International Journal of Sustainable Development and Planning
Vol. 16, No. 7, November, 2021, pp. 1263-1273
Journal homepage: http://iieta.org/journals/ijsdp

Water Resilience in the Indian Context: Definitions, Policies, Approaches and Gaps

Kaaviya Rajarethinam*, Varuvel Devadas

Department of Architecture and Planning, Indian Institute of Technology Roorkee, Roorkee 247667, India

Corresponding Author Email: kaaviya.r@ar.iitr.ac.in

https://doi.org/10.18280/ijsdp.160707

Received: 23 June 2021
Accepted: 10 October 2021

Keywords:
water resilience, Indian water policy, governance, Delphi technique

ABSTRACT

India has been facing multiple water-related challenges owing to a large population. Increase in water crisis, water resources-related pollution, mismanagement of existing resources, and an imbalance in water policies due to various gaps and lacuna at both State and Central level of governance. Water resilience is emerging as a research field that addresses multiple water management issues responding to emerging challenges, such as global climate and environmental changes. The study focuses on secondary data and literature studies from Web of Science and Scopus databases to examine the concepts of resilience as defined by literature, dimensions with planning and governance and its implications in the existing Indian water policy framework. The methodology incorporated the systematic Delphi technique in formulating the governance gaps in the research area. The highlighted gaps are further ranked using statistical methods. According to the findings, the most critical gap is the lack of integrated strategic policy planning encompassing all water-related disruptions. As its identified gaps are interconnected and aggravate each other, a comprehensive approach is required. The study suggests potential research areas that strengthen water resilience governance. There is a need to increase resilience, signifying the sheer urgency in embellishing resilience to the increasing demands and effective management of existing water resources.

1. INTRODUCTION

Resilience hails from the Latin word 'resilio', denoting 'to bounce back or bounce forward'. The concept of *resilience* provides insight into managing sudden shocks or stresses that threaten or collapse the prevailing system. Resilience has also helped bridge the gap between risk reduction methodologies during disasters and compliance with climate changes by focusing on strengthening the performance of a system at the time of hazards rather than preventing those from occurring. Among the subsystems, the water system is the most critically affected by environmental disruptions. Water use has grown sixfold over the last century and is increasing at a rate of around 1% each year. Climate change, coupled with the rising frequency and severity of extreme events such as storms, floods, and droughts, is expected to exacerbate the situation in countries already facing 'water stress' [1]. Water-related problems have raised concerns worldwide among the scientific community [2].

Water systems throughout the world are trapped in conventional infrastructure histories and design paradigms that are difficult to adapt to change. The water sector has struggled to implement substantially novel and revolutionary approaches with widespread recognition of the need for change. However, a significant gap persists between the governmental aims of increasing water resilience and the scientific literature. There is, in particular, a dearth of sufficient knowledge and understanding about how the water system will adapt to any water-related crises, not only in terms of technology but also in governance, behavioural, structural and transformational dimensions. The Climate-water governance pattern in Pakistan was examined by Yasin et al., using a systematic literature review technique, comprising key areas and functions, significant gaps, and feasible strategy [3]. The present study's primary intent is to identify the gaps in the water-related Indian government policies by deriving specific dimensions from literature based on water resilience and governance to improve water resiliency in the study area. To address the gaps, this study employs data from a systematic assessment of the peer-reviewed literature from Web of Science and Scopus databases to highlight underlying features, notions, and perspectives that resilience brings to the broader domain of water management and policy governance. The present study presents a broad and integrated view of the latest 20-year water resilience and governance planning literature, analyzing the subject's behaviour along the 2000-2021 period.

The water-related legal framework in India (1954-2018) as a conceptual foundation, this study analyses water governance inadequacies in India. Identifying the gaps might aid policymakers to identify alternatives for strengthening the governance. This study adds to the empirical literature on water governance by identifying gaps in governance; categorizing and prioritizing them.

