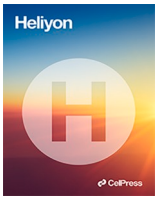
Heliyon 10 (2024) e37001

Contents lists available at ScienceDirect

Heliyon

journal homepage: www.cell.com/heliyon



Research article

Combating urban heat: Systematic review of urban resilience and adaptation strategies

Qingchen Fu [a], Zhouhua Zheng [a], Md Nazirul Islam Sarker [b,*], Yang Lv [c]

[a] School of Management, Guizhou University of Commerce, Guiyang, China
[b] Miyan Research Institute, International University of Business Agriculture and Technology, Dhaka, 1230, Bangladesh
[c] College of Teachers, Chengdu University, Chengdu, 610106, China

ARTICLE INFO

Keywords:
Climate adaptation
Heatwave mitigation
Land use
Policy innovation
Urban vulnerability
Community resilience

ABSTRACT

Urban areas are currently facing the increasingly pressing issue of urban heat worldwide, which is being worsened by climate change and rising urbanization. As a result, there is a growing need for new approaches to enhance urban resilience and adapt to these challenges. The escalating occurrence and severity of urban heat events provide notable hazards, particularly to susceptible groups, necessitating proactive efforts to alleviate detrimental consequences. Therefore, this research addresses the inquiry, "What strategic approaches can be effectively employed to mitigate vulnerability and strengthen urban resilience in response to urban heat?" Thus, this study ascertains and examines approaches to enhance urban resilience, mitigate susceptibility, and implement adaptation strategies to combat urban heat. Utilizing the content analysis method, a comprehensive assortment of documents encompassing academic publications, policy documents, and reports was subjected to a systematic analysis employing the MAXQDA software. Databases searched included Web of Science, Scopus, and Google Scholar, and a total of 72 studies were included in the final analysis. The research reveals a wide range of novel ideas and practical measures that can be implemented to improve urban resilience and mitigate vulnerability to urban heat. Urban greening strategies, heatwave early warning sys-tems, and community involvement projects have exhibited differing effectiveness, application, and adaptation levels in many urban landscapes and socio-economic circumstances. Additionally, this research emphasizes the value of using multidimensional, context-specific strategies to address the unique challenges and needs of diverse urban regions and marginalized communities. Furthermore, structural changes, legislative reforms, and community-based solutions may be necessary to manage complex issues posed by urban heat. Therefore, effectively implementing adaptation strategies is vital to effectively combating challenges caused by urban heat in urban areas.

1. Introduction

Urban areas, which are characterized by high population density and highly complex infrastructure networks, are more vulnerable to climate change as a result of an even more pronounced urban heat island (UHI) effect. The UHI exacerbates the effects of changes in climatic conditions in urban settings [1]. An increase in temperature in urban areas as opposed to the surrounding rural districts is a

* Corresponding author.
E-mail addresses: qcchenfu@163.com (Q. Fu), gbmtning@icloud.com (Z. Zheng), sarker.usm@yahoo.com (M.N.I. Sarker), lvyang@cdu.edu.cn (Y. Lv).

https://doi.org/10.1016/j.heliyon.2024.e37001
Received 17 March 2024; Received in revised form 16 August 2024; Accepted 26 August 2024
Available online 27 August 2024

qualitative factor characteristic of this anomaly. To explain the phenomenon occurring in cities, it is necessary to point to disparities in the energy balance of the areas distinguished by their type of development, especially in terms of the absorption and retention of solar energy [2]. In these terms, cities differ somewhat from rural areas, which feature a larger area under vegetation and a smaller area of impermeable surfaces in which the retention of energy is greater [2]. However, UHI is not only an effect of the increasing urbanization worldwide. A system of consolidation and multifaceted factors directly influencing this phenomenon resulted in an extension of the heat that occurred in cities located insignificantly in various climatic zones or under different socio-economic conditions, which has become the monotonous signature of increasing urban temperatures in recent years. Therefore, the UHI phenomenon offers a good monitoring tool for spreading urban changes in the world today, imposing the need for individual strategies and tactics that must be thoroughly developed [3].

Several systematic reviews have previously explored the themes of urban resilience and adaptation to urban heat [4–7]. For example, reviews by Bowler et al. [8] and Roy et al. [9] focused on technological interventions and policy frameworks for mitigating urban heat. These reviews have highlighted the importance of integrated approaches but have not fully addressed the multidimensional strategies involving urban resilience, vulnerability, community engagement, policy integration, and adaptations in a comprehensive manner. This review aims to fill this gap by providing a holistic analysis that incorporates these dimensions, thus adding to the existing knowledge by offering a more complete understanding of urban resilience strategies.

Urban resilience is the ability of an urban structure to operate despite stress and shock and to display transformative reactions that support sustainable urban growth [10]. Urban heat, due to climatic shifts, is apparent in higher temperatures found in urban environments in comparison with their rural counterparts [11]. Causes include changes in land usage and plant loss due to human activities and heat generated from human activities [12]. Vulnerability in this context refers to the susceptibility of cities and their inhabitants to adverse effects wrought by urban heat [13]. However, adaptation involves applying various strategies and practices to mitigate their impacts and increase urban resilience overall. Resilience in urban areas has become more relevant with rapid urbanization and climate changes that alter urban climates and growing dangers associated with urban heat [14]. Urban regions undergoing rapid urbanization are seeing immediate land use and cover transformation, increasing the UHI phenomenon and ultimately impacting climate and air quality [12]. Climate changes intensify extreme weather events like floods, heatwaves, and droughts, increasing global urban risk. This is an especially significant concern in metropolitan cities worldwide. Urbanization and climate change pose unique and substantial problems to urban areas, necessitating creative strategies for resilience and adaptation in cities [15]. Such measures are crucial for mitigating negative impacts of urban heat as well as improving sustainability and high-quality living in these locations. Recent studies, such as those by García-Blanco et al. [16] and De Fino et al. [17], have emphasized the need for context-specific strategies that address both environmental and socio-economic aspects of urban heat. This review aims to build on these works by systematically analyzing a wider range of strategies and their effectiveness across different urban contexts, thereby providing a more comprehensive framework for policymakers and practitioners.

Urban heat reduction can bring many advantages beyond environmental concerns, including economic, social, and health considerations [18]. Heat stress can have a significant impact on humans through heat stroke, exhaustion, and it may also be intensified if they have asthma or similar breathing problems as well as heart-related problems. According to the World Health Organization, heat waves have led to an increase in mortality rates, particularly among vulnerable populations such as the elderly and those with pre-existing health conditions [19]. There are many implications for urban heat on city people, which are reflected by not being able to get to sleep at night, reduced comfort, productivity as well as elevated energy bills–primarily from air cooling devices– and associated greenhouse CO2. Implications to infrastructure include accelerated textile degradation, which increases the need for increased maintenance and repair through dairy low temperatures and ultimately impacts the health of the case. The cost that these impure causes surrounds all people residing in urban areas – not just the flat plan itself [20]. Economically, a study by the International Labour Organization estimated that productivity losses due to heat stress could result in a global economic loss of $2.4 trillion by 2030 [21]. These statistics emphasize the urgent need for effective urban heat mitigation strategies to alleviate both social and economic burdens.

To cope with urban heat, cities need to devise a plan for resilience and adaptation. Cities can take a practical approach in creating a resilient and sustainable urban environment by studying the effects of urban environment on quality of life and standard of living and increasing it, increasing the environmental sustainability, reduce the financial strain of urban environments by reducing urban heat, and create and implement urban heat plan [22]. Urban heat problems encompass more than the need to minimize their adverse impacts; they also present opportunities to transform urban environments and innovate. Tackling urban heat could spur advances in urban design, planning, and governance that create resilient cities that offer heat resilience, sustainability, inclusion, and energy [23,24]. Implementing adaptive and resilient mechanisms into urban development projects may change how people live in cities while helping build more environmentally friendly places.

Recent academic research has focused on understanding and exploring the complex factors relating to urban resilience and adaption to urban heat [16,25–27]. It has examined various strategies and techniques to counteract its adverse impact on urban areas. Urban design methods often present the challenge of understanding hydraulic dangers and using natural solutions for stormwater management issues. Implementation of these strategies is often limited in specific instances, emphasizing the need for more holistic urban planning strategies to adapt to climate change [28,29]. Leone et al. [30] highlighted the role that urban planning can play in defining and incorporating solutions for climate adaptation through sustainable stormwater management to protect urban waterways from hazards. Implementation of innovative strategies may be limited by current urban planning methods that neglect environmental considerations and offer opportunities through nature-based solutions. Tu and Yu [28] conducted a comparative analysis of climate adaptation strategies employed in Taipei and Boston. They discovered striking variations between their approaches and approaches used to deal with the challenges posed by climate change. Urban planning strategies should be comprehensive and contextually suitable to address climate change effectively. Each metropolis will face unique challenges and opportunities, which must be

considered when developing such plans. Wu et al. [31] researched the heat sensitivities of coastal cities in Southeast China. Researchers highlighted the significance of collecting thorough information regarding all processes contributing to heat vulnerability within urban systems. These authors conducted research highlighting the significance of employing dynamic assessment techniques that use multiple sources of data in order to gain a thorough understanding of heat sensitivities within cities and create adaptation and resilience strategies to address them effectively.

Urban pollution severely threatens the quality of life and sustainable urban development in cities worldwide, impacting health and environmental ramifications as well as environmental degradation [32]. Strategies designed to promote urban resilience must be employed to combat its harmful effects [22]; unfortunately, there are currently no comprehensive studies that address all issues surrounding urban heat scientifically and practically. Current scholarship lacks comprehensive solutions encompassing vulnerability assessment, adaptation measures implementation and practical implementation for dealing with urban heat-related challenges. Current methods and strategies do not adequately capture the interdependency of urban systems and the multifaceted nature of heat impacts in cities. Research beyond individual disciplines is needed urgently and comprehensively to offer complete understanding on designing and implementing strategies to increase urban resilience against rising temperatures. Due to the variety of urban settings and effects associated with urban heat, solutions must be tailored specifically for each metropolitan area in which urban heat issues have an impact. Existing literature lacks adaptable and contextually relevant solutions that could maximize urban resilience strategies and help cities cope with and recover from adverse urban temperatures.

Examining solutions to resilient urban areas is of utmost importance because it provides invaluable insight into developing effective policies and urban planning strategies to combat problems created by urban heat and other climate threats. This research emphasizes the significance of adapting resilience-related thinking to natural-based strategies in urban area planning. Experiences like those in Valencia, Spain, show this to be true; climate-resilient planning was used as part of their urban growth plans [16]. This research significantly impacts planning, urban policy-making, and community wellbeing. It offers valuable insights and frameworks for mitigating the negative effects of urban heat islands (UHIs) while improving the quality of life and sustainability in urban zones. This study contributes to creating equitable, inclusive, and sustainable urban environments by exploring the vulnerabilities of urban areas and strengthening their resilience zones. As a result, this work will aid social and economic growth and improve community wellbeing.

Although a considerable amount of literature exists about urban heat and resilience, there is a noticeable deficiency in research that comprehensively examines the integration of urban resilience tactics and adaptation methods. Numerous scholarly investigations sometimes concentrate on distinct facets of urban resilience, such as evaluating vulnerability or formulating strategies for adaptation, while neglecting to offer a holistic understanding of the complex nature of urban heat concerns. There exists a scarcity of scholarly investigations that effectively integrate a range of tactics, approaches, and perspectives to offer comprehensive solutions for addressing the issue of urban heat. This gap highlights the necessity for multidisciplinary research that surpasses the confines of conventional urban resilience studies and provides comprehensive perspectives on the creation and execution of efficient urban resilience measures. To fill the existing research gap, this study's primary objective is to answer the following research inquiries: (a) What are the strategic solutions that may be applied to effectively manage vulnerability and build urban resilience to mitigate the impact of urban heat? And (b) how can the measures above be effectively incorporated into urban development plans and regulations to cultivate resilient urban ecosystems capable of withstanding the increasingly severe consequences of urban heat? Consequently, the primary aim of this study is to ascertain and examine various approaches to enhance urban resilience, mitigate susceptibility, and implement adaptive measures to mitigate the impact of urban heat. The findings of this research will offer practical and valuable insights for urban planning and policy formulation.

This research makes a valuable contribution to urban resilience by undertaking a comprehensive analysis of urban resilience strategies, vulnerability mitigation, and adaptation implementation using content analysis. This study presents fresh perspectives and frameworks, using integrative methodology to offer an all-inclusive view of strategic urban resilience. Furthermore, this research advances urban heat resilience discussion by drawing upon various methods and insights.

This study stands out for its attempt to broadly and comprehensively investigate the resilience of cities-based on the combination of two decades of literature, analyzed across four system variables – categorizing urban resilience inquiry across major societal challenges. Urban resilience research up to then had only analyzed its dimensions separately. Consequently, this work genuinely moves the state of knowledge forward on urban resilience while adding practical planning, capacity-building and stadnars and decision-making tools. It also offers utilities – framings and knowledge – to urban stakeholders in dealing with complicated heat issues and innovating out of them. Furthermore, it has the potential of reshaping the treatment and study of urban development decision-making as a product of this unique urban heat-analytic investigation.

