
# URBAN WATER RESILIENCE: STRATEGIES AND CHALLENGES CONSIDERING CLIMATE CHANGE

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## Abstract

The increasing urbanization and climate change have placed significant pressure on water resources in urban areas, leading to more frequent water scarcity and extreme weather events. This pressure can be addressed by understanding the challenges of water management from the perspective of sustainability and urban resilience. The purpose of this study was to identify the challenges and strategies for managing water resources in urban areas during periods of water scarcity and extreme weather events in urban environments. To achieve this, we conducted an exploratory and qualitative study using secondary data from government reports, academic studies, and climate data. The results are presented in sections addressing the challenges and strategies for enhancing urban water resilience considering climate change. These findings highlight key safety concerns that have already been issues for cities but have been exacerbated by climate change. The strategies are categorized into the following groups: (I) Urban Infrastructure Strategies, (II) Water Management Strategies, and (III) Policy and Planning Strategies. The results indicate that the restoration of water bodies, the expansion of permeable areas, proactive stakeholder participation, and strategic planning are critical differentiators for mitigating impacts and enhancing cities resilience to climate change.

**Keywords:** Water Resources, Climate Change, Urban Planning, Water Resilience, Water Management.

## 1. Introduction

Urban systems play a crucial role in the pursuit of substantial reductions in polluting gas emissions and in fostering development that can withstand the impacts of climate change (KYPRIANOU *et al*., 2023). This significance is particularly evident in the context of integrated planning, which involves the interconnection between physical infrastructure, natural elements, and social aspects (IPCC, 2023; KYPRIANOU *et al*., 2023).


Recent research has indicated that climate change can have critical impacts on water resources management (MARQUES; VERAS; RODRIGUEZ, 2023). Currently, urban areas are already facing a concerning scenario regarding the availability and demand for these resources (KYPRIANOU *et al*., 2023). The growth in population and economic activities in cities has significantly increased the demand for water, while the availability of water resources has decreased (SACHIDANANDA; WEBB; RAHIMIFARD, 2016), placing greater pressure on water resources and leading to challenges related to water supply pollution (RAMOS *et al*., 2019; MARQUES; VERAS; RODRIGUEZ, 2023). The vulnerability of water resources in urban environments is a primary and complex responsibility for planners in both the public and private sectors. Moreover, it involves challenges in gathering and accessing information, considering various aspects of human life in the decision-making process (KUMAR; DEKA; KUMARI, 2020)

Water resources management in urban environments has led to increasing costs in economic, social, and environmental aspects, even in nations with a history of well-established practices. This is attributed to the obsolescence of existing infrastructure, the intensification of the urbanization process, the emergence of new contaminants, conflicts over water use, and actions to mitigate the impacts of climate change (LARSEN *et al*., 2016).

This study has identified gaps in the field, some of which informed the research question: 'What strategies for water resource management can effectively promote water resilience in urban areas, addressing issues of water scarcity and extreme weather events, and how can these strategies be tailored to the unique needs of urban environments?' In this context, the study aimed to pinpoint the challenges and strategies for water resource management in urban areas during periods of water scarcity and extreme weather events.

## 2. Theoretical foundation

Climate change, resulting from human actions, is causing an increased frequency of extreme weather events in various parts of the world (YANG; YANG; XIA, 2021; IPCC, 2023), especially in urban areas (SALIMI; AL-GHAMDI, 2020). These changes have resulted in widespread negative impacts, affecting food and water security, public health, economic structures, and society, causing associated losses and damages to the environment and the population (IPCC, 2023).