2. RESEARCH AREA DESCRIPTION

India is among the world's most vulnerable regions to climatic changes. Because of its unique topography and microclimates, it is susceptible to a wide range of water-related threats. The recurrent drought to heavy rain and flooding has left the country reckoning the cost of climatic changes in terms of lives lost and destroyed livelihoods [4, 5]. Researchers are working on solutions to fulfil the growing demand for water while addressing climate change. The issues faced by the research area are complicated and critical: Growing population and climate change are imposing further stress on the country's water supply; further, sea levels rise and their resources to support floods. Rising water demand is increasing groundwater depletion. Since 1970s, flooding and water contamination have been a prime focus in developed countries [6]. Cities that rely solely on water imports from neighbouring areas are similarly impacted by transmission and distribution losses. The vulnerable coastal areas, river flood plains and delta regions are prone to frequent floods and areas away from the coast. The areas near the foothills are also prone to flood due to the intense rainfall or melting of snow. During periods of scanty rainfall, the state struggles to deal with the prevailing seawater. During arid conditions, the problems worsen. Climate change-induced sea-level rise is more likely to fracture the existing coastal/river defences. Meanwhile, saline water intrusion runs the risk of making groundwater supplies unusable.

2.1 'Resilience' definitions

Diverse disciplines cite resilience to explain the reaction and retaliation of a system to a certain kind of disruptions. As the cities are complex and multi-dimensional, elucidating resilience in an urban context encompasses perceptions from various distinct disciplines. In ecology, Holling's notion of "resilience" was used to describe a system's ability to accept a disturbance, reorganize and combat the changes while still maintaining the needed function, structure, and identity [7]. In management, Scholars use resilience to retaliate from the shock, which is a distinct part of the supply networks and return to the existing business. Economists employ resilience as the capability of an institution to respond and reclaim from financial loss. Psychologists also use resilience to elucidate individuals' potential to endure significant stress and continue performing effectively. Engineers and scientists researching materials use resilience to measure bouncing back ability after a tension, which is the material's innate quality. Thus, there is a need to integrate the ideas from varied disciplines using the term resilience.

Pickett examined the city's resilience definition, comparing its variations on equilibrium and non-equilibrium perspectives of resilience. He also attempted to combine the equilibrium and non-equilibrium aspects of resilience where the resilient cities are planned considering hazards based on past experiences and the system's ability to adjust and adapt [8].

Perrings propagated the economic attribute to resilience. He studied the withstanding ability of a system, efficient resource allocation aftermarket stress, causing minimum damages to the system's utility [9]. According to his notion, an ecosystem's resilience depends on four significant aspects: Altering a system to an extent before losing its capacity to reorganize. The second aspect is the capacity of a system to safeguard itself from the variations caused. It determines the robustness of the prevailing system. The third aspect is the unstable position within the domain. Fourth is the inter-relation within the system. The resilient system thus planned and designed requires an overall analysis of interrelations between humans and the environment (urban form, land use distribution, connectivity, etc.) at varied temporal and spatial scales. Cities tolerate various disturbances before recovering /restructuring after a tremor.

Cutter et al. [10] analyzed various characteristics of communities in measuring resilience. By devising the baseline criteria, it is viable to observe and record variation and compare these variations to define physical and social attributes. Some of the composite indicators used in his study are the social vulnerability index, disaster risk index, predictive indicator of vulnerability, Human development index, environment sustainability index, ecological health index. In anthropology defined resilience as the potentiality of a community /society to combat /counter and reorganize so that society can function. He also analyzed several approaches for an adequate adaptation after a shock. Enhancing the physical infrastructure's capacity to resist the climate change impacts, increasing the natural system's adaptability by measuring the possible risks humans can mitigate, and discouraging further developments in the risk zone plays a vital role [11].

In management, Vale describes resilience as the capability of a market to operate or counter the prior function after a distraction [12]. This process involves the interlinked capacity to design flow chains of disruptions and resilience, including retaliation. The significant potential of resilience is the capability of a system to convert the flexibility to maximum supremacy by considering all the interconnections prevailing with varied domain in the system. Preventive and restorative resilience are two significant aspects of the complex nature of resilience. The system's capacity to function after the shock/stress wherein the average inadequacy is critical and crucial to utilize the available resources during the revival period efficiently. The study evaluates the individual and regional economic resilience to counter various disruptions. Here the resilience is interlinked with the minimizing approaches- mitigation and recovery management. Neglecting resilience in estimating loss will lead to blown up valuation. On the other hand, neglecting resilience in policy guidelines will lead to a failed scenario in mitigating and minimizing the failures or damages.