2. Theoretical framework

Urban Resilience plays an essential role in strengthening communities' and cities' ability to withstand disruptions quickly and recover quickly [16]. Shi et al. [33] contend that high-quality development, regional coherence, and strengthening resilience in cities should all be top priorities. Urban resilience is a multidimensional concept which must be carefully understood. This concept encompasses economic resilience, social capability building, infrastructure development, and ecological resiliency [33]. Urban resilience is crucial to successful urban growth, as it allows cities and towns to effectively respond and adapt to threats such as flooding in their city and other disasters [34]. Cities prone to regular disasters must coordinate between city subsystems to respond effectively against flooding risks; the resilience of cities against flooding thus becomes fundamental for economic development [16].

Urban resilience and urban heating research encompass an abundance of techniques and dimensions [35–37]. Yet, there remain unanswered questions and gaps that point towards potential areas for further investigation and advancement in this topic. Research

lacks interdisciplinary approaches. To fully comprehend urban heat and resilience, it is necessary to integrate multiple disciplines, including social sciences, environmental sciences, urban planning and public health. Current research does not include enough interdisciplinary studies. Furthermore, multidisciplinary investigations are underrepresented, leading to an unacceptable knowledge deficit concerning how factors interconnect and impact urban environments. Lack of localized research that examines specific locations and urban environments is evident across multiple metropolitan areas that present unique issues and opportunities related to climate and urbanization [38]. Research in local settings is crucial to developing interventions and methods tailored specifically to address diverse urban settings' unique demands and issues. There have been few comprehensive studies that examine the needs, experiences and adaptabilities of marginalized communities such as economically disadvantaged groups, older people, and those living with medical issues. To create equitable resilience plans and treatments that consider unique vulnerabilities and adaptive capabilities shown by various groups.

One notable shortcoming of rapid urbanization is the absence of research on the implementation and effectiveness of urban planning and resilience measures in developing nations. As part of urban planning reform, policies must be assessed within their practical environments, yet this area has seen little research attention in current scholarly work [39]. The existing literature does not accurately reflect the evaluation and study of emerging adaptation and mitigation techniques. Innovative strategies and solutions, such as smart city technologies or nature-based approaches, must be employed to advance the field and address urban heat island and resilience concerns.

This research utilizes two relevant theoretical frameworks: Urban Resilience Theory (URT) and Human-Nature Connection Theory. These theories provide a comprehensive approach to how cities can increase their resilience against heat waves by simultaneously addressing weak spots and developing adaptation strategies. Urban Resilience Theory (URT), puts a special focus on developing planning and policies, implementing risk reduction strategies, and creating adaptation plans; it also includes mechanisms for recovering from disasters quickly [40,41] - for example, eco-friendly replacement fuel sources for fossil fuels. Parker and Simpson [42]'s research highlights the significance of building social capital to increase cities' capacity to address heat islands in metropolitan areas. Human-Nature Connection Theory (HNCT) fosters environmentally-friendly actions and access to top-quality, remaining, and renovated Urban Green Infrastructure (UGI) [40]. This aspect is key for understanding how nature benefits both human health and well-being and increases biodiversity and ecosystem health. The framework emphasizes eco-friendly infrastructure solutions and sustainable design techniques to strengthen urban resilience (Fig. 1).

Fig. 1 depicts the significance of taking a strategic approach in urban resilience to address risk and heatwave effects and to reduce heat stress and flooding from climate change-related hazards [43]. Blue green infrastructure was central in discussions, mitigating climate-change-related hazards like heat stress and flooding while improving urban landscapes and resident health (BGI is a long-standing opportunity that offers both benefits. Using grey and blue-green systems could provide better options for combining water management strategies with climate change adaptation strategies [43]. Studies conducted over time have shed light on the vulnerabilities faced by poor urban communities living in informal settlements subject to severe resource limitations [44,45].

3. Research methodology

3.1. Research design

This study employed a mixed method approach comprising a systematic review method and thematic analysis. The systematic

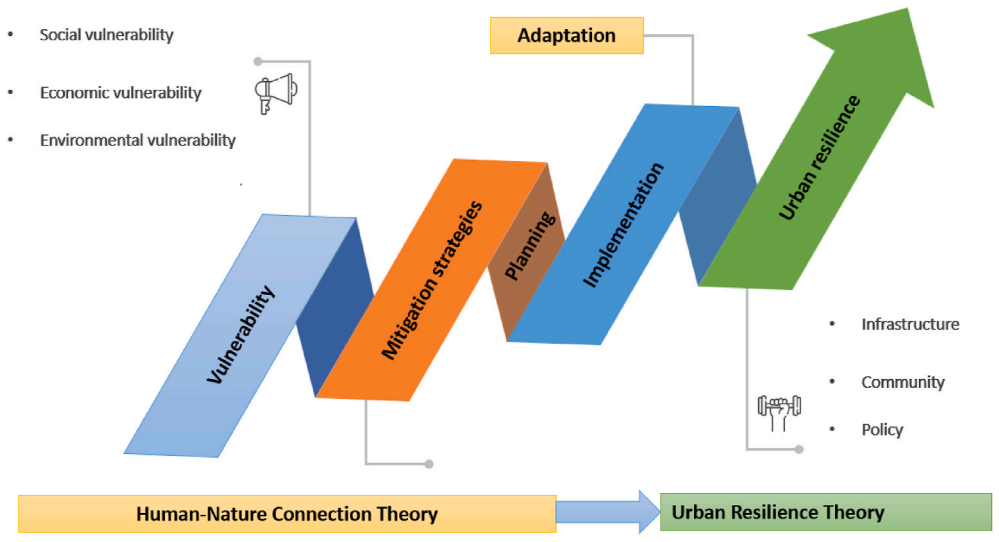


Fig. 1. Theoretical framework of urban resilience in the face of heat.

review method includes developing a research protocol (Table 1) and reviewing the literature to locate relevant data. Systematic literature reviews (SLR) are an approach for systematically gathering, analyzing, and synthesizing existing academic research from academics, scholars, and professionals in an orderly way that is comprehensive, clear, and reusable [46]. This research employed tools like the Preferred Reporting Item for Systematic Review Meta-Analyses Method (PRISMA), to design an investigation plan and conduct literature reviews to gather pertinent information [47]. PRISMA is a widely recognized technique that utilizes research evidence for comprehensive reviews and meta-analyses. It comprises four steps - identification, screening, eligibility, and inclusion - with 27 items used as a checklist [48].

3.2. Search string

We developed search strings based on urban resilience and urban heat mitigation strategies incorporating items such as urban resilience, city resilience, urban heat, mitigation, climate change, and adaptation strategies to ensure a comprehensive literature collection.

3.3. Search strategy

We conducted initial searches using Web of Science and Scopus, as both search engines were excellent in providing articles related to resilience research in cities and adaptation to climate change. We limited our search to English-language journals only for consistency.

3.4. Inclusion and exclusion criteria

To make sure that our work maintained accuracy and validity, we have included a set of rigorous inclusion and exclusion criteria by developing an ethical consideration for this study. The following are the criteria that have to be met for any study to be included in this review: (a) it must focus on urban resilience strategies targeted explicitly at reducing urban heat; (b) it should address sustainable planning of urban areas, adaptation strategies, and resilience-building approaches; c) published in peer-reviewed journals with wide access, and (d) available in English were eligible. These are the broad criteria that we used as inclusion criteria. If studies do not match these criteria, we ignore the study.

Research that did not meet these criteria—for instance, studies not directly addressing urban strategies to reduce heat or those not published in peer-reviewed journals—was excluded. This approach provided a solid foundation for our study, emphasizing relevant, high-quality, and accessible research that enhances the understanding of the role of strategic urban resilience in addressing the increasing heat in today's cities. By adhering to these standards, we aimed to create an evidence base that accurately reflects current knowledge in the field, while offering valuable data for urban planners, policymakers, and other stakeholders involved in efforts to enhance urban resilience.

3.5. Criteria of analysis for document review

Several criteria were followed to analyze the selected documents (Table 2). This approach provides comprehensive and flexible analyses with guidelines carefully selected as comprehensive analysis of the studies selected for review.

Table 2 describes the process used to review documents in the research. The guidelines ensured a comprehensive review of the literature analyzed during this research. The initial stage involved choosing terms that corresponded with the research question and

Table 1
Research protocol.

Items	Description
Research problem	Investigate strategic urban resilience approaches for mitigating urban heat, understand their implementation variations, and explore associated challenges and opportunities.
Databases	Web of Science, Scopus, Google Scholar
Search terms	Urban resilience, urban heat, climate adaptation, adaptation strategies, green infrastructure, sustainable urban planning
Time frame	Studies published from January 01, 2000 to January 31, 2024.
Search strategy	Utilized a combination of keywords with Boolean operators for an exhaustive search.
Inclusion criteria	(a) it must focus on urban resilience strategies targeted explicitly at reducing urban heat; (b) it should address sustainable planning of urban areas, adaptation strategies, and resilience-building approaches; c) published in peer-reviewed journals with wide access; and (d) available in English were eligible.
Exclusion criteria	Non-English articles, studies not directly addressing urban resilience or heat adaptation, unpublished or non-peer-reviewed articles.
Types of studies	Both empirical and theoretical research concerning urban resilience against heat.
Geographical scope	No geographical limitation to including diverse urban contexts and strategies.
Language	Articles published in English
Data extraction	Authors, publication year, study location, strategies identified, primary findings, and methodological approach.
Quality assessment	Evaluation is based on methodological rigour, relevance to research questions, and clarity of outcomes.
Analytical approach	Thematic analysis is used to identify core themes and strategies within the collected literature.

creating a term sheet to make sure the information analyzed was pertinent to the themes or topics that had been decided upon. Document analysis involves finding specific examples that relate to term sheets while understanding their narrative. Coding has enabled research-based issues and research projects to evolve.

3.6. Qualitative aspects of analysis

After reading through selected research papers, a thematic analysis was done to comprehend their contributions to urban resilience against heat. Text segments dealing with strategies used by cities against excessive heat were coded before being organized into themes that represent fundamental strategies and perspectives regarding urban resilience.

The term sheet, developed through a structured and iterative process, guided this analysis. Initially, a comprehensive literature review identified key themes and concepts such as policy interventions, technological solutions, and community engagement. These themes were refined through expert consultations and brainstorming sessions. A preliminary draft of the term sheet was created and applied to a subset of documents for testing, followed by refinement based on feedback, resulting in the final term sheet. This term sheet ensured clarity and consistency in the thematic analysis. We identified key themes within the collected data by organizing codes into broad categories, highlighting common themes among documents. Topics like integrating blue-green infrastructure, community involvement, and policy implementation were iteratively discussed and refined.

3.6.1. Theme identification

We identified key themes within the collected data by organizing codes into broad categories that highlighted common themes among documents. Through iterative discussions, we identified topics like integrating and implementing blue-green infrastructure in cities, community involvement in resilience-building efforts, and policy implementation that supports or hinders urban adaptation strategies. These technological advances increase urban resilience against heat. Each theme was developed to offer a collection of ideas and insights that illuminate various approaches to combatting urban heat. These themes are central to understanding urban resilience through strategic means; they reveal different strategies employed across urban settings and any issues or opportunities associated with urban heat reduction strategies.

3.6.2. Reviewing themes

An in-depth review of the selected studies was conducted after identifying themes to ensure proper data presentation and to advance the understanding of urban resilience to heat. We analyzed each theme to assess its relevancy to research objectives, such as accurately representing urban resilience strategies used to combat urban heat. Specific themes were combined or refined to represent the data more accurately while offering distinct and informative themes. Repeated reviews included ongoing analyses of data, codes, and themes that were identified. After our process, the themes identified were used to organize the findings section of our research and create a cohesive story connecting the results of the study with discussions about urban resilience. A careful review ensured that topic analysis accurately represented both information gathered and academic discussions surrounding strategic urban resilience and adapting to urban heat (Table 3).

This theme analysis term sheet offers a systematic method for classifying and evaluating the literature studied in this research. Each category and subcategory are defined with an operational definition to ensure clarity and consistency in the thematic analysis process. Organizing and synthesizing the results from the studied papers is made easier with the help of the codes. Certain categories may be based on the larger body of literature and hence lack particular sources; nonetheless, the sources column contains references that serve as examples or as a basis for comprehending each category or subcategory. Strategic urban resilience and adaptation to mitigate urban heat are better understood with the help of this framework, which highlights important themes and patterns.

3.7. Data analysis

This study employed MAXQDA, a software application that assists with quantitative data analysis. MAXQDA assists researchers in organizing, categorizing, and interpreting collected data efficiently using its powerful features, such as code hierarchies, search capabilities, and memo functions, to manage large quantities of qualitative information efficiently [70]. Visualizing frequency charts or code maps makes data interpretation much simpler.