Ensuring a more sustainable future for humanity is the primary aim of the Sustainable Development Goals (SDGs), and this goal is intrinsically linked to water security, especially during extreme events. In alignment with this research, SDG 6 places central importance on ensuring access to clean water and sanitation for all, with the objective of optimizing water use across all sectors by 2030. It also aims to establish a sustainable water supply, thereby reducing


the number of people facing water scarcity. Within the context of this discussion, SDG 13 also plays a crucial role by encouraging the adoption of immediate measures to mitigate the impacts of climate change. It focuses on increasing resilience and adaptability to climate risks and natural disasters by incorporating adaptation strategies into national policies, strategies, and planning (UNITED NATIONS ORGANIZATION, 2019). Considering this framework, it is essential to underscore the importance of scenario planning in decision-making processes. Scenario planning helps identify uncertainties and prepares responses to potential impacts on the water resources sector in urban environments.

In response to this pressing need, the development of strategies should primarily focus on ensuring a sustainable supply of water resources. This requires the formulation of projects based on an understanding of climate change projections (KUMAR; DEKA; KUMARI, 2020). From this perspective, it is crucial for water service providers to create more robust, resilient, and ecologically responsible urban systems capable of addressing future uncertainties (CASAL-CAMPOS *et al.*, 2018).

The limitations of the current water management system in urban environments also stem from its significant dependence on large volumes of water, high investment costs, and the necessity of stable government institutions. Moreover, these issues are exacerbated by extended planning deadlines and inefficient utilization of available resources. (LARSEN *et al.*, 2016).

Considering the theme at hand, the concept of Urban Water Resilience emerges as an alternative for adapting to the new reality in the face of climate change. Thus, Urban Water Resilience is defined as 'the degree to which an urban water system continues to function under progressively increasing disturbance" (MAKROPOULOS *et al.*, 2018).

Achieving Urban Water Resilience in the face of climate change involves water resource management strategies that ensure the availability of high-quality water for the population, even in times of scarcity or crisis. Integrating resilience into urban drainage systems holds significant importance in mitigating threats or disruptions caused by floods, restoring operation after unexpected failures due to increased water volume, preventing service interruptions, and reducing losses and costs associated with the cities served (LI *et al.*, 2023).

## 3. Methodology

This study was based on exploratory and qualitative research, where the procedure for collecting relevant data and conducting analysis relied on a bibliographic search of secondary sources. Exploratory research aims to deepen the understanding of a problem while simultaneously developing hypotheses and offering a comprehensive perspective on a specific event or


object of study (GIL, 2019). Qualitative research, as an approach, seeks to understand the underlying reasons for issues without involving the quantification of values, given that the data examined are non-metric in nature (GERHARDT; SILVEIRA, 2009)

The bibliographic survey focused on the following aspects: Water Resources, Climate Change, Extreme Climate Events, Water Vulnerability, Urban Planning, and Water and Urban Resilience. The bibliographic survey involves materials that use secondary sources, which are materials proven scientifically or through analytical methods (GIL, 2019).

The literature review aimed to investigate the following questions:

(Q1): What are the primary challenges faced by water resource sectors in urban areas as a result of climate change?

(Q2): What water resource management strategies can effectively promote water resilience in urban areas, helping to address water scarcity and extreme weather events?

(Q3): How can these water resource management strategies be adapted to meet the specific needs of urban environments?

The research was conducted by examining electronic resources from public institutions and Non-Governmental Organizations (NGOs), which included research articles and recent books related to the topic of study. The academic databases consulted included Google Scholar, Scopus, Springer and the Portal de Periódicos da Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES).

## 4. Results

Faced with potential changes in water resources, stemming from both climate change and human activities, it is crucial to adopt a multidisciplinary approach to water management and planning to enhance decision-making strategies and guidance (SHANNON *et al.*, 2023).

This approach requires understanding and effectively integrating these potential pressure factors into the planning cycle (MARQUES; VERAS; RODRIGUEZ, 2023) while also gaining a clear understanding of its primary challenges (KUMAR; DEKA; KUMARI, 2020)

### 4.1. Main Challenges and Impacts of Climate Change on Water Resources Management on Urban Environments.

Urban areas face a series of challenges when it comes to water resilience. Urbanization is one of the main factors contributing to water scarcity in cities. Rapid urban growth results in increased demand for drinking water and decreased availability of water resources (RAMOS *et*


*al.*, 2019). The main challenges and impacts related to climate change in the management of water resources in urban environments are outlined in Table 1.