3. METHODOLOGY

The present paper brings together current literature on water resilience to identify tools to be effectively analyzed by decision-makers towards optimal water resilience planning. In this study, a methodology for assessing water resilience and its impact on water governance and policies are developed by determining the gaps of resilience approaches in addressing the developmental challenges. We have systematically reviewed the literature on water resilience, following the procedures outlined below. The first step was to search for scientific literature using search terms “water resilience” AND “governance policies” in the Web of Science and Scopus databases. To reduce bias and assure comprehensiveness, the two main online datasets were used. Scopus and Web of Science encompass 95% of published research publications, enabling an extensive set of data [13]. The initial search yielded 301 documents between 1997 and 2021, encompassing document categories such as journal articles and conference proceedings. Later, to get the most recent literature on this subject, the search was restricted between 2000 and 2021, yielding 274 records. Second, the exclusion criteria were developed (water resilience is not the main focus, those did not include governance policies on climate-related disasters). During the abstract screening step, these criteria were used in the remaining articles (n = 274) to determine if they are relevant in assessing water resilience to climate-related disasters and the governance policies managing them. Third, this process was repeated during the stage of full-text screening. As a consequence, 68 articles were deleted from the records for the reasons listed below. 1) articles (n = 24) that are duplicated in both databases; 2) articles (n = 11) only have abstract available; 3) articles (n = 15) do not focus on water resilience assessment to climate-related disasters, and 4) articles (n = 18) have analysed the water resilience but do not analyse the governance policy of the case study.

Categorizing literature was done based on sector-based linkages involved in resilient development planning. The two primary metrics to consider are bibliometric and informetric analysis to analyze the scientific literature quantitatively. The quantitative examination of published papers, such as the number of publications each year, research area and geographical distribution of the literature, focus on bibliometric analysis.

In contrast to the above, the informetric analysis aims to gain extra information, such as word frequency and dimensions of literature. The information gained from this study was then verified using content analysis, which identified gaps. The literature study also included understanding the structure of the governance system and the notion of resilience in the existing water-related legal frameworks in India from 1954 to 2018. The methodology incorporated the systematic Delphi technique in formulating the governance gaps in the research area. It suggests potential research areas which can be explored to strengthen water governance and improvise the institutional factors, thereby contributing towards water resilience in India. It encompassed 30 knowledge experts from the Central and State Water Authority, Water supply and sewerage boards and Disaster management authorities to reach a consensus. The first open-ended set of questionnaires helped in brainstorming the latter rounds. The second questionnaire is analyzed using the preliminary round's answers to identify similarities and eliminate irrelevant information. After reading the summary report and other experts' opinions, some of their choices were the same and few varied. It stretched till three stages when a consensus of 12 out of 18 gaps was taken for further analysis. Then, the ranking round determined participant consensus on the gaps identified during the sessions.

A structured questionnaire based on the gaps was constructed using a 'five-point Likert scale (from very low = 1 to very high = 5)' to assess the relevance of each gap. Then Mean and standard deviation of the results are determined to understand the strength of consensus. If SD is equal to or less than one, the level of consensus is considerable. The findings of the ranking round revealed that a significant level of consensus was obtained on the identified 12 gaps. The Wilcoxon test findings aided in analyzing the results' credibility since there is no significant difference between the first and second ranking responses for 10 of the 12 gaps. The mean value indicates the severity/ acuteness of gaps. Further, Friedman's non-parametric test helped prioritize the identified gaps by determining the significance level and the mean rank.

4. ANALYSIS AND DISCUSSION

4.1 Bibliometric and informetric analysis

This article analyses the results by using bibliometric and informetric indicators. The results revealed, there has been an increase in the growth rate of water resilience literature since 2013. The water resilience-related publication's growth gradually increased from 4.75 per cent in 2013 to 24.45 per cent in 2020 (Figure 1). Furthermore, it has been found that publications on this subject have grown exponentially, with 74.82 per cent of papers published in the past five years. As a whole, scholars from 65 countries have contributed to the publication in the water resilience area. All countries contributing to the potency of publications in this research area are presented in Figure 2. Top on the list is the United States of America (USA), with a total of 26.64 per cent of publications, followed by England (16.78 per cent) and China (12.40) per cent. This study then classified the published research by topic area, as shown in Figure 3. Altogether, the distribution suggests that the study on water resilience arises in diverse areas, including Environmental Science, Water Resource, Green, Sustainable Science & Technology, Ecology and Urban Planning. As per the analysis, about 47.45 per cent of the documents examined falls in the Environmental Science area, followed by Water Resources (29.56 per cent). The Sustainability journal has 8.40 per cent (23 articles) of the total articles, followed by Water (15 articles) and Science of the Total Environment (9 articles).