The coding procedure was conducted carefully to ensure accuracy and reliability. An initial code was written according to research

Table 2
Criteria of analysis for document review.

Criteria	Description
Key phrases selection	Initial analysis began with identifying keywords relevant to our research goals, such as urban greening, heatwave management, and community-based adaptation.
Term sheet development	Developed to guide literature analysis, focusing on policy interventions, technological solutions, and community engagement.
Document reading strategy	Two researchers reviewed Each selected document independently to ensure comprehensive understanding and alignment with research goals.
Codification of terms	Employed thematic analysis, categorizing literature excerpts under relevant themes, refining these themes iteratively to enhance research depth and breadth.

Table 3
Term sheet for thematic analysis.

Themes	Sub-themes	Description	Code	Sources
Urban resilience	Infrastructure	The ability of urban infrastructure to absorb and recover from climate-related shocks.	UR-I	[43,49,50]
	Community	The capacity of urban communities to adapt to and recover from climate-related events.	UR-C	[26,45,51]
	Policy	The role of urban policies in enhancing resilience to climate-related risks.	UR-P	[52–55]
Vulnerability	Social	The susceptibility of urban social systems to be harmed by climate-related events.	V-S	[51,53,56,57]
	Economic	The susceptibility of urban economic systems to be harmed by climate-related events.	V-E	[41,58–60]
	Environmental	The susceptibility of urban environmental systems to be harmed by climate-related events.	V-EN	[32,59,61,62]
Adaptation	Mitigation strategies	The actions taken to reduce or prevent the impact of climate-related events.	A-M	[28,59] [63,64,65]
	Planning	The process of designing urban areas to better handle climate-related events.	A-P	[16,53,66] [67,68]
	Implementation	The execution of plans and actions to improve urban resilience.	A-I	[43,52,55] [68,69]

questions and goals; additional codes were added as needed. MAXQDA software was used for in-depth text coding on urban environment concepts like resilience, adaptation, and vulnerability. MAXQDA also assisted us in accurately assessing its efficacy and efficiency. An iterative coding approach was utilized in this research to ensure every code created met research questions accurately and followed research objectives. The efficient form of codification was used across all documents studied, as well as individual ones that underwent rigorous codification checks for reliability and consistency (Table 4).

3.7.1. Generation of initial list of codes

The initial list of codes was generated through a multi-step process to ensure comprehensive coverage of relevant themes and concepts. Firstly, a thorough literature review was conducted, encompassing academic publications, policy documents, and reports related to urban resilience, adaptation strategies, and urban heat mitigation. Key themes and recurring concepts identified in this literature formed the foundation of the initial coding scheme. Secondly, the research team held several brainstorming sessions to discuss and refine the initial codes. These sessions involved the identification of core themes based on the study's research questions and objectives, ensuring that the codes were aligned with the overarching goals of the research. During these discussions, each potential code was evaluated for its relevance and applicability to the study's context. Thirdly, a preliminary coding scheme was developed and applied to a subset of documents using MAXQDA. This trial phase allowed the research team to test the initial codes and make necessary adjustments based on their applicability and effectiveness in capturing relevant data. Feedback from this trial phase was used to refine the coding scheme further.

3.7.2. Selection of key phrases

Key phrases for the initial analysis were chosen through a systematic process involving several steps to ensure alignment with the study's objectives and capture relevant information. The process began with a comprehensive literature review on urban resilience, adaptation strategies, and urban heat to identify frequently used terms. This was followed by expert consultations to gather insights and ensure comprehensiveness. The team then conducted brainstorming sessions to compile a list of potential phrases. A preliminary analysis was performed on a subset of documents to test the relevance and effectiveness of these phrases. Based on the results, the list was refined, with broad or irrelevant phrases revised or replaced. The final list was then applied to the full set of documents for comprehensive analysis.

3.7.3. Conflict resolution during coding

During the coding process, several conflicts arose between coders, which were resolved through structured discussions and consensus-building strategies. One specific example involved the categorization of "urban greening" initiatives. While one coder argued that these initiatives should be classified solely under "infrastructure," another coder believed they also fit within the "community engagement" category due to their impact on public participation and social cohesion. To resolve this conflict, the research team conducted a thorough review of relevant literature and case studies. This review highlighted that urban greening projects often serve dual purposes, enhancing both infrastructure and community engagement. Consequently, the team decided to code urban greening initiatives under both categories, ensuring a comprehensive understanding of their multifaceted impact.

Table 4
Steps of analysis.

Step	Description
1. Development of preliminary coding scheme	A list of codes was generated based on the research questions and objectives.
2. Application of coding scheme	The preliminary coding scheme was applied to a subset of documents using MAXQDA.
3. Review and refinement of coding scheme	The coding scheme was reviewed and refined based on the emerging themes and patterns.
4. Finalization and application to all documents	The final coding scheme was applied to all the documents in the study.
5. Conflict resolution	Conflicts between coders were resolved through structured discussions and consensus-building strategies.

Another conflict arose regarding the coding of "policy interventions." One coder suggested that policies promoting "green roofs" should be categorized under "urban resilience - infrastructure," whereas another coder felt they belonged under "policy and governance." After several discussions and reviewing the specific contexts in which these policies were implemented, the team reached a consensus to code such policies under "policy interventions" with a cross-reference to "urban resilience - infrastructure." This approach maintained clarity and allowed for the representation of policies' dual nature in promoting infrastructural resilience through governance.

By addressing and resolving these conflicts, the coding process became more robust and reflective of the complex interactions between different urban resilience strategies (Table 4).

Coding disagreements were resolved through discussions and consensus among members within the research group. When problems between coders arose, these required a comprehensive review of the scheme as well as modifications to definitions for consistency and clarity. Once conflicts between coders had arisen, open discussions between members were used to reach an unambiguous resolution if required by revisions to the coding scheme, and changes made to meanings or definitions to enhance clarity or increase consistency.

3.8. Bias resolution process

To ensure the robustness and validity of this study, we implemented a comprehensive bias resolution process. Selection bias was mitigated by using a broad range of databases and diverse search terms, and publication bias was addressed by including grey literature alongside peer-reviewed studies. To reduce subjectivity in coding, multiple coders were involved, and discrepancies were resolved through consensus meetings. Temporal bias was managed by periodically updating the review to include the latest studies. Standardized data extraction and quality assessment forms were used, with regular cross-checks to ensure consistency. Potential conflicts of interest were transparently reported and managed to maintain the integrity of the review process.

4. Results

4.1. Overview of included studies

The systematic review yielded a diverse range of strategies for addressing urban heat and enhancing urban resilience. The findings revealed significant overlaps as well as notable divergences from existing studies in the field.

4.1.1. Document selection

PRISMA flow diagram was carefully used to select documents for review, providing a logical and transparent process. Fig. 1 depicts this step-by-step journey from an initial selection of studies that could be included in our literature search to reviewing these studies that were included subsequently. Our search strategy on selected databases yielded 1345 results, plus 37 records discovered via references list searches that we also reviewed.

Once duplicate records were eliminated, we kept 289 distinct records for further examination. Abstracts and titles for these files

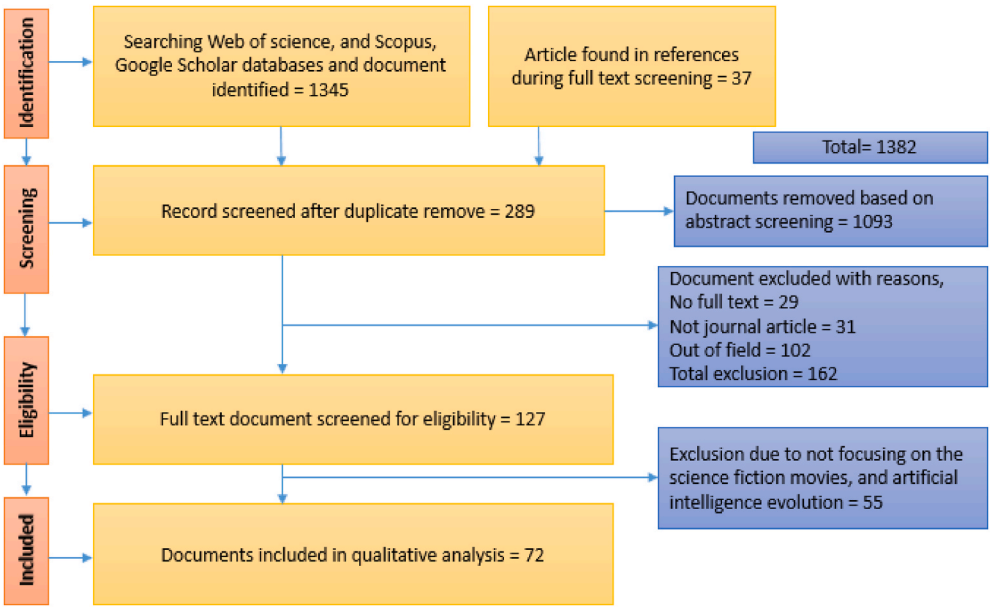


Fig. 2. Relevant document selection process.

were assessed against predetermined eligibility criteria for evaluating inclusion or exclusion, specifically looking at their connection with strategies for urban resilience against urban heat and sustainable urban planning practices and implementation practices. We focused specifically on their link with strategies for resilience against urban heat as well as sustainable planning implementation practices; many records were rejected at this phase, primarily because they did not directly address key issues related to urban heat reduction or did not explicitly discuss strategies intended to increase resilience; ultimately leaving only 127 eligible records eligible for full-text evaluation. In the assessment phase of full-text, the documents were rigorously assessed for eligibility and relevance, paying particular consideration to whether the research dealt with urban resilience strategies and adaptation strategies to tackle urban heat effectively and if it was conducted with the highest methodology standards. The main reasons for excluding at this point were studies that did not focus specifically on the strategic aspects of urban resilience to heat, or that had methodological weaknesses that affected the reliability and clarity of their conclusions. After a thorough review of 72 studies, they met all the criteria for inclusion and were included in our final review for a comprehensive analysis, analysis, and synthesis (Fig. 2).

4.1.2. Publication over time

The studies we reviewed span from January 2000 through January 2024 and demonstrate the progression of urban resilience research, specifically regarding urban heat mitigation strategies and resilient urban development (Fig. 3). An increase in publications after 2018 indicates increased attention in scholarly communities towards these issues as they become a greater issue that demands strategic solutions within urban design and resilience practices. The selected documents were an impressive combination of both theoretical and empirical findings, using various methods such as survey-based interviews with qualitative content case study analysis and participatory action research to examine strategies used to increase urban resilience across various urban settings. Such studies also provided insight into practical implementation measures designed to build resilience, participation by urban communities in resilience efforts, and the efficacy of policymaker interventions designed to increase urban heat resilience.

Theoretical papers typically focus on research reviews and conceptual analyses to understand the theoretical foundation of urban resilience and strategies for adaptation [4,26]. Through such analyses, this research led to an understanding of resilient cities, including governance's ability or lack thereof to support or thwart efforts at adaptation and the role of innovative strategies such as green infrastructure or smart technology in mitigating urban heat. Studies on urban resilience have examined specific elements, including blue and green infrastructure integration, heatwave early warning systems, and community adaptation projects. Researchers explored how such strategies could be successfully implemented across environments and socio-economic settings to meet challenges associated with urban heat. Their lessons provide useful tips to urban planners, politicians, and practitioners of resilience alike. Studies reveal a rich and comprehensive collection of research aimed at understanding and increasing urban resilience against urbanization and climate change. Their various methodologies and research areas add depth and breadth to knowledge bases while offering insight into strategies that could create more livable urban areas in response to rising temperatures.

4.1.3. Network of the concepts

Network visualizations were employed using VOS viewer to illuminate the complex relationships among essential components of urban resilience, adaptation strategies, and approaches for mitigating urban heat (Fig. 4). Visualization was devised on the principle that more mutual references mean an increase in the probability that two papers are related closely. VOS Viewer aids this process by producing an occurrence matrix to measure similarities between items, followed by a two-dimensional visual representation of these similarities in which each item is situated relative to its connectivity to one another, and proximity on a map is used as an indication of the strength of their relationship, and cluster analysis identifies areas that share common themes in research. The network

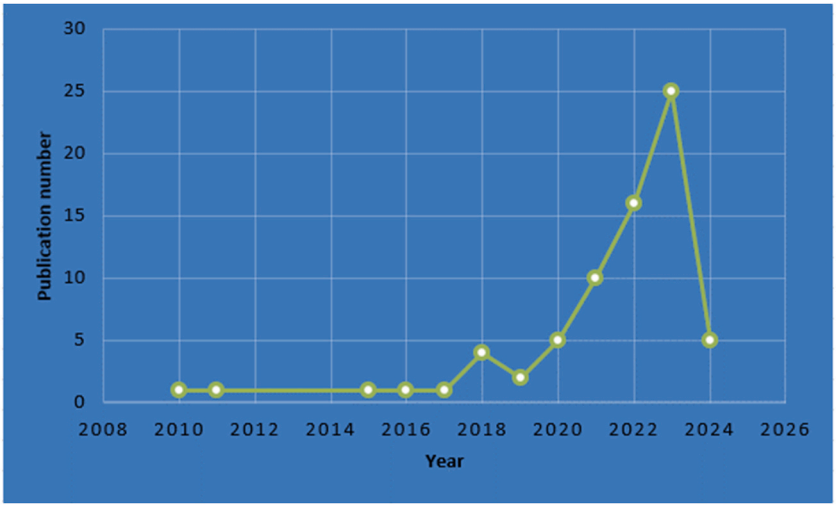


Fig. 3. Published documents over the years.

visualization identified elements vital to understanding and increasing urban resilience to urban heat. It provides a complete picture of concepts interlinked, such as eco-friendly infrastructures, Heatwave Preparedness community involvement in resilience projects, and governance/policy to support urban adaptation/technological advancements to mitigate heat. Fig. 4 highlights some of the most frequently used terms across all studies collected; a minimum of three appearances across studies are considered sufficient criteria.

