominant research themes and the adaptation practices observed in the case studies. Governance and institutional capacity, for example, emerge as a prominent focus in both the literature and the case evidence, where coordinated planning, policy integration, and multi-level collaboration are repeatedly identified as key drivers of urban resilience and adaptive capacity (Shao et al., 2021; Carter et al., 2015; Groot et al., 2015; MacKillop, 2012; Manchester Climate Ready, 2024). Similarly, themes related to climate exposure, urban heat, and infrastructure resilience are well represented across both bibliometric clusters and case studies, particularly through investments in climate-responsive urban planning, flood protection measures, and resilient infrastructure systems (Leichenko, 2011; Oleson et al., 2015; Wilhelmi and Hayden, 2010; Huang et al., 2019; Ajibade and McBean, 2014; Tapia et al., 2017; Abdrabo et al., 2023; Liu et al., 2022). These results indicate a strong alignment between research priorities and practical responses in cities facing acute climate-related risks. Other thematic domains reveal more uneven alignment between research and practice. Although social vulnerability and equity feature prominently in the literature (Elmqvist et al., 2019; Fratini et al., 2012; McClymont et al., 2020; Meerow and Newell, 2019; Rosenzweig et al., 2018; Ziervogel et al., 2017; Simon and Leck, 2015), the case studies demonstrate that targeted actions addressing vulnerable populations are often context-specific and unevenly implemented, particularly in cities in the global South where limited resources and institutional constraints shape adaptive capacity (Leal Filho et al., 2019; Cobbinah, 2021; Twinomuhangi et al., 2021). These persistent gaps are not primarily the result of conceptual neglect, but rather reflect structural and institutional constraints, including uneven governance capacity, political-economic dynamics, and the risk of maladaptation, that limit the translation of well-established research insights on equity and participation into sustained urban practice, particularly in resource-constrained contexts.

Risk communication and community participation represent another area of partial convergence. While these issues are well documented in the literature on urban adaptation and resilience (McClymont et al., 2020; Meerow and Newell, 2019; Bahadur et al., 2010), their practical implementation is more visible in a limited number of cases, such as those focusing on flood risk communication and community-based adaptation (Ling et al., 2022). This suggests that participatory approaches remain unevenly embedded within broader urban adaptation strategies.

While ecosystem-based and nature-based approaches are well established in the literature, the case studies reveal substantial variation in how these strategies are implemented and integrated into broader urban adaptation frameworks. In some cities, green infrastructure and ecosystem services are embedded within long-term resilience strategies, whereas in others they remain fragmented or project-based interventions, often dependent on governance capacity and planning frameworks (Bush and Doyon, 2019; Ribeiro and Pena Jardim Gonçalves, 2019; Wamsler et al., 2013; Roe and Mell, 2013).

This synthesis demonstrates that bibliometric trends provide a useful overview of dominant research priorities, but they do not fully capture the contextual, institutional, and socio-economic factors that shape how urban resilience and adaptive capacity are operationalised at the city level (Meerow et al., 2016; Leal Filho et al., 2019; Araya-Muñoz et al., 2016). The comparison between literature trends and case evidence underscores the importance of integrating quantitative mapping approaches with qualitative insights from city experiences. By explicitly linking research clusters with city-level adaptation practices, this section advances a more integrated understanding of climate change adaptation in urban settings, identifying both areas of strong alignment and domains where further empirical research and policy attention are required (Economist Impact, 2023; Leal Filho et al., 2019).

5. Conclusions

This study examined how climate change is addressed within urban contexts by integrating bibliometric mapping of the scientific literature with a qualitative synthesis of published city-level case studies. By combining these two approaches, the paper moved beyond descriptive reviews to explore how dominant research themes on urban resilience and adaptive capacity are reflected in practical adaptation efforts implemented by cities. This integrative perspective represents the main contribution of the study, addressing a gap in the literature where bibliometric analyses and empirical case evidence are often treated separately. In particular, the discussion explicitly considers climate justice and maladaptation risks as explanatory factors for why social equity and participation remain unevenly operationalised across reported city practices.