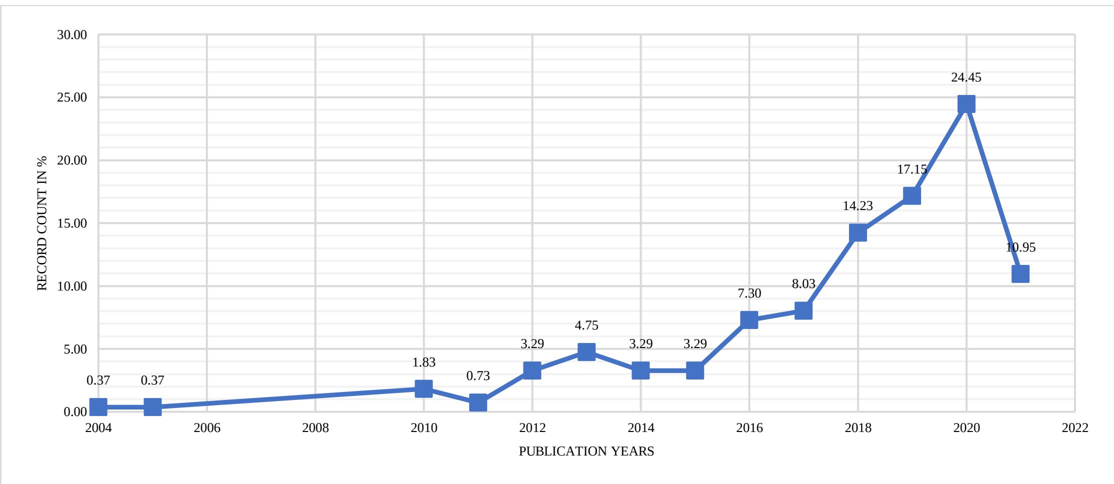

Figure 1. Publication by year and annual growth

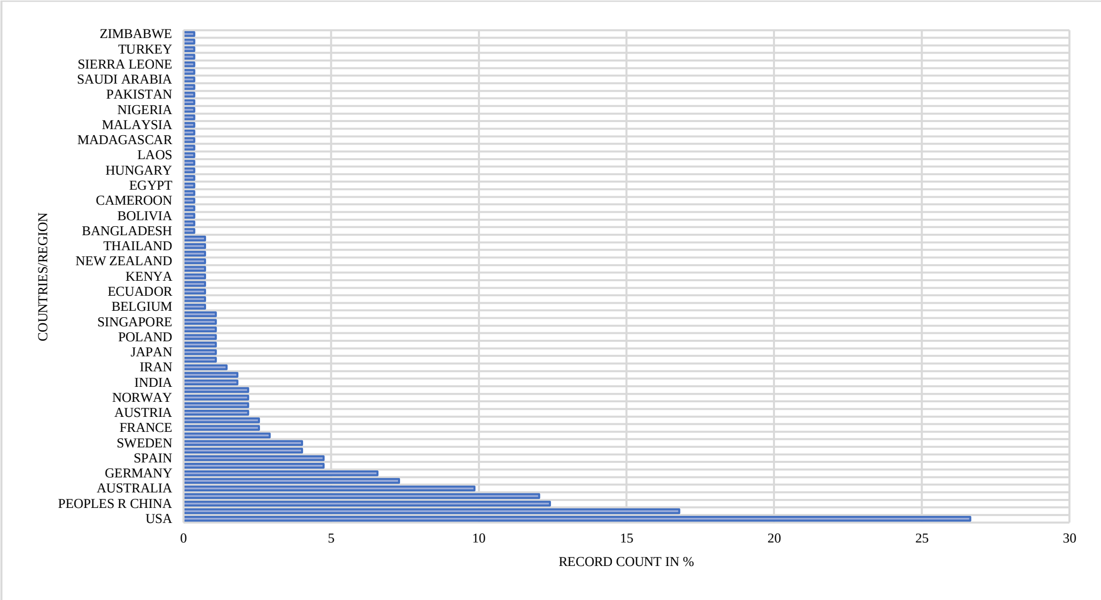

Figure 2. Geographical distribution of publications

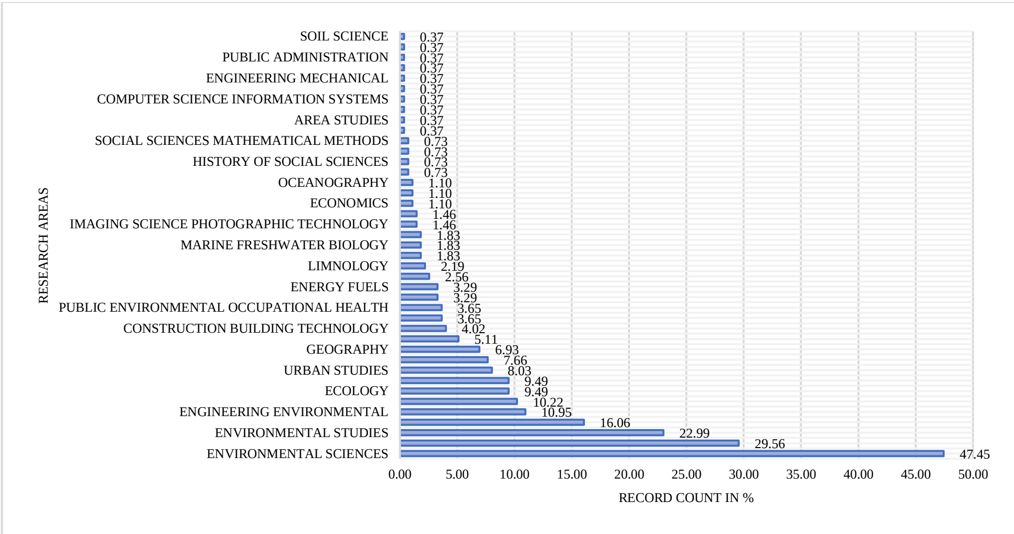

Figure 3. Subject area

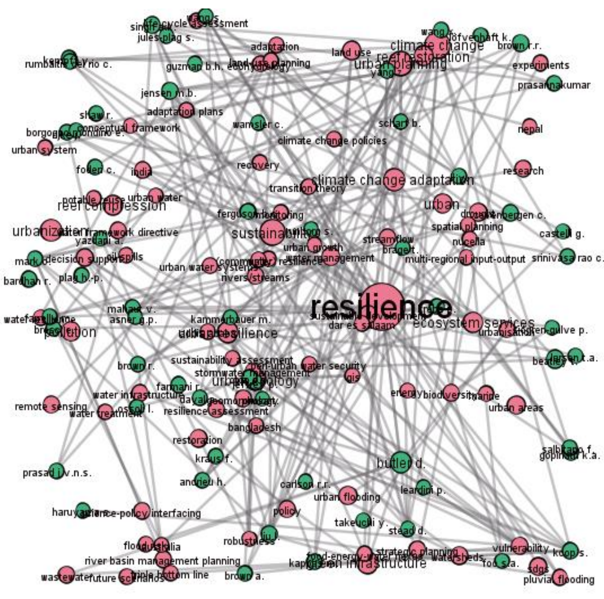

Figure 4. Network analysis

Figure 4 depicts the network and cluster analysis of the authors' key terms. In the network visualization, the keywords and the authors are represented in pink and green coloured circles. The top five terms in the papers are climate change adaptation, sustainability, environmental issues, vulnerability, and policy intervention. The size of the label and the circle determines the heft of the item. The higher the weightage of an item, the larger the label and the circle of the item. Lines between elements represent links. By default, 100 lines are displayed at most, meaning the 100 most robust connections between components. In the visualization, the pertinence of the journals concerning the co-citation linkages is indicated in the spacing between the two journals. In general, the closer two journals are spaced to each other, the stronger their relatedness. Lines also represent the most robust co-citation links between journals.

4.2 Dimensions of water resilience

The aspects of water resilience are studied and tabulated for further analysis. The dimensions considered for analysis are multifunctionality, redundancy, interconnectedness, robustness, vulnerability reduction capacity, adaptability, efficiency, sustainability, tenacity and rapidity are elucidated in Table 1.