Network mapping illustrates the scenery for research that presents various strategies and approaches to combating urban heat. Through its identification of groups that share research interests, network mapping provides a visual aid in recognizing established research areas as well as new ones and understanding how various methods and ideas interrelate, ultimately providing a roadmap for future investigations as well as stressing the importance of interdepartmental efforts to develop comprehensive yet efficient urban strategies against heat.

4.1.4. Regional distribution of the selected documents

Fig. 5 depicts the number of documents from various countries focused on urban heat resilience strategies. China leads with 14 documents, indicating significant research emphasis in this region. The United States follows with 12 documents, showing a strong focus on urban heat resilience. The United Kingdom has 8 documents, reflecting substantial research activities. Italy and Germany have 6 and 5 documents respectively, indicating moderate research engagement. The Netherlands and Spain both contribute 4 documents each, while Australia, Canada, and France each have 3 documents. This distribution highlights an overrepresentation of studies from China and the United States, suggesting these countries are prioritizing urban heat resilience. In contrast, regions like Australia, Canada, and France appear to be underrepresented, potentially pointing to differing regional priorities or resource allocations in addressing urban heat challenges.

The regional differences in urban heat resilience strategies reveal varied approaches based on local contexts and climate challenges. In Asia, particularly China, there is an emphasis on large-scale urban planning, infrastructure upgrades, and technological solutions to manage urban heat. This includes integrating both traditional and modern practices to enhance urban resilience. In North America, the United States and Canada strongly focus on policy frameworks, community engagement, and advanced technological interventions. The US, in particular, highlights a diverse range of strategies tailored to its different climatic zones. In Europe, countries such as the United Kingdom, Italy, Germany, the Netherlands, Spain, and France emphasize green infrastructure, nature-based solutions, and sustainable urban design. European strategies often involve comprehensive policy measures and strong institutional support, reflecting their commitment to sustainability and climate action. Meanwhile, Australia, with its hot climate and urbanization challenges, focuses on addressing heatwaves and urban heat islands through green infrastructure and thoughtful urban planning. These regional differences highlight the importance of tailoring urban heat resilience strategies to local contexts, leveraging global knowledge while addressing specific regional needs.

4.1.5. Presentation of coded data

Following the coding, this study counted the frequency and percentage of each theme. It clearly and concisely depicts the main patterns and themes that the content analysis process has discovered (Table 5).

Table 5 illustrates the frequency and the proportion of each code seen in the content analysis. In the table above, the code UR - I

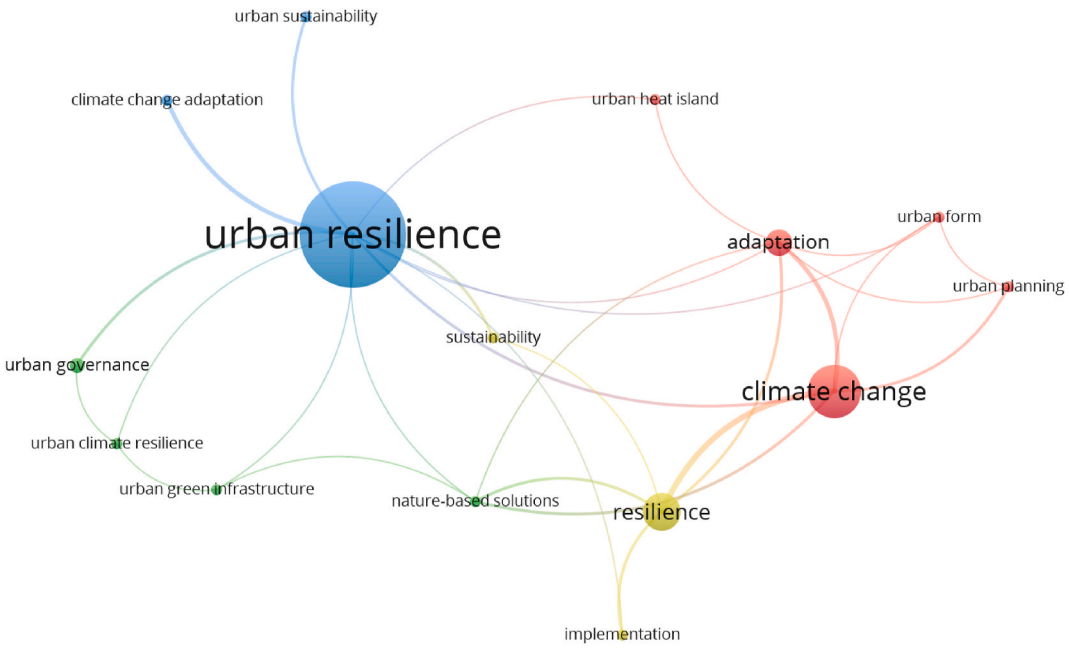


Fig. 4. Network visualization of keyword co-occurrences.

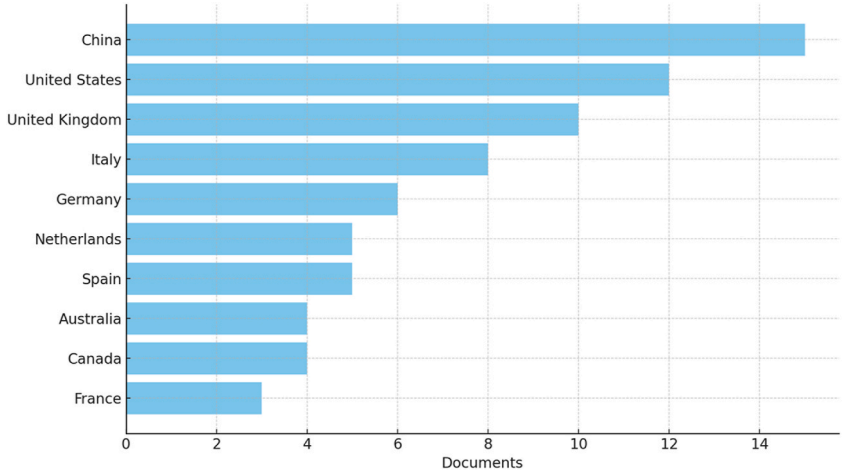


Fig. 5. Selected documents' regional distribution.

(Urban Resilience - Infrastructure) has the highest frequency. It is followed by the UR-C (Urban Resilience - Community) and the UR-P (Urban Resilience - Policy).

4.2. Analytical results

4.2.1. Strategies for urban resilience

Our study has identified several comprehensive solutions to increase cities' resilience to the issue of urban heat, which can be categorized into three major categories: Community, infrastructure, and policy. These initiatives offer a broad urban design and planning method, emphasizing the necessity of integrating solutions incorporating physical infrastructure, engagement with communities, and legislative frameworks (Table 6).

Our results indicate that strategies such as the implementation of green roofs and urban forests are widely acknowledged in the literature for their effectiveness in mitigating urban heat islands, aligning with the findings of Ordóñez Barona and Trammell [86], who documented similar impacts in European cities. Furthermore, the effectiveness of heatwave early warning systems as observed in our study resonates with the conclusions drawn by Rezvani et al. [81], underscoring their pivotal role in reducing heat-related morbidity. However, our findings diverge significantly when it comes to community involvement in urban resilience initiatives. Unlike Colding and Barthel [87], who found minimal impact of community involvement on actual resilience outcomes, our review highlights substantial positive impacts, especially in socio-economically diverse urban areas. This discrepancy could be attributed to the varying methodologies employed or differences in the socio-economic contexts of the studied urban settings.

4.2.2. Addressing vulnerability in urban areas

Urban vulnerability should be tackled through an integrated, multifaceted strategy considering cities' social, environmental, and economic dimensions. Mitigating urban vulnerability using a multidimensional strategy that addresses all three dimensions is best managed. It offers a structured overview of all strategies designed to mitigate urban heat effects while strengthening resilience. Implementing such strategies will mitigate heat-related urban effects while strengthening urban resilience (Table 7).

The identified strategies emphasize the significance of integrating diverse approaches to address urban area vulnerabilities effectively. By considering cities' social, economic, and environmental aspects as they develop plans for resilience, they reduce immediate heat impacts and contribute towards long-term sustainability and resilience. Furthermore, community engagement, economic

Table 5
Coded data and frequency.

Code	Frequency	Percentage
UR-I	25	20 %
UR-C	20	16 %
UR-P	17	13.6 %
V-S	8	6.4 %
V-E	5	4 %
V-EN	10	8 %
A-M	15	12 %
A-P	13	10.4 %
A-I	7	5.6 %
Total	125	100 %

Table 6
Potential strategies for urban resilience in the face of urban heat.

Strategy category	Strategy	Description	Implications	Source
Infrastructure	Green spaces (GSs)	Utilization of parks and urban forests to mitigate heat effects and enhance biodiversity.	Reduces vulnerability to heat waves; enhances resilience.	[26,51,71]
	Sustainable urbanization and planning	Strategic urban design to reduce vulnerability and promote sustainability.	Promotes health and reduces climate change risks.	[68,72,73]
	Urban greening	Implementation of green roofs and walls to reduce heat absorption.	Improves air quality; potential for recreational spaces.	[3,59,74]
	Cool roofs	Reflective roofing materials to decrease heat absorption.	Reduces energy consumption for cooling buildings.	[75,76]
	Urban planning and zoning	Zoning regulations for heat-resistant construction and design.	Improves urban design and heat resilience.	[4,74]
Community	Community engagement and education	Engaging communities in resilience planning and education on heat risks.	Increases community awareness and preparedness.	[45,77,78] [79]
	Early warning systems	Systems for alerting about extreme heat events and coordinating responses.	Improves public safety and reduces heat-related health impacts.	[52,73,80] [81]
	Shade provision in public spaces	Offering shade to protect from direct sunlight in public areas.	Improves public comfort and health.	[3,82]
Policy	Integration into 15-min city planning	Incorporating heat adaptation into the 15-Minute City model for accessible environments.	Addresses urban heat in FMC goals.	[83]
	Water-sensitive urban design	Design that manages stormwater and mitigates heat through cooling mechanisms.	Improves water management and reduces urban heat.	[32,84,85]

readiness, and environmental stewardship all play key roles in creating resilient urban environments capable of withstanding climate change and urbanization challenges. For example, community-based adaptation initiatives are crucial for empowering local communities for resilience building through engagement and adaptation activities, enhancing social cohesion and localized resilience, aligning with the findings of Chu et al. [68] who emphasize inclusive approaches to urban climate adaptation planning in the Global South. Economic vulnerability can be addressed by combining technical measures with human coping mechanisms for residential heat protection, reducing the economic burden of heatwaves on households. This finding is supported by Gültekin [72] who highlights strategies to improve urban energy efficiency for urban resilience. Environmental vulnerability can be mitigated by incorporating green infrastructure to enhance ecosystem services and improve urban microclimates and biodiversity. Our findings align with those of Eldesoky et al. [59] who emphasize the importance of combining environmental and social dimensions in urban resilience. Urban greening and cooling strategies, such as the role of green infrastructure in reducing heat island effects and improving air quality, resonate with the research of Irfeey et al. [3].

4.2.3. Adaptation challenges

The quest to adapt urban environments to address the ever-increasing heat challenges caused by urban areas has revealed many obstacles and hurdles, improving an arduous endeavor. The following table details some challenges identified as obstacles to progress: budgetary restrictions, governance concerns, technological restrictions, and socio-economic inequities. Every challenge has unique

Table 7
Approaches to addressing urban vulnerability.