Table 1 - Challenges to climate change in the management of water resources in urban environments

| Challenge | Description |
|---|---|
| Accelerated Urban Growth | Population growth and rapid urban expansion lead to an increased demand for water, extensive soil sealing, and degradation of green areas. These factors affect the river basins' capacity to regulate water flow, thereby raising the risks of both flooding and water scarcity (; LARSEN et al., 2016; IPCC, 2023; KYPRIANOU *et al.*, 2023). |
| Water Pollution | The discharge of untreated sewage and pollution contaminate water sources, damaging their quality and availability for human supply and economic activities (LARSEN *et al.*, 2016; SHANNON *et al.*, 2023). |
| Climate Change | Climate change has been one of the biggest uncertainties that impact the planning and management of urban water systems (CASAL-CAMPOS, 2018) due to its effects on the hydrological cycle, altering rainfall patterns, runoff volumes and peak flows (ZAHMATKESH *et al.*, 2015). |
| Inefficiency in water consumption | The inefficient use of water in urban activities increases pressure on water resources and contributes to water scarcity in urban environments (LASEN *et al.*, 2016). |
| Lack of integrated planning | The absence of integrated planning and the lack of coordination between sectors make it difficult to implement sustainable water resources management strategies in cities (KUMAR; DEKA; KUMARI, 2020; LASEN *et. al.*, 2016). |
| Improper occupation and use of land | Climate change and changes in land use have emerged as the main contributors to urban flooding, overcoming factors such as undersized infrastructure features (LI *et al.*, 2023). |
| Social vulnerability | Low-income populations and vulnerable communities are often most affected by water scarcity and extreme weather events, due to a lack of access to adequate infrastructure and resources to face these challenges (BUTLER *et al.*, 2017; LASEN *et al.*, 2016) |


| | |
|---|---|
| Lack of investment in urban infrastructure | The limited supply of financial resources and insufficient investments in water infrastructure make it challenging to ensure universal access to drinking water and basic sanitation in urban areas (LASEN *et al*., 2016). |
| Institutional and Legal Barriers | Institutional and legal barriers, such as conflicts of competence between different spheres of government and lack of alignment, can hinder the effective implementation of water resources management plans and programs in urban areas (KUMAR; DEKA; KUMARI, 2020). |

Source: The Authors.

Considering the challenges in regions with high urbanization, it's crucial to prioritize the development of cost-effective and resource-efficient water management systems that can provide necessary services to urban areas without the limitations of traditional centralized systems (LARSEN *et al*., 2016).

The challenges caused by flooding in urban areas are influenced by various factors, such as (LI *et al*., 2023): (I) variations in precipitation patterns, (II) changes in land use and occupation, (III) degradation and aging of urban stormwater infrastructure, (IV) obstruction of drainage systems and, (V) overflow of water bodies.

The remaining permeable areas in urban environments have limited capacity to fully intercept extreme rainfall. Additionally, high urbanization reduces the permeable areas, leading to increased flooding during heavy rainfall events (LI *et al*., 2023).

It is observed that most of the challenges identified in Table 1 are not solely the result of climate change; they stem from integrated urban planning and city management. Climate change exacerbates these challenges, leading to economic, social, and environmental losses. Municipalities may not always resolve these issues and enhance urban water resilience, but they make progress by implementing dialogues, communication, and information channels to address these problems.

Finally, it is understood that solving urban water challenges requires innovation and development processes in almost all technical, organizational and institutional dimensions. (LASEN *et al.*, 2016).

### 4.2. Strategies for Water Resources Management

Adaptation and mitigation actions that cities can adopt in the coming decades, through urban revitalization, play a crucial role in addressing climate change (KYPRIANOU *et al*.,


2023). However, addressing obstacles related to water resources management in urban areas requires the implementation of innovative procedures and progress in almost all technical, organizational, and institutional aspects (LARSEN *et al.*, 2016).