Table 1. Dimensions of water resilience

S.No	Dimension	Explanation	References
1.	Multifunctionality	Interlinkages of various functions; Varied response to disruptive situations; Strengthens the economic and spatial capability. Greater capability speeder is the recovery duration.	[14-17]
2.	Redundancy	It is the capability of identifying issues and deploying necessary resources. A redundancy-based management system would include various methods for mitigation, readiness, reaction, and reorganization. The response capacity would be dispersed across the levels. When one level's capacity is exhausted, the city may still rely on the others.	[18, 19]
3.	Interconnectedness	Combined network to acquire support from other systems in the network. It is necessary to determine the measures to integrate the interdisciplinary strategies developed for resilience for extreme weather occurrences to proactively prepare for this enhanced resilience.	[20-22]
4.	Robustness	Ensures the imbuing capacity of a system to strengthen the robustness and functional linkage's strength within the subsystems to withstand disruptions or disturbances.	[18, 19, 23-25]
5.	Vulnerability reduction capacity	To build resilience, vulnerability reduction capacities are required by developing adaptation, threshold, coping, and recovery capability. All-inclusive vulnerability reduction strategies are necessary. It is dependent on an area's present vulnerability to determine the extent to which the capacities to be strengthened, and the combination of actions is most effective in increasing resilience to extreme events.	[22, 26-28]
6.	Adaptability	Reduces the failure risks. The system's flexibility from the past disturbances can absorb and tackle the impacts to minimize the loss. Ensures supportive capacity derived from the prevailing components to perform towards similar function during a crisis situation to respond better, but the failure of one component does not impact/adverse effect on the entire system. Rather than just resisting the effects of disturbance, this strategy tries to prepare, cope, manage and recover	[14, 15. 22-26]
7.	Efficiency	It is the extent to which standard functions are carried out through policies, institutions, finance and management. The extent to which plans are implemented enhances resilience by evaluating the water utilities' performance and productivity. It indicates the efficacy of the system.	[15, 29, 30]
8.	Sustainability	A sustainable water system approach includes measures to reduce environmental impact, improve human well-being, and preserve water for future generations. It depicts the impact of external or internal influences on the optimal operation of the water system. Sustainability is assessed using behaviour and understanding of a community's social and institutional elements.	[14, 31-35]
9.	Tenacity	It depicts the stability of the subsystems in retaliating the disruptions. Fluctuations or variations in environments may occur in a system, and these changes explain the system's persistence. The resilient system's capacity need not revert to a past equilibrium path following a disturbance or stress. It is linked with the system's tolerance for change and ability to restructure or renew	[19, 20, 25, 36]
10.	Rapidity	It is the capability of restoring the system in a timely way to minimize losses. Rapidity measures how swiftly a network's utilization can be resumed after a shock. It is critical for building resilience; thus, examining how multi threats influence a system is required.	[25, 27, 32]

4.3 Dimensions of water governance

The prevailing dimensions of water governance are studied and tabulated for further analysis. The dimensions considered for analysis are comprehensive approach, socially equitable, adaptive capacity, systematic intervention, inclusiveness, technical feasibility, preparedness, smart monitoring, resilience impact analysis, financial viability and public/ stakeholder engagement, elucidated in Table 2.