Vulnerability aspect	Strategy	Description	Implications	Source
Social vulnerability	Community-based adaptation initiatives	Empowering local communities for resilience building through engagement and adaptation activities.	Enhances social cohesion and localized resilience.	[36,65,88]
	Heat resilient cities project	Utilizes visualizations and design guidelines focused on community-specific resilience measures.	Improves community preparedness and urban heat management.	[64,89,90]
Economic vulnerability	Adaptation against heat waves in building areas	Combines technical measures with human coping mechanisms for residential heat protection.	Reduces economic burden of heatwaves on households.	[69,75,90]
	Sustainable urban drainage systems (SUDS)	Implements SUDS to mitigate heat and reduce flood hazards, supporting economic stability.	Lowers infrastructure repair costs and promotes water conservation.	[43,64,91]
Environmental vulnerability	Nature-based solutions in urban planning	Incorporates green infrastructure to mitigate urban heat and enhance ecosystem services.	Improves urban microclimates and biodiversity.	[16,79,92] [77,82,93]
	Urban greening and cooling strategies	Emphasizes the role of urban greening in reducing heat island effects and improving air quality.	Contributes to long-term environmental sustainability and resilience.	[3,74,80]
	Smart urban infrastructure for heat management	Explores smart technology applications for efficient urban heat management.	Facilitates adaptive environmental management and resource efficiency.	[52,58,78]

ramifications that could impede the implementation and effectiveness of strategies for adaptation. This section presents an in-depth assessment of the challenges associated with adapting strategically to urban heat and describes them in depth. A variety of studies reveals their complexity and the need for innovative programs for urban resilience that address them efficiently while still meeting all-inclusiveness goals (Table 8).

Our findings are consistent with those of Prashar et al. [26], who document similar financial challenges in urban flood resilience. Policy and governance issues, such as the lack of supportive policies and effective governance structures, affect the coordination and execution of urban resilience plans, aligning with the conclusions of Hao and Wang [51] on urban form and accessibility. Technical limitations in applying advanced technologies in existing urban settings limit the scope of innovative solutions for heat mitigation. This aligns with Wardekker [99]'s observations on the framing of urban climate resilience. Public awareness and engagement are crucial, yet low levels of public awareness and participation in resilience initiatives impact the effectiveness and sustainability of adaptation measures, a challenge similarly noted by Chu et al. [68].

4.2.4. Opportunities and enablers for effective adaptation

In this study, we have identified multiple enablers for effective adaptation to urban heat, categorized under community engagement, green infrastructure, policy integration, technological innovations, public-private partnerships, climate-smart urban design, education and awareness, financial incentives, research and development, and multi-sectoral collaboration. These enablers offer distinct advantages and implications for urban resilience, promoting a collaborative and innovative approach to mitigating urban heat. While country-specific contexts vary, the identified opportunities provide a flexible framework that can be tailored to meet local needs and conditions (Table 9).

Effective adaptation to urban heat involves leveraging opportunities such as community engagement, green infrastructure, and technological innovations. Involving local communities in planning and implementation enhances the relevance and acceptance of adaptation measures, consistent with the findings of Chu et al. [68] on inclusive approaches to urban climate adaptation. The development of parks, green roofs, and urban forests reduces the urban heat island effect and improves air quality, aligning with Shirgir et al. [71] on strategic principles of intervention in urban green infrastructure.

4.2.5. Emerging themes

Inspecting emerging issues is significant when researching urban resilience and adaptation to urban heat. This section shows various innovative concepts and strategies revealed through content analysis. These issues demonstrate the vitality of research on urban resilience. Each theme indicates its relation to various aspects of urbanization, creating opportunities to boost urban resilience and sustainability. However, these benefits have downsides, which must be carefully considered when designing urban strategies and policies. Information from these emerging patterns provides a robust base for further research that may reveal innovative and multifaceted strategies for mitigating urban heat. Based on these scientific results, further discussion focuses on various emerging topics related to urban resilience as well as methods of adapting to heat in urban areas (Table 10).

The strategies mentioned above demonstrate the various methods required to combat urban heat and build resilience. They highlight the need for collaborative efforts across academic and industrial fields to tackle the challenges associated with rising temperatures in urban areas.

Table 8
Adaptation challenges.

Serial	Challenges	Description	Implications	Sources
1	Financial constraints	Limited funding and resources for adaptation projects	Hinders the implementation of comprehensive adaptation strategies.	[4,26,65]
2	Policy and governance issues	Lack of supportive policies and effective governance structures	Affects the coordination and execution of urban resilience plans.	[55,73,94]
3	Technical limitations	Challenges in applying advanced technologies in existing urban settings	Limits the scope of innovative solutions for heat mitigation.	[15]
4	Public awareness and engagement	Low levels of public awareness and participation in resilience initiatives	Impacts the effectiveness and sustainability of adaptation measures.	[68,78,91]
5	Climate data and prediction challenges	Inaccuracies and uncertainties in climate data and predictions	Affects the planning and prioritization of adaptation strategies.	[58,91]
6	Intersectoral coordination	Lack of coordination among different sectors and stakeholders	Leads to fragmented efforts and inefficiencies in adaptation planning.	[56,89,95]
7	Socio-economic disparities	Disparities in the distribution of resources and benefits of adaptation measures	Exacerbates existing inequalities and hinders inclusive resilience building.	[68,94,96]
8	Legal and regulatory barriers	Complex legal frameworks and regulatory hurdles	Slows down the implementation of adaptation projects.	[41,59,97]
9	Technological adaptation	Challenges in integrating new technologies with existing urban infrastructure	Impedes the adoption of innovative solutions for urban heat management.	[69,93,98]
10	Stakeholder conflicts	Conflicts of interest among various stakeholders	Leads to delays and compromises in adaptation planning.	[45,65,77]

Table 9
Opportunities and enablers for effective adaptation to urban heat.

Serial	Opportunities/Enablers	Description	Implications	Sources
1	Community engagement	Involving local communities in planning and implementation	Enhances the relevance and acceptance of adaptation measures.	[77,78] [45,79]
2	Green infrastructure	Development of parks, green roofs, and urban forests	Reduces urban heat island effect and improves air quality.	[40,71] [82,100]
3	Policy integration	Integrating urban heat adaptation into broader urban planning and policies	Ensures a holistic approach to urban resilience.	[40,55] [52]
4	Technological innovations	Utilizing advanced technologies for monitoring and mitigating urban heat	Facilitates efficient and effective adaptation strategies.	[33,88] [53,77]
5	Public-private partnerships	Collaboration between government and private sector	Mobilizes resources and expertise for adaptation projects.	[96,101] [54]
6	Climate-smart urban design	Designing cities to be more resilient to heat through smart urban planning	Improves living conditions and reduces vulnerability.	[78]
7	Education and awareness	Raising awareness and educating the public about urban heat risks	Increases community preparedness and response capacity.	[76,89, 100] [80,102]
8	Financial incentives	Providing subsidies and incentives for implementing heat adaptation measures	Encourages adoption of resilience-building practices.	[81,103]
9	Research and development	Investing in research to understand urban heat dynamics	Informs evidence-based decision-making and innovation.	[3,97]
10	Multi-sectoral collaboration	Fostering collaboration across different sectors and disciplines	Enhances the effectiveness of urban heat adaptation strategies.	[78,79] [103]

5. Discussion

5.1. Insights of the selected studies regarding urban resilience

This study's primary results, which focus on enhancing urban resilience and increasing adaptability when dealing with urban heat, align with urban resilience to climate change. Components identified, such as green infrastructure policies and community involvement programs, are aligned with Folke et al. [113] conceptual framework for urban resilience; it represents an effective, comprehensive strategy for dealing with climate issues.

Contrasting with other research, ours focuses on the latest technological advancements and urban design that prioritize health-oriented views, offering a distinctive perspective. Huang et al. [61] highlighted the significance of technology for monitoring heat

Table 10
Emerging themes.

Serial	Theme/Strategy	Interconnectedness	Synergies	Trade-offs	Source
1	Integration of urban heat adaptation in urban planning	Links urban planning goals with heat adaptation strategies, promoting holistic urban development.	Enhances overall urban sustainability and resilience.	It may require trade-offs in land use and resource allocation.	[40,55, 83] [52]
2	Impact of urban configuration on urban heat island	Demonstrates how urban design influences heat distribution, emphasizing the need for strategic planning.	Potential to reduce urban heat islands and improve living conditions.	Balancing urban development with heat mitigation can be challenging.	[104, 105]
3	Perceptions of blue-green infrastructure	Highlights preference for BGI over grey infrastructure for its multifunctional benefits.	Offers aesthetic, environmental, and health benefits.	Initial investment and maintenance costs could be higher.	[43, 106] [94]
4	Urban and peri-urban agriculture	Connects food security and climate change adaptation, emphasizing sustainable urban development.	Addresses multiple urban challenges.	Requires careful planning to integrate into urban landscapes.	[93, 104] [107]
5	Community engagement in resilience building	Emphasizes the role of community participation in resilience strategies.	Strengthens social cohesion and public awareness.	Balancing diverse community interests can be complex.	[77,78] [79]
6	Technological innovations for heat monitoring	Links technology with urban heat management, offering real-time data and solutions.	Enhances precision in heat mitigation strategies.	Requires investment in technology and training.	[33,53, 88]
7	Policy integration for climate adaptation	Connects policy frameworks with climate adaptation measures.	Ensures coordinated and comprehensive approach.	Policy changes may face resistance or require time for implementation.	[40,52] [55]
8	Economic instruments for heat mitigation	Explores financial tools like incentives for green buildings.	Encourages private sector participation in resilience efforts.	Financial constraints or market fluctuations can impact effectiveness.	[108, 109]
9	Health-centric urban design	Focuses on designing cities that prioritize public health, especially in heatwave conditions.	Improves overall public health and well-being.	It may require significant urban redevelopment.	[110, 111]
10	Energy efficiency in building design	Promotes energy-efficient buildings to reduce heat generation.	Reduces energy consumption and urban heat island effect.	Initial costs for retrofitting or new designs can be high.	[72,80, 112]

in urban areas. Our research illustrates its broad applicability, particularly through incorporating technology into daily efforts to strengthen urban resilience. Kjellstrom and Weaver [114] conducted research that focused on including public health considerations in urban design. Our investigation is more in-depth than their work by showing a link between health-oriented urban design and methods to reduce heat.

This study presents an innovative, multifaceted approach to understanding urban resilience using economic tools and energy-efficient design of buildings, in line with Wang et al. [64] and Koutra et al. [115], who highlighted the significance of including energy and economic considerations in urban planning processes. Our study incorporates all these factors into an overall model for heat resilience that emphasizes their interdependency.

To conclude, this study's results provide a solid grounding for prior urban resilience research and can add new perspectives to the ongoing debate by including various interconnective techniques. Furthermore, its holistic nature emphasizes the difficulty in dealing with urban heat and its need for multidimensional solutions, with theoretical and practical applications being part of its solution set.

5.2. Integration with urban resilience theories

Prioritizing green infrastructure and creating sustainable urban designs are strategies discussed in this study that are deeply rooted in theories of urban resilience that advocate a holistic, eco-friendly method of urban planning [116]. Walker and Salt [117] have defined resilience thinking as transformation and adaptation when faced with environmental stresses, consistent with the adaptive methods we identified during our investigation. Ernstson et al. [118] proposed the concept of urban resilience as the result of redundancy and diversity; their results fit within this framework. They noted the significance of using various methods, including policy integration and community-based initiatives, to increase urban resilience against heat stress.

Urban resilience theories emphasize the importance of integrating multiple disciplines and approaches to enhance the resilience of urban systems. Green infrastructure (GI) is a key component that aligns with these theories, offering a multifaceted approach to urban resilience. GI contributes to urban resilience by providing ecosystem services, improving air quality, and mitigating urban heat islands (UHI). For example, the implementation of GI in cities like Seoul and Beijing has demonstrated significant benefits, including stormwater management and enhanced biodiversity [82].

Policy integration is crucial for the successful implementation of urban resilience strategies. Policies that support the development and maintenance of GI can drive significant improvements in urban sustainability. The concept exemplifies how policies can facilitate the integration of GI into urban planning, promoting social justice and ecological benefits [119].

5.3. Implications

5.3.1. Contribution to urban heat adaptation research

This study is an outstanding contribution to urban heat adaptation research. It analyzes various methods and their interrelationships, investigates vulnerable communities thoroughly, and extensively analyses adaptation strategies. The findings provide urban planner and policymakers insights about the implications, both positive and negative, of the different strategies of the benefits of the heat resilience urban planning. Furthermore, the study addresses practical implementation issues and potential roadblocks, often neglected during academic research studies.

The research results in this study make both practical and theoretical contributions on urban adaptation and resilience, by providing an integrated approaches in ensure effective controls on urban heat issue are in place. This research demonstrates what does urban resilience means in adaptation to climate changes or mitigating the urban heat issues.

5.3.2. Policy recommendations

The findings from this study are particularly relevant against the backdrop of rising temperatures in cities. The following specific, actionable recommendations for urban planners and policymakers can strengthen urban areas and reduce heat-related risks while encouraging sustainable urban development:

Firstly, urban planners should prioritize the implementation of green infrastructure by integrating green roofs, urban forests, and green spaces. Evidence shows that these strategies effectively mitigate urban heat islands by cooling urban areas, enhancing biodiversity [81], and improving air quality [120]. Secondly, policymakers should invest in the development of robust heatwave early warning systems. These systems play a crucial role in reducing heat-related health risks and can be tailored to specific urban contexts [81]. Thirdly, engaging local communities in resilience planning is essential. Community involvement enhances urban resilience and ensures that all social groups are represented in resilience projects. Fourthly, urban resilience strategies should be integrated into broader urban planning policies. This includes zoning regulations and building codes that promote heat-resistant construction, addressing multiple dimensions of urban resilience and improving sustainability and livability. Finally, embracing and integrating technological innovations such as smart sensors and climate monitoring tools is critical. These innovations facilitate real-time data collection and adaptive responses to changing conditions.