The main strategies identified for Climate Change in Water Resources Management for Urban Environments are proposed in Tables 2, 3 and 4, divided respectively into the following groups: (I) Strategies for Urban Infrastructure, (II) strategies for Water Management and, (III) Policy and Planning strategies.

Table 2 - Main strategies for Urban Infrastructure in managing urban environments adapting to Climate Change.

| **Strategies for Urban Infrastructure** | |
|---|---|
| **Strategies** | **Description** |
| Green and Blue Infrastructure | Designing stormwater infrastructure in response to a set of possible future events is crucial to building a resilient urban drainage system (LI *et al.*, 2023).<br><br>The adaptation of green/natural and gray/physical infrastructure has the potential to reduce costs and contribute to flood control, sanitation, water resource management, landslide prevention, and coastal region protection (IPCC, 2023; SHANNON, 2023).<br><br>Green infrastructure has the potential to significantly enhance the sustainability and resilience of traditional urban drainage systems (SITZENFREI; DIAO; BUTLER, 2022).<br><br>Green and blue infrastructure, which encompasses practices like urban tree planting, green roofs, pond and lake creation, and waterway restoration, can combat climate change in several ways. This includes capturing and storing carbon, preventing excessive emissions, reducing energy consumption, lowering the risk of extreme climate events such as heatwaves, heavy rains, and droughts, and promoting additional benefits for health, well-being, and livelihoods (IPCC, 2023) |

Source: The Authors.

Table 3 - Main strategies for water management in water resources management in urban environments adapting to climate change.


| Strategies for Water Management | |
|---|---|
| **Strategies** | **Description** |
| Recovery of Water Sources and Environmental Protection Areas | Removing pollutants from water sources is an additional task to make a river basin resilient (KUMAR; DEKA; KUMARI, 2020).<br>Maintaining or reintroducing a more natural state of the urban river basin will result in mitigating the impacts of rainwater drainage on the aquatic ecosystem and consequently minimizing the risk of flooding (LARSEN *et al.*, 2016). |
| Revitalization of floodplain areas and wetlands | Restore floodplain areas and urban wetlands to improve water retention and aquifer recharge, reducing vulnerability to extreme weather events (IPCC, 2023).<br>Preservation and restoration of "blue carbon" coastal ecosystems, such as mangroves, tidal marshes and seagrass meadows, can trigger a reduction in carbon emissions and/or an increase in carbon capture and storage (IPCC, 2023).<br>These coastal wetlands also play a key role in protecting against coastal erosion and flooding (IPCC, 2023). |
| Conservation and efficient use of water | The implementation of intelligent rainwater collection systems can play a significant role in reducing the use of drinking water and optimizing the urban drainage system (SITZENFREI; DIAO; BUTLER, 2022). |
| Monitoring and use of advanced technologies | Monitoring, computational modeling, and remote sensing technologies enable real-time tracking of water resource conditions, facilitating rapid responses to climate change (SITZENFREI; DIAO; BUTLER, 2022; RAMOS *et al.*, 2019; SALIMI; AL-GHAMDI, 2020; SHANNON, 2023).<br>Adopting combinations of non-structural measures, such as early warning systems, has been shown to reduce the number of casualties (IPCC, 2023). |
| Diversification of supply sources | The management system must maintain its service during a critical event, despite the social system responding to strong changes in the distribution of demand (SITZENFREI; DIAO; BUTLER, 2022; SHANNON, 2023). |

Source: The Authors.