Table 2. Dimensions of water governance

S.No	Dimensions	Importance	Contributing Authors
1	Comprehensive approach	It helps increase flexibility and responsiveness in dealing with uncertainty and change. Integrated governance approaches to water services are required, as are multi-functional benefits that promote social well-being, ecosystem services, and growing economies. Includes parameters of supply-demand drivers within a comprehensive approach. It would involve analyzing and modelling system performance or malfunction data under the normal and abnormal operating condition to decide upon the response action.	[30, 37-39]
2	Socially equitable	It dealt with the regional scale environmental planning and management, decision-making approach. Ensure the inclusion and representation of a diverse variety of viewpoints in governance structures and decision-making. It helps in analyzing the degradation of the environment and water quality due to socioeconomic growth patterns.	[30, 40-42]
3	Adaptive capacity	It is critical in creating more alternatives for generating strength in disruptive dynamics to balance sustaining dynamics, especially in policy direction and policymaking. As a result, adaptive capacity for radical institutional changes in response to uncertainty and complexity in a dynamic environment might be enhanced. With adaptive capacity, it identifies the ability to sustain or improve the existing condition over the future. It assesses governance's ability to cope with shifting stresses continually.	[18, 36, 43-45]
4	Systematic intervention & Inclusiveness	The need for a systematic approach to the combined examination of potential hazards is vital. A systematic intervention by analyzing the causes, constraints, and possibilities that improve water resilience must be facilitated by viewpoints from various local council regions. It also includes exchanging learning and experiences across sectors. In governance systematic framework and decision-making, inclusivity and representation of a diverse range of perspectives are essential.	[25, 27, 42, 44, 46]
5	Technical feasibility	It is the capacity of a measure to execute its purpose', which is affected by external factors. The approach is intended to produce a rating of adaption methods based on technical feasibility. This evaluation is a data-intensive approach that makes use of fundamental field data and dynamics. Climate variables have an impact on the performance and effectiveness of technical feasibility. Innovative approach dealing with dynamics models incorporating spatial changes and their influences in the feedback loops of the interconnected systems is crucial.	[15, 26, 27, 30, 47, 48]
6	Preparedness and smart monitoring	It includes plans with enough resources to respond to possible risks. In addition, it comprises factors such as the legislative framework with monitoring programmes and institutional financial preparedness. Therefore, a monitoring system to assess crisis preparedness is vital. Capability to evaluate change and implement change depending on these assessments. The creation of a monitoring system to demonstrate progress tracking is essential. Furthermore, smart monitoring intensifies the policy regulation mechanism, carefully evaluating the decision support system.	[25, 27, 29, 30, 38, 42]
7	Resilience impact analysis	The analysis of impact is a critical component of appropriate requirements management. It offers a thorough knowledge of the ramifications of a proposed change, allowing for more informed decisions. It analyses the proposed change to identify components that may need to be developed, modified, or eliminated and estimate the duration and efforts involved in building resilience measures.	[38, 44, 48, 49]
8	Financial viability	Cost recovery, monetary benefits and balance are essential in enhancing resilience. In addition, integrating financing prospects to learning gaps, establishing various experiments, and promoting innovation with risk-management systems imbibed with funding scenarios enhances resilience strategies.	[42, 50, 51]
9	Public participation & Stakeholder engagement	The strategies for accrediting water management to users and civil society and opportunities for public engagement contribute to the extent to which the community is actively involved in water-related activities. The participatory modelling approach is flexible and transparent, including the study of various sectors. However, to guarantee involvement while being cost and time efficient, well-resourced, consistent, and well established, governance and mechanisms are required.	[23, 27, 41, 52, 53]

5. WATER-RELATED LEGISLATIVE FRAMEWORK IN INDIA

The Indian water policies from the year 1954 to 2021 have been illustrated in Figure 5. Most of the water policies were pertaining majorly towards flood management. (Policy statement-1954, 1958, National Flood commission policy-1980, 2003, National Flood management guidelines- 2008, Urban flood management guidelines- 2010). Very few policies stressed comprehensive water management (National water policy-1983, 2002, 2012). So far, only in 2013, Drought management policy guidelines were devised by the Indian government. The environment Protection Act (2005) focused on environmental degradation, including groundwater and water pollution overexploitation. The National Disaster Management plan was devised in 2016, including the comprehensive guidelines for the recent catastrophes. The water-related legal frameworks are discussed in the following paragraphs.

The first policy statement prepared by the Central Ministry for Planning, Irrigation and Power in 1954 includes introducing the flood control programme. The prime focus was the issues and immediate solutions towards flood. The second policy statement prepared by the Central Flood Control Board in 1958 dealt with the zoning of flood plains. Forecasting and warning measures are significant as the funding was minimum. It was specified that coupling multi-utilitarian projects with flood control schemes gave importance to protection measures like the construction of dykes.

Figure 5. Water-related legal frameworks in India

The National flood commission formulated the National Flood policy (1980) involved rendering practical guidance on implementation. Preparation of a distinct report on the damage caused by the flood in the unprotected, protected areas lying between the dykes and effective management of floodplains should be part of the legislation. The policy also focuses on the vulnerable zones to frequent damages caused by flood, including economic and human loss. It also specifies that states have the rights to include these by enforcement of section 17(II) of the Land acquisition act and organizing a distinct council for disaster mitigation during flood control works. The National Water Policy (1987), devised by the National Water Resources Council, specifies attenuating the downstream of flood and providing ample facilities for effective flood management to minimize life and property loss. The National Water Policy (2002), prepared by the National Water Resources Council, devised a practical and feasible management plan for flood-prone areas. Following are the policy's salient features: Efficient land use zone analysis and prohibition of unauthorized developments, including strict rules and acts as part of legislation to be added to reduce the loss. Technological advancement in the field of flood forecasting. The state government and Union territories should take the necessary steps to prepare inclusive planning and management by analyzing the environmental, ecological, and social impacts, thereby regulating the developments and abridging of soil erosion in the coastal regions, the areas near the river plains employing the river cost-effective mechanism.