While these recommendations are framed in a generalized manner, they offer a versatile blueprint that can be adapted to specific country contexts, ensuring relevance and effectiveness in diverse urban environments.

5.3.3. Future effectiveness in the context of climate change

As climate patterns continue to change, certain urban heat resilience strategies may become more or less effective. Firstly, while green infrastructure will likely remain beneficial, its effectiveness could be compromised in areas experiencing severe droughts or

changing precipitation patterns. Future designs should incorporate drought-resistant vegetation and advanced irrigation systems to maintain their effectiveness. Secondly, heatwave early warning systems will continue to be vital; however, their success will depend on advancements in climate prediction technologies and public health infrastructure. Continuous improvement and adaptation of these systems are necessary to address increasing climate variability. Thirdly, additionally, promoting local adaptation and resilience-building through community-based approaches will become increasingly important. Finally, as climate impacts become more pronounced, community-based approaches will gain even greater importance. Strategies that promote local adaptation and resilience-building will be essential. Engaging communities in ongoing dialogue and adaptation efforts ensures that resilience strategies remain relevant and effective.

6. Conclusion

This study comprehensively examines strategies, measures, and approaches that aim to strengthen urban resilience against an intensifying heat challenge. Considering the heterogeneity in the approach of different authors the strategy, approaches and measures has been generated as per the common type and opinion shared by respective articles instead of any systematic classification. The content analysis of this study highlights a range of strategy, approaches, and measures from green infrastructure development to policy reforms and highlights the diversify characteristic of urban resilience.

The results from this study indicate that it is important to incorporate green open spaces, design of buildings, and the community being engaged in the system for an area to have resilience. Implementing green spaces, sustainable urban planning, urban greening, cool roofs, and zoning regulations are essential for reducing urban heat vulnerability and enhancing resilience. Active community engagement in resilience planning and educational initiatives significantly improves awareness, preparedness, and social cohesion. Integrating urban heat adaptation into broader urban planning and policy frameworks ensures a holistic and coordinated approach to resilience. Utilizing advanced technologies for monitoring and mitigating urban heat enhances the precision and effectiveness of adaptation strategies.

The novelty of this review lies in its holistic examination of urban resilience strategies that encompass physical infrastructure, socio-economic dimensions, and policy frameworks. Unlike previous studies, our review integrates technological advancements, health-centric urban design, and economic instruments, offering a comprehensive approach to urban heat mitigation. This integrative perspective is crucial for developing adaptive and resilient urban ecosystems capable of withstanding the multifaceted impacts of climate change. The research contributes to existing knowledge through a detailed exploration of the interconnections between a variety of resilience strategies, and the implications of this for urban planning and policy. It also makes a theoretical contribution in aligning, and in some cases challenging, existing theories within the field of urban resilience.

The findings from the study serve as a significant blueprint for urban planners, policy makers and communities to implement measures to alleviate urban heat. This study recommends to prioritize green infrastructure projects, supportive policies, community-based initiatives, and technological investments for fostering urban environments capable of withstanding the impacts of climate change and urban heat. By adopting this integrative approach, our study transcends individual country contexts, offering broader insights and strategies that can be tailored to local conditions. This comprehensive perspective ensures that urban heat resilience measures are both effective and adaptable, addressing the diverse challenges posed by urban heat in different regions around the world.

7. Limitations and future research direction

This study has several limitations. First, systematic review analysis could introduce bias, overlook emerging strategies due to their breadth and depth, and limit generalizability beyond urban settings. Specifically, potential biases in study selection and data extraction, such as excluding non-English studies or unpublished research, could skew the review towards more favorable or well-documented outcomes. Second, the lack of empirical data hinders our ability to generalize findings, while this research may not fully represent all stakeholder perspectives, especially marginalized groups. Third, though the provided recommendations for policy and practices are comprehensive, they may fail to consider variations in policy implementation across different urban contexts, and the exclusion of certain studies might overlook successful interventions in non-Western contexts, which could be highly relevant given differing urban layouts and cultural approaches to city planning and community involvement. Finally, technological advancements could outstrip the findings of this study over time and require ongoing updates of these results. To enhance the reliability of future reviews, it is recommended to expand the linguistic scope, include grey literature, and consider a broader array of urban environments and smaller-scale interventions.

Future studies must address the above limitations while exploring new dimensions. First, empirical studies involving primary data could offer deeper insights into adaptation strategies. Second, research should focus on various geographic locations, including both developed and developing nations, to enhance the generalizability and effectiveness of these strategies. Third, conducting longitudinal studies will be essential to track the success and sustainability of these strategies over time. Fourth, involving diverse stakeholders, particularly marginalized groups, is crucial to ensure equity and inclusivity in urban resilience planning. Finally, assessing the effectiveness of multi-stakeholder collaboration will be crucial for enhancing urban resilience.

Funding

This study is funded by the National Education Science Program for Youth Project, under the National Social Science Fund, China

(grant no. CFA220309). The project's title is "Research on the Suitability Evaluation and Spatial Optimization of the Supply and Demand of Inclusive Early Childhood Education Resources in the County."

Data availability statement

Data will be made available on request.

CRediT authorship contribution statement

Qingchen Fu: Writing – review & editing, Writing – original draft, Visualization, Software, Resources, Methodology, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Zhouhua Zheng:** Writing – review & editing, Writing – original draft, Validation, Supervision, Project administration, Investigation, Formal analysis, Data curation. **Md Nazirul Islam Sarker:** Writing – review & editing, Writing – original draft, Validation, Supervision, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Yang Lv:** Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Resources, Project administration, Methodology, Investigation, Formal analysis, Data curation.

Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests:

The corresponding author, Dr. Md Nazirul Islam Sarker, is an academic editor of Heliyon journal (Society & Politics section). There are other authors, they declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.heliyon.2024.e37001.

References

[1] A.T. Kullberg, K.J. Feeley, Urban heat islands and what they can teach us about climate change, Front. Young Minds 11 (2023), https://doi.org/10.3389/frym.2023.943515.
[2] M. Técher, H. Ait Haddou, R. Aguejdad, Urban heat island's vulnerability assessment by integrating urban planning policies: a case study of montpellier méditerranée metropolitan area, France, Sustainability 15 (2023) 1820, https://doi.org/10.3390/su15031820.
[3] A.M.M. Irfeey, H.-W. Chau, M.M.F. Sumaiya, C.Y. Wai, N. Muttil, E. Jamei, Sustainable mitigation strategies for urban heat island effects in urban areas, Sustainability 15 (2023) 10767, https://doi.org/10.3390/su151410767.
[4] S.M.H.S. Rezvani, M.J. Falcão, D. Komljenovic, N.M. de Almeida, A systematic literature review on urban resilience enabled with asset and disaster risk management approaches and GIS-based decision support tools, Appl. Sci. 13 (2023) 2223, https://doi.org/10.3390/app13042223.
[5] J.R. Escorcia Hernández, S. Torabi Moghadam, A. Sharifi, P. Lombardi, Cities in the times of COVID-19: trends, impacts, and challenges for urban sustainability and resilience, J. Clean. Prod. 432 (2023) 139735, https://doi.org/10.1016/j.jclepro.2023.139735.
[6] J. Ren, K. Shi, Z. Li, X. Kong, H. Zhou, A review on the impacts of urban heat islands on outdoor thermal comfort, Buildings 13 (2023), https://doi.org/10.3390/buildings13061368.
[7] B.J. He, W. Wang, A. Sharifi, X. Liu, Progress, knowledge gap and future directions of urban heat mitigation and adaptation research through a bibliometric review of history and evolution, Energy Build. 287 (2023) 112976, https://doi.org/10.1016/j.enbuild.2023.112976.
[8] D.E. Bowler, L. Buyung-Ali, T.M. Knight, A.S. Pullin, Urban greening to cool towns and cities: a systematic review of the empirical evidence, Landsc. Urban Plan. 97 (2010) 147–155, https://doi.org/10.1016/j.landurbplan.2010.05.006.
[9] S. Roy, J. Byrne, C. Pickering, A systematic quantitative review of urban tree benefits, costs, and assessment methods across cities in different climatic zones, Urban For. Urban Green. 11 (2012) 351–363, https://doi.org/10.1016/j.ufug.2012.06.006.
[10] X. Zeng, Y. Yu, S. Yang, Y. Lv, M.N.I. Sarker, Urban resilience for urban sustainability: concepts, dimensions, and perspectives, Sustainability 14 (2022) 2481, https://doi.org/10.3390/su14052481.
[11] H.B. Roland, External vulnerability, local resilience, and urban-rural heterogeneity in the Marshall Islands, Environ. Sci. Policy 152 (2024) 103643, https://doi.org/10.1016/j.envsci.2023.103643.
[12] M. Makvandi, W. Li, X. Ou, H. Chai, Z. Khodabakhshi, H. Chai, Z. Khodabakhshi, J. Fu, P.F. Yuan, de la J. Horimbere E., Urban heat mitigation towards climate change adaptation: an eco-sustainable design strategy to improve environmental performance under rapid urbanization, Atmosphere 14 (2023) 638, https://doi.org/10.3390/atmos14040638.
[13] P. Sidiqui, P.B. Roös, M. Herron, D.S. Jones, E. Duncan, A. Jalali, Z. Allam, B.J. Roberts, A. Schmidt, M.A.U.R. Tariq, A.A. Shah, N.A. Khan, M. Irshad, Urban Heat Island vulnerability mapping using advanced GIS data and tools, J. Earth Syst. Sci. 131 (2022) 266, https://doi.org/10.1007/s12040-022-02005-w.
[14] S.K. Rathi, S. Chakraborty, S.K. Mishra, A. Dutta, L. Nanda, A heat vulnerability index: spatial patterns of exposure, sensitivity and adaptive capacity for urbanites of four cities of India, Int. J. Environ. Res. Public Health 19 (2021) 283, https://doi.org/10.3390/ijerph19010283.
[15] C. Heinzlef, B. Robert, Y. Hémond, D. Serre, Operating urban resilience strategies to face climate change and associated risks: some advances from theory to application in Canada and France, Cities 104 (2020) 102762, https://doi.org/10.1016/j.cities.2020.102762.
[16] G. García-Blanco, D. Navarro, E. Feliu, Adopting resilience thinking through nature-based solutions within urban planning: a case study in the city of València, Buildings 13 (2023) 1317, https://doi.org/10.3390/buildings13051317.
[17] M. De Fino, R. Tavolare, G. Bernardini, E. Quagliarini, F. Fatiguso, Boosting urban community resilience to multi-hazard scenarios in open spaces: a virtual reality – serious game training prototype for heat wave protection and earthquake response, Sustain. Cities Soc. 99 (2023) 104847, https://doi.org/10.1016/j.scs.2023.104847.

[18] S. Khorat, D. Das, R. Khatun, S.M. Aziz, P. Anand, A. Khan, M. Santamouris, D. Niyogi, Cool roof strategies for urban thermal resilience to extreme heatwaves in tropical cities, Energy Build. 302 (2024) 113751, https://doi.org/10.1016/j.enbuild.2023.113751.

[19] WHO, Heatwaves, World Heal. Organ. (2024) 1–3. https://www.who.int/health-topics/heatwaves#tab=tab_1. (Accessed 25 June 2024).

[20] H. Eakin, S. Keele, V. Lueck, Uncomfortable knowledge: mechanisms of urban development in adaptation governance, World Dev. 159 (2022) 106056, https://doi.org/10.1016/j.worlddev.2022.106056.

[21] United Nations, Heat stress spike predicted to cost global economy $2.4 trillion a year, UN News Glob. Perspect. Hum. Stories (2019) 1–7. https://news.un.org/en/story/2019/07/1041652. (Accessed 25 June 2024).

[22] B. Stone, J.J. Hess, H. Frumkin, Urban form and extreme heat events: are sprawling cities more vulnerable to climate change than compact cities? Environ. Health Perspect. 118 (2010) 1425–1428, https://doi.org/10.1289/ehp.0901879.

[23] S. Eugenio Pappalardo, C. Zanetti, V. Todeschi, Mapping urban heat islands and heat-related risk during heat waves from a climate justice perspective: a case study in the municipality of Padua (Italy) for inclusive adaptation policies, Landsc. Urban Plan. 238 (2023) 104831, https://doi.org/10.1016/j.landurbplan.2023.104831.

[24] J. Luo, W. Zhuo, S. Liu, B. Xu, The optimization of carbon emission prediction in low carbon energy economy under big data, IEEE Access 12 (2024) 14690–14702, https://doi.org/10.1109/ACCESS.2024.3351468.