Table 4 - Main policy and planning strategies for managing water resources in urban environments adapting to climate change


| Strategies for policy and planning | |
|---|---|
| **Strategies** | **Description** |
| Integrated management of water resources | In order to support strategic planning, water companies need a way to assess how their system performs under a range of changing conditions. (NIKOLOPOULOS *et al.*, 2019). |
| Development of contingency plans | Obtaining a deeper understanding of changes in urban water systems during these events is essential for conducting a more accurate and comprehensive resilience assessment. This helps avoid the adoption of inappropriate or insufficient emergency solutions and ensures water supply in critical situations (SITZENFREI; DIAO; BUTLER, 2022; SHANNON, 2023). |
| Sustainable urban planning | Urban planning that includes the conservation of aquifer recharge areas, preservation of floodplain areas, and protection of springs is essential to ensure the availability of water in sufficient quantity and quality in cities (SHANNON, 2023). |
| Environmental Education | Raising public awareness about the importance of conservation and rational use of water is crucial to promoting behavioral change and the adoption of sustainable practices (SHANNON, 2023). |
| Climate Adaptation Policies | Long-term political planning, through the analysis of possible event scenarios with climate change, is an essential tool for ensuring water security in the urban environment (MARQUES; VERAS; RODRIGUEZ, 2023). |
| Partnerships and governance | For evaluating and implementing an efficient water management system, it's crucial to involve various levels of government and engage participants from the scientific and civil society sectors. This includes key collaborators such as users, scientists, authorities, planners, and policymakers (IPCC, 2023; KUMAR; DEKA; KUMARI, 2020) |

Source: The Authors.

To formulate strategies with a high probability of success, both in the present and the future, it is essential to gain a deep understanding of the attributes and interconnections that define the operational characteristics (reliability and resilience) and strategic aspects (sustainability) of Urban Water Resource Management (CASAL-CAMPOS *et al.*, 2018). This understanding should encompass elements related to health, the environment, the economy, sociocultural factors, and technical aspects (KUMAR; DEKA; KUMARI, 2020).

The inclusion of innovation in urban water management systems capable of addressing sector challenges has sparked significant debates. These visions represent focal points for future


innovation initiatives, and while not mutually exclusive, they offer multiple areas of overlap and potential collaboration (LARSEN *et al.*, 2016).

Furthermore, there is an undeniable need to invest financial resources in climate-resilient infrastructure and targeted plans and programs to reduce vulnerability (SALIMI; AL-GHAMDI, 2020). The required resource allocation will depend on the existing infrastructure, site-specific environmental analysis, and climate projections for the future.

nother alternative to enhance the resilience of water resource management systems in urban environments is the application of intelligent strategies that significantly improve information collection and system monitoring using data as a foundation. This also involves the adoption of decentralized options for real-time control of intelligent components (SITZENFREI; DIAO; BUTLER, 2022). Such implementations can also support telecommunications sectors in an integrated manner to alert residents in vulnerable or high-risk areas (SALIMI; AL-GHAMDI, 2020).

Ultimately, there is no universal solution to these challenges. However, given the complexity of urban water management, it is crucial to accelerate efforts in scientific research and build on successful experiences in other scenarios with a similar challenge (LARSEN *et al.*, 2016).

## 5. Conclusions

The results suggest that restoring the river basin and water courses plays a fundamental role in reducing the impacts of climate change in the urban environment. Furthermore, this initiative tends to strengthen the recovery capacity of the water bodies that make up the urban landscape and improve the quality of life of its inhabitants.

Strategies aimed at structures should aim to improve the environment, focusing on sustainability and flexibility over climate conditions, considering more permeable areas. In addition, expansion of green areas in urban areas reduces the flood peak in cases of torrential events or intense, short-term rainfall.

In this context, developing public policies focused on water resilience in the urban environment promotes effective and sustainable water resource management in response to emerging challenges. It also fosters collaboration among stakeholders and aids in the implementation of multidisciplinary tools.

In response to climate change and its recurrent, severe effects, it is of utmost importance for managers, supported by technologies such as indicators, remote sensing, warning systems, and mobile applications, to monitor extreme events. This monitoring helps in developing plans


and strategies to prepare cities, enhancing their resilience to extreme weather events. The goal is to ensure water and human life security while minimizing environmental and economic damage.

The main contribution of this article is to highlight the main challenges and strategies for urban water management in the face of climate change as a precaution against water scarcity and combating extreme weather events.

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