The synthesis of results highlights several key insights. Themes related to governance, institutional capacity, infrastructure resilience, and climate exposure emerge prominently in both the literature and the case studies, suggesting a relatively strong alignment between research priorities and practical implementation in these domains. In contrast, issues of social vulnerability, equity, and participatory adaptation are unevenly translated into practice, particularly in cities facing resource constraints or complex socio-economic challenges. Ecosystem-based and nature-based approaches, while increasingly visible in the literature, show considerable variability in their implementation, ranging from integrated long-term strategies to more fragmented, project-based interventions. These findings underscore the importance of context in shaping urban adaptation outcomes. While bibliometric trends provide valuable insights into dominant research agendas, they do not fully capture the institutional, socio-economic, and governance conditions that influence how resilience and adaptive capacity are operationalised at the city level. The case studies demonstrate that effective urban adaptation depends not only on the availability of technical solutions, such as green infrastructure or resilient buildings, but also on governance arrangements, cross-sectoral coordination, and the engagement of local communities. Globally, the analysis suggests that the persistence of equity and participation gaps in urban adaptation is less a failure of knowledge production than a manifestation of deeper institutional, political-economic, and capacity constraints that shape how resilience and adaptive capacity are operationalised at the city level.

From a policy and research perspective, the results suggest that urban resilience strategies should be tailored to local conditions rather than derived solely from widely cited thematic priorities. Cities with limited resources or high social vulnerability may require targeted approaches that emphasise social equity, institutional strengthening, and inclusive decision-making alongside technical interventions. At the same time, greater attention is needed to ensure that lessons from successful adaptation initiatives are transferable across different urban contexts without oversimplifying local complexities.

This study has several limitations. The bibliometric analysis was restricted to publications focusing on climate change in urban settings and did not include rural or peri-urban contexts. This study acknowledges that this strategy may under-capture relevant interdisciplinary scholarship that frames similar phenomena using alternative terms, e.g., disaster risk reduction/management, climate risk governance, urban transformation, or sustainability transitions. To address this concern transparently, the study reports this limitation explicitly and clarifies that the bibliometric component is complemented by the city-level synthesis, which draws on empirically grounded studies spanning multiple sectors and methods. In addition, the synthesis of twelve city case

studies, while diverse, does not provide a comprehensive representation of all urban adaptation experiences worldwide. This study further acknowledges potential selection bias towards cities with greater English-language scholarly coverage and data availability. Despite these limitations, the paper provides a welcome addition to the literature since it provides an overview of current patterns observed in the selected literature and case studies, which serve the purpose of illustrating global trends.

This paper makes important contributions to urban resilience theory by linking gaps in knowledge and integrating cross-city evidence to help transition from isolated case studies to a unified framework. Its implications of this paper to theory and practice are as follows: for practice, it offers an invaluable diagnostic instrument, which allows policymakers to benchmark adaptive capacities and prioritise interventions based on synthesised global learning. For theory, by combining theoretical concepts with applicable pathways, the integrated bibliometric and synthesis approach demonstrates that effective resilience is context-specific and must be informed by transdisciplinary, cross-scale learning. The paper also shows that theory and on-the-ground adaptation need to become co-evolving via continuous evidence integration.

Future research may focus on expanding empirical evidence from under-represented regions, particularly in the global South, and include longitudinal studies that examine how urban resilience and adaptive capacity evolve over time. Further work is also needed to strengthen the connection between quantitative mapping approaches and in-depth qualitative analyses, enabling a more nuanced understanding of how climate change adaptation strategies are designed, implemented, and sustained in cities. By advancing such integrative approaches, research can better support cities in developing resilient, inclusive, and sustainable responses to the challenges posed by climate change.

CRediT authorship contribution statement

Walter Leal Filho: Writing – review & editing, Writing – original draft, Supervision, Conceptualization. **Roberto Schoproni Bichueti:** Writing – review & editing, Writing – original draft, Visualization, Project administration, Investigation. **Maria Alzira Pimenta Dinis:** Writing – review & editing, Writing – original draft, Investigation. **Halima Begum:** Writing – original draft, Investigation. **Paul O'Hare:** Writing – original draft, Investigation. **Krishna Malakar:** Writing – original draft, Investigation. **Jean-Luc Kouassi:** Writing – original draft, Investigation. **Jean Homian Danumah:** Writing – original draft, Investigation.

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Declaration of competing interest

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

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Data availability

Data will be made available on request.

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