[25] D.S. Williams, O. Balaban, A. Ilhan, H. Paker, Ü. Şahin, B.S. Yıldırım, E. Turhan, B.A. Uncu, M. Olazabal, A policy content analysis for evaluating urban adaptation justice in İstanbul, Environ. Sci. Policy 136 (2022) 476–485, https://doi.org/10.1016/j.envsci.2022.07.014.

[26] N. Prashar, H.S. Lakra, R. Shaw, H. Kaur, Urban Flood Resilience: a comprehensive review of assessment methods, tools, and techniques to manage disaster, Prog. Disaster Sci. 20 (2023) 100299, https://doi.org/10.1016/j.pdisas.2023.100299.

[27] D. Dai, W. Dong, Y. Wang, S. Liu, J. Zhang, Exploring the relationship between urban residents' emotional changes and built environment before and during the COVID-19 pandemic from the perspective of resilience, Cities 141 (2023) 104510, https://doi.org/10.1016/j.cities.2023.104510.

[28] S. Tu, S. Yu, Urban planning for climate change: comparing climate adaptation plans between Taipei and boston, Sustainability 15 (2023) 934, https://doi.org/10.3390/su15020934.

[29] M. Shang, J. Luo, The tapio decoupling principle and key strategies for changing factors of Chinese urban carbon footprint based on cloud computing, Int. J. Environ. Res. Public Health 18 (2021) 1–17, https://doi.org/10.3390/ijerph18042101.

[30] A. Leone, L. Grassini, P. Balena, Urban planning and sustainable storm water management: gaps and potential for integration for climate adaptation strategies, Sustainability 14 (2022) 16870, https://doi.org/10.3390/su142416870.

[31] C.-D. Wu, D. Xu, M. Esperon-Rodriguez, X. Qi, W. Shui, fpubh Copyright, C. Wu, Z. Huang, C. Wang, Y. Wu, Y. Wu, C. Xue, Y. Huang, Y. Zhang, D. Zheng, Urban heat vulnerability: a dynamic assessment using multi-source data in coastal metropolis of Southeast China, Front. Public Heal. (2022), https://doi.org/10.3389/fpubh.2022.989963.

[32] L. Barrico, P. Castro, Sustainable urban expansion to make climate-resilient cities: the 21st century challenge, Urban Resil. Risk Adapt. Gov. (2019) 75–91, https://doi.org/10.1007/978-3-319-76944-8_6.

[33] Y. Shi, T. Zhang, Y. Jiang, Digital economy, technological innovation and urban resilience, Sustainability 15 (2023) 9250, https://doi.org/10.3390/su15129250.

[34] J. Ji, J. Chen, Urban flood resilience assessment using Raga-PP and KL-TOPSIS model based on PSR framework: a case study of Jiangsu province, China, Water Sci. Technol. 86 (2022) 3264–3280, https://doi.org/10.2166/wst.2022.404.

[35] K. Burchell, B. Fagan-Watson, M. King, Watson Tom, D. Holland, H. Jennings, S. Palmer, D. Thorne, C. Whitehead, T. Watson. Urban Heat: Developing the role of community groups in local climate resilience, 2017, pp. 1–88.

[36] K. Deilami, S. Shooshtarian, J. Rudner, A. Butt, M. Amati, Resilience and adaptation strategies for urban heat at regional, city and local scales. https://doi.org/10.1007/978-3-030-72196-1_8, 2022.

[37] W. Zhu, C. Yuan, Urban heat health risk assessment in Singapore to support resilient urban design — by integrating urban heat and the distribution of the elderly population, Cities 132 (2023) 104103, https://doi.org/10.1016/j.cities.2022.104103.

[38] R. Li, G. Zhu, S. Lu, L. Sang, G. Meng, L. Chen, Y. Jiao, Q. Wang, Effects of urbanization on the water cycle in the Shiyang River basin: based on a stable isotope method, Hydrol. Earth Syst. Sci. 27 (2023) 4437–4452, https://doi.org/10.5194/hess-27-4437-2023.

[39] Alexander Aylett, Progress and Challenges in the Urban Governance of Climate Change: Results of a Global Survey, MIT, Cambridge, MA, 2014.

[40] J. Parker, G.D. Simpson, A theoretical framework for bolstering human-nature connections and urban resilience via green infrastructure, Land 9 (2020) 252, https://doi.org/10.3390/land9080252.

[41] S. Krishnan, N.Y. Aydin, T. Comes, RISE-UP: resilience in urban planning for climate uncertainty-empirical insights and theoretical reflections from case studies in Amsterdam and Mumbai, Cities 141 (2023) 104464, https://doi.org/10.1016/j.cities.2023.104464.

[42] J. Parker, G.D. Simpson, Public green infrastructure contributes to city livability: a systematic quantitative review, Land 7 (2018) 161, https://doi.org/10.3390/land7040161.

[43] E.C. O'Donnell, S.N. Gosling, N.R. Netusil, F.K. Shun Chan, N.J. Dolman, Perceptions of blue-green and grey infrastructure as climate change adaptation strategies for urban water resilience, J. Br. Acad. 9 (2021) 143–182, https://doi.org/10.5871/jba/009s9.143.

[44] D.B.K. Dovie, O. Pabi, Partial climatic risk screening, adaptation and livelihoods in a coastal urban area in Ghana, Habitat Int. 138 (2023) 102868, https://doi.org/10.1016/j.habitatint.2023.102868.

[45] P.K. Appau, M.O. Asibey, R. Grant, Enabling asset-based community development solutions: pro-poor urban climate resilience in Kumasi, Ghana, Cities 145 (2024) 104723, https://doi.org/10.1016/j.cities.2023.104723.

[46] M.N.I. Sarker, B. Hossain, G. Shi, R.B.R. Firdaus, Promoting net-zero economy through climate-smart agriculture: transition towards sustainability, Sustain. Sci. (2023), https://doi.org/10.1007/s11625-023-01379-0.

[47] D. Moher, A. Liberati, J. Tetzlaff, D.G. Altman, Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement, PLoS Med. 6 (2009) e1000097, https://doi.org/10.1371/journal.pmed.1000097.

[48] M.J. Page, J.E. McKenzie, P.M. Bossuyt, I. Boutron, T.C. Hoffmann, C.D. Mulrow, L. Shamseer, J.M. Tetzlaff, E.A. Akl, S.E. Brennan, R. Chou, J. Glanville, J. M. Grimshaw, A. Hróbjartsson, M.M. Lalu, T. Li, E.W. Loder, E. Mayo-Wilson, S. McDonald, L.A. McGuinness, L.A. Stewart, J. Thomas, A.C. Tricco, V.A. Welch, P. Whiting, D. Moher, The PRISMA 2020 statement: an updated guideline for reporting systematic reviews, BMJ 372 (2021) n71, https://doi.org/10.1136/bmj.n71.

[49] F. Asif, L. Beckwith, C. Ngin, People and politics: urban climate resilience in phnom penh, Cambodia, Front. Sustain. Cities 4 (2023), https://doi.org/10.3389/frsc.2022.972173.

[50] R.R. Shaker, G. Rybarczyk, C. Brown, V. Papp, S. Alkins, (Re)emphasizing urban infrastructure resilience via scoping review and content analysis, Urban Sci 3 (2019) 1–15, https://doi.org/10.3390/urbansci3020044.

[51] H. Hao, Y. Wang, Disentangling relations between urban form and urban accessibility for resilience to extreme weather and climate events, Landsc. Urban Plan. 220 (2022) 104352, https://doi.org/10.1016/j.landurbplan.2022.104352.

[52] G. Hatvani-Kovacs, J. Bush, E. Sharifi, J. Boland, Policy recommendations to increase urban heat stress resilience, Urban Clim. 25 (2018) 51–63, https://doi.org/10.1016/j.uclim.2018.05.001.

[53] N. Allarané, V.V.A. Azagoun, A.J. Atchadé, F. Hetcheli, J. Atela, Urban vulnerability and adaptation strategies against recurrent climate risks in central africa: evidence from N'djaména city (Chad), Urban Sci 7 (2023), https://doi.org/10.3390/urbansci7030097.

[54] S. Fastenrath, L. Coenen, K. Davidson, Urban resilience in action: the resilient Melbourne strategy as transformative urban innovation policy? Sustainability 11 (2019) 693, https://doi.org/10.3390/su11030693.

[55] M.C. Therrien, J.M. Normandin, From policy challenge to implementation strategy: enabling strategies for network governance of urban resilience, risk, hazards cris, Publ. Pol. 11 (2020) 320–341, https://doi.org/10.1002/rhc3.12192.

[56] G. Datola, Implementing urban resilience in urban planning: a comprehensive framework for urban resilience evaluation, Sustain. Cities Soc. 98 (2023) 104821, https://doi.org/10.1016/j.scs.2023.104821.
[57] P. Chen, Inequality in heat: the role of spatial patterns of urban green infrastructure, Urban Clim. 53 (2024) 101820, https://doi.org/10.1016/j.uclim.2024.101820.
[58] A.A. Kutty, T.G. Wakjira, M. Kucukvar, G.M. Abdella, N.C. Onat, Urban resilience and livability performance of European smart cities: a novel machine learning approach, J. Clean. Prod. 378 (2022) 1–7, https://doi.org/10.1016/j.jclepro.2022.134203.
[59] A.H. Eldesoky, J. Gil, M.B. Pont, Combining environmental and social dimensions in the typomorphological study of urban resilience to heat stress, Sustain. Cities Soc. 83 (2022) 103971, https://doi.org/10.1016/j.scs.2022.103971.
[60] M. Moench, F. Khan, K. MacClune, C. Amman, P. Tran, K. Hawley, Transforming vulnerability: shelter, adaptation, and climate thresholds, Clim. Dev. 9 (2017) 22–35, https://doi.org/10.1080/17565529.2015.1067592.
[61] X. Huang, R. Yao, T. Xu, S. Zhang, The impact of heatwaves on human perceived thermal comfort and thermal resilience potential in urban public open spaces, Build. Environ. 242 (2023) 110586, https://doi.org/10.1016/j.buildenv.2023.110586.
[62] S. Kang, M. Lee, J. Jung, Analysis of sustainable urban forms for climate change adaptation and mitigation, Environ. Sustain. Indic. 22 (2024) 100337, https://doi.org/10.1016/j.indic.2024.100337.
[63] J. Wei, Z. Chen, X.-Y.X.Y. Kong, Y.J.Y.-J. Zhang, The prevention strategies for strengthening the resilience of urban high-rise and high-density built environment based on multi-objective optimization: an empirical study in Guangzhou, China, Environ. Impact Assess. Rev. 101 (2023) 107106, https://doi.org/10.1016/j.eiar.2023.107106.
[64] H. Wang, S. Du, Y. Zhong, S. Liu, T. Xu, Y. Zhao, W. He, H. Xue, Y. He, X. Gao, R. Jiang, Unveiling the impact mechanism of urban resilience on carbon dioxide emissions of the Pearl River Delta urban agglomeration in China, Environ. Impact Assess. Rev. 105 (2024) 107422, https://doi.org/10.1016/j.eiar.2024.107422.
[65] M.O. Asibey, F. Mintah, I.O. Adutwum, R.S. Wireko-Gyebi, J.N. Tagnan, L.L. Yevugah, K.O. Agyeman, A.J. Abdul-Salam, Beyond rhetoric: urban planning-climate change resilience conundrum in Accra, Ghana, Cities 131 (2022) 103950, https://doi.org/10.1016/j.cities.2022.103950.
[66] G. Rohat, O. Wilhelmi, J. Flacke, A. Monaghan, J. Gao, M. van Maarseveen, H. Dao, Assessing urban heat-related adaptation strategies under multiple futures for a major U.S. city, Clim. Change 164 (2021), https://doi.org/10.1007/s10584-021-02990-9.
[67] K. Bosomworth, A. Trundle, D. McEvoy. Responding to the urban heat island: a policy and institutional analysis, 2013, pp. 1–64. Melbourne, Australia, http://www.vcccar.org.au/publication/final-report/responding-to-urban-heat-island-policy-and-institutional-analysis.
[68] E. Chu, I. Anguelovski, J.A. Carmin, Inclusive approaches to urban climate adaptation planning and implementation in the Global South, Clim, Policy 16 (2016) 372–392, https://doi.org/10.1080/14693062.2015.1019822.
[69] G. Masik, R. Gajewski, Working towards urban capacity and resilience strategy implementation: adaptation plans and strategies in Polish cities, Cities 119 (2021), https://doi.org/10.1016/j.cities.2021.103381.
[70] H.A.C. Thái, Vulnerability context: a study on livelihood pathways of the indigenous people, in: Adv. Asian Human-Environmental Res, 2018, pp. 1–34, https://doi.org/10.1007/978-3-319-71171-3_1.
[71] E. Shirgir, R. Kheyroddin, M. Behzadfar, Developing strategic principles of intervention in urban green infrastructure to create and enhance climate resilience in cities—case study: yousef abad in tehran, J. Clim. Chang. 5 (2019) 61–73, https://doi.org/10.3233/jcc190007.
[72] Y. Gültekin, Strategies to improve urban energy efficiency for urban resilience, IOP Conf. Ser. Mater. Sci. Eng. 1203 (2021) 022020, https://doi.org/10.1088/1757-899x/1203/2/022020.
[73] A. Wardekker, Contrasting the framing of urban climate resilience, Sustain. Cities Soc. 75 (2021) 103258, https://doi.org/10.1016/j.scs.2021.103258.
[74] I. Kyprianou, G. Artopoulos, A. Bonomolo, T. Brownlee, R.Á. Cachado, C. Camaioni, V. Đokić, R. D'Onofrio, Z. Đukanović, S. Fasola, C.F. Di Giovanni, R. Cocci Grifoni, P. Hadjinicolaou, G. Ilardo, P. Jovanović, S. La Grutta, V. Malizia, G.E. Marchesani, M.F. Ottone, E. Trusiani, J. Živković, S. Carlucci, Mitigation and adaptation strategies to offset the impacts of climate change on urban health: a European perspective, Build. Environ. 238 (2023), https://doi.org/10.1016/j.buildenv.2023.110226.
[75] X. Liu, G. Tian, J. Feng, H. Hou, B. Ma, Adaptation strategies for urban warming: assessing the impacts of heat waves on cooling capabilities in Chongqing, China, Urban Clim. 45 (2022) 101269, https://doi.org/10.1016/j.uclim.2022.101269.
[76] E. Boyd, S. Juhola, Adaptive climate change governance for urban resilience, Urban Stud. 52 (2015) 1234–1264, https://doi.org/10.1177/0042098014527483.
[77] O.P. Agboola, M. Tunay, Urban resilience in the digital age: the influence of Information-Communication Technology for sustainability, J. Clean. Prod. 428 (2023) 139304, https://doi.org/10.1016/j.jclepro.2023.139304.
[78] S. Mehryar, I. Sasson, S. Surminski, Supporting urban adaptation to climate change: what role can resilience measurement tools play? Urban Clim. 41 (2022) 101047 https://doi.org/10.1016/j.uclim.2021.101047.
[79] C. Adams, M. Moglia, N. Frantzeskaki, Realising transformative agendas in cities through mainstreaming urban nature-based solutions, Urban For. Urban Green. 91 (2024) 128160, https://doi.org/10.1016/j.ufug.2023.128160.
[80] L. Keith, S. Meerow. Planning for Urban Heat Resilience, American Planning Association, Chicago, US, 2022, pp. 1–101.
[81] S. Rezvani, N. de Almeida, M. Falcão, Climate adaptation measures for enhancing urban resilience, Buildings 13 (2023) 2163, https://doi.org/10.3390/buildings13092163.
[82] P. Pamukcu-Albers, J.C. Azevedo, F. Ugolini, A. Zuniga-Teran, J. Wu, Urban resilience through green infrastructure, Adapt, Built Environ. Clim. Chang. Des. Princ. Clim. Emergencies (2023) 53–69, https://doi.org/10.1016/B978-0-323-95336-8.00018-4.
[83] N. Abuwaer, S. Ullah, S.G. Al-Ghamdi, Building climate resilience through urban planning: strategies, challenges, and opportunities, sustain, Cities a Chang. Clim. (2023) 185–206, https://doi.org/10.1002/9781394201532.ch12.
[84] T.H.F. Wong, R.R. Brown, The water sensitive city: principles for practice, Water Sci. Technol. 60 (2009) 673–682, https://doi.org/10.2166/wst.2009.436.
[85] E. Sharifi, A. Sivam, S. Karuppannan, J. Boland, Landsat surface temperature data analysis for urban heat resilience: case study of Adelaide, Lect. Notes Geoinf. Cartogr. (2017) 433–447, https://doi.org/10.1007/978-3-319-57819-4_24.
[86] C. Ordóñez Barona, T.L.E. Trammell, Editorial: urban trees in a changing climate: science and practice to enhance resilience, Front. Ecol. Evol. 10 (2022) 1–3, https://doi.org/10.3389/fevo.2022.882510.
[87] J. Colding, S. Barthel, The potential of "Urban Green Commons" in the resilience building of cities, Ecol. Econ. 86 (2013) 156–166, https://doi.org/10.1016/j.ecolecon.2012.10.016.
[88] I. Malik, A.L. Prianto, A. Abdillah, Z. Rusnaedy, A.A. Amalia, Urban resilience strategy in the climate change governance in makassar city, Indonesia, J. Gov. Civ, Soc. 5 (2021) 31, https://doi.org/10.31000/jgcs.v5i1.3884.
[89] L. Liu, Y. Luo, J. Pei, H. Wang, J. Li, Y. Li, Temporal and spatial differentiation in urban resilience and its influencing factors in henan province, Sustainability 13 (2021) 12460, https://doi.org/10.3390/su132212460.
[90] V. D'Ambrosio, Climate vulnerability, impact scenarios and adaptation strategies for resilient cities, Techne 15 (2018) 246–256, https://doi.org/10.13128/Techne-22097.
[91] H. Wang, H. Xue, W. He, Q. Han, T. Xu, X. Gao, S. Liu, R. Jiang, M. Huang, Spatial-temporal evolution mechanism and dynamic simulation of the urban resilience system of the Guangdong-Hong Kong-Macao Greater Bay Area in China, Environ. Impact Assess. Rev. 104 (2024) 107333, https://doi.org/10.1016/j.eiar.2023.107333.
[92] E. Adu Boateng, M.O. Asibey, P.B. Cobbinah, I.O. Adutwum, D.K. Blija, Enabling nature-based solutions: innovating urban climate resilience, J. Environ. Manage. 332 (2023) 117433, https://doi.org/10.1016/j.jenvman.2023.117433.
[93] A. Sharifi, Resilience of urban social-ecological-technological systems (SETS): a review, Sustain. Cities Soc. 99 (2023) 104910, https://doi.org/10.1016/j.scs.2023.104910.

[94] M. Suárez, A.M. Rieiro-Díaz, D. Alba, J. Langemeyer, E. Gómez-Baggethun, I. Ametzaga-Arregi, Urban resilience through green infrastructure: a framework for policy analysis applied to Madrid, Spain, Landsc. Urban Plan. 241 (2024), https://doi.org/10.1016/j.landurbplan.2023.104923.
[95] R. Zhao, C. Fang, J. Liu, L. Zhang, The evaluation and obstacle analysis of urban resilience from the multidimensional perspective in Chinese cities, Sustain. Cities Soc. 86 (2022) 104160, https://doi.org/10.1016/j.scs.2022.104160.
[96] M. Mabrouk, H. Haoying, Urban resilience assessment: a multicriteria approach for identifying urban flood-exposed risky districts using multiple-criteria decision-making tools (MCDM), Int. J. Disaster Risk Reduct. 91 (2023) 103684, https://doi.org/10.1016/j.ijdrr.2023.103684.
[97] F. Gaglione, D.A. Ayiine-Etigo, Resilience as an urban strategy: the role of green interventions in recovery plans, TeMA J. L. Use Mobil, Environ. Times 14 (2021) 279–284.
[98] L. Liu, Z. Zhang, S. Ding, F. Yang, T. Fu, Combined effects of climate change on urban resilience in the Tibetan Plateau, Environ. Impact Assess. Rev. 102 (2023) 107186, https://doi.org/10.1016/j.eiar.2023.107186.
[99] A. Wardekker, Contrasting the framing of urban climate resilience, Sustain. Cities Soc. 75 (2021) 103258, https://doi.org/10.1016/j.scs.2021.103258.
[100] P. Pamukcu-Albers, F. Ugolini, D. La Rosa, S.R. Grădinaru, J.C. Azevedo, J. Wu, Building green infrastructure to enhance urban resilience to climate change and pandemics, Landsc. Ecol. 36 (2021) 665–673, https://doi.org/10.1007/s10980-021-01212-y.
[101] H. Leitner, E. Sheppard, S. Webber, E. Colven, Globalizing urban resilience, Urban Geogr. 39 (2018) 1276–1284, https://doi.org/10.1080/02723638.2018.1446870.
[102] S.E. Sharma, Urban climate resilience under racial capitalism: governing pluvial flooding across Amsterdam and Dhaka, Geoforum 145 (2023) 103817, https://doi.org/10.1016/j.geoforum.2023.103817.
[103] M.C. Therrien, S. Usher, D. Matyas, Enabling strategies and impeding factors to urban resilience implementation: a scoping review, J. Contingencies Cris. Manag. 28 (2020) 83–102, https://doi.org/10.1111/1468-5973.12283.
[104] P. Varnakovida, H.Y.K. Ko, Urban expansion and urban heat island effects on Bangkok metropolitan area in the context of eastern economic corridor, Urban Clim. 52 (2023) 101712, https://doi.org/10.1016/j.uclim.2023.101712.
[105] L. T. A., I. M. H., I. M. I. M. M. A, The potential of urban green infrastructure in mitigating urban heat islands in the semi-arid regions Int. J. Acad. Res. Bus. Soc. Sci. 13 (2023) 180–190, https://doi.org/10.6007/ijarbss/v13-i6/17392.
[106] L. Wang, Exploring a knowledge map for urban resilience to climate change, Cities 131 (2022) 104048, https://doi.org/10.1016/j.cities.2022.104048.
[107] G. Lucertini, G. Di Giustino, Urban and peri-urban agriculture as a tool for food security and climate change mitigation and adaptation: the case of mestre, Sustainability 13 (2021) 5999, https://doi.org/10.3390/su13115999.
[108] H. Bulkeley, Cities and the governing of climate change, Annu. Rev. Environ. Resour. 35 (2010) 229–253, https://doi.org/10.1146/annurev-environ-072809-101747.
[109] N. Muse, D.M. Iwaniec, C. Wyczalkowski, K.J. Mach, Heat exposure and resilience planning in Atlanta, Georgia, Environ. Res. Clim. 1 (2022) 015004, https://doi.org/10.1088/2752-5295/ac78f9.
[110] K. Ferhati, S. Chouguiat Belmallem, A. Burlea-Schiopoiu, The role of the COVID-19 crisis in shaping urban planning for improved public health: a triangulated study, Int. J. Environ. Res. Public Health 20 (2023), https://doi.org/10.3390/ijerph20053804.
[111] J. Chen, Z. Tao, W. Wu, L. Wang, D. Chen, Influence of urban park pathway features on the density and intensity of walking and running activities: a case study of Shanghai city, Land 13 (2024) 156, https://doi.org/10.3390/land13020156.
[112] P.K. Diem, C.T. Nguyen, N.K. Diem, N.T.H. Diep, P.T.B. Thao, T.G. Hong, T.N. Phan, Remote sensing for urban heat island research: progress, current issues, and perspectives, Remote Sens. Appl. Soc. Environ. 33 (2024) 101081, https://doi.org/10.1016/j.rsase.2023.101081.
[113] C. Folke, S.R. Carpenter, B. Walker, M. Scheffer, T. Chapin, J. Rockström, Resilience thinking: integrating resilience, adaptability and transformability, Ecol. Soc. 15 (2010) art20, https://doi.org/10.5751/ES-03610-150420.
[114] T. Kjellstrom, A.J. McMichael, Climate change threats to population health and well-being: the imperative of protective solutions that will last, Glob. Health Action 6 (2013) 1–10, https://doi.org/10.3402/gha.v6i0.20816.
[115] S. Koutra, M. Balsells Mondejar, V. Becue, The nexus of 'urban resilience' and 'energy efficiency' in cities, Curr. Res. Environ. Sustain. 4 (2022) 100118, https://doi.org/10.1016/j.crsust.2021.100118.
[116] L. Chelleri, J.J. Waters, M. Olazabal, G. Minucci, Resilience trade-offs: addressing multiple scales and temporal aspects of urban resilience, Environ. Urban. 27 (2015) 181–198, https://doi.org/10.1177/0956247814550780.
[117] B. Walker, D. Salt, Resilience Thinking: Sustaining Ecosystems and People in a Changing World, Island Press, 2012.
[118] H. Ernstson, S.E.V. Der Leeuw, C.L. Redman, D.J. Meffert, G. Davis, C. Alfsen, T. Elmqvist, Urban transitions: on urban resilience and human-dominated ecosystems, Ambio 39 (2010) 531–545, https://doi.org/10.1007/s13280-010-0081-9.
[119] R.P.H. Snep, J. Klostermann, M. Lehner, I. Weppelman, Social housing as focus area for Nature-based Solutions to strengthen urban resilience and justice: lessons from practice in The Netherlands, Environ. Sci. Policy 145 (2023) 164–174, https://doi.org/10.1016/j.envsci.2023.02.022.
[120] A. Gamal, O.A. Eleinen, S. Eltarabily, D. Elgheznawy, Enhancing urban resilience in hot humid climates: a conceptual framework for exploring the environmental performance of vertical greening systems (VGS), Front. Archit. Res. 12 (2023) 1260–1284, https://doi.org/10.1016/j.foar.2023.09.003.