The National Flood Commission report (2003), devised by the Ministry of Water Resource, stressed incorporating the curative and reparatory steps in evaluating and estimating the damages incurred by the flood. Remedial measures included the futuristic system taking into account feasible and functional mechanisms in implementing these projects. The Environment Protection Regulation (2005) specifies the protection of water sources from various pollutants. It also ensures the non-contamination of the stormwater system and the corresponding penalties. The Central Ground Water Authority Model Bill formulated by the Central Ground Water Authority (2005), stresses on identifying and delineating zones where groundwater is in the state of over-exploitation, setting up a distinct Central and State Government authority with the potential of reporting and alerting the exploited areas to regulate and managing the groundwater level. The National Disaster Management Act (2005) is a comprehensive risk reduction approach. The Union government devised a National Disaster Response Fund (NDRF) with the recommendations put forth by the National Disaster Management Authority to manage the expenditure during the crucial response, mitigation and rehabilitation. This Act also recommends a National Disaster Mitigation Fund (NDMF) exclusively for mitigation.

The NDMA Flood Management Guidelines (2008) focused on disaster preparedness. A distinct combination of technological advancements in forecasting, economic feasibility, and time-bound flood management projects enhances community participation to improve the alertness and readiness of the people by organizing capacity development programmes, including training, research, documentation, and development. The NDMA Urban Flood Management Guidelines (2010) focused on urban flooding causing inevitable damages. The guidelines specified that at the community level, urban local bodies are liable for framing an effective and efficient framework for the floods in urban areas and the respective State Government also have equal responsibility in devising a framework prioritizing the urban floods. The National Water Policy (2012) devised by the National Water Resources Council includes Channelisation of rivers, construction of dykes with the ample linkages of surface communications to increase the responsiveness of the community prone to frequent floods and increasing the dredging, lining activities to reduce soil erosion in the embankment and maintaining the drains and the channels to improve the discharge capacity. Clearing encroachments in these drains and canals. Reducing the downstream of water during floods and arrest silting effective watershed management of catchment areas with the help of landscaping and afforestation inclusive of the structural works is recommended. Zoning in the flood plains, Floodproofing techniques were also given importance [54].

The National Drought Management Policy Guidelines (2013), prepared by the Ministry of Agriculture, Government of India, involves devising a proactive plan aiming at risk reduction, including the threats associated with droughts, by incorporating relevant mitigation measures. It also includes delineation of the drought management regions encompassing their hydrological, climatological, meteorological characteristics. The planning devised is a continuous evaluation process to evolve a distinct system including drought monitoring, forewarning, assessing impacts, relief and response. The National Disaster Management Plan (2016) includes the governance framework and the potential central agencies, state agencies. It also stresses establishing and integrating disaster risk reduction mechanisms with the current institutional framework, capacity building and participatory stakeholder mechanisms. While all key central and state actors, linked with these actions, linkage with the Urban Local Body (ULB) is limited. The Central and State governments must take a leadership role to create platforms for other key actors such as community groups, and the private bodies to engage and participate in disaster prevention, recovery and response.

6. UNDERSTANDING THE GAPS

The systematic Delphi technique helped in formulating the governance gaps. The knowledge experts included in the process are from the State and Central water authorities, Water supply and sewerage boards, Disaster management authorities. Table 3 illustrates the identified gaps in India's water governance. A structured questionnaire based on the gaps, using a 'five-point Likert scale (from very low = 1 to very high = 5)', assessed each gap's relevance in the ranking round. The Wilcoxon test findings aided in analyzing the results' credibility since there is no significant difference between the first and second ranking responses for 10 of the 12 gaps. The mean value indicates the severity of gaps. Each of these is discussed in detail in the following paragraphs. Further, Friedman non-parametric test helped in prioritizing the identified gaps (N=30; df = 11; p-value = 0.00).

The lack of a comprehensive framework in enhancing resilience in the water system is one of the critical gaps identified in the governance system (M = 4.47). The present framework includes flood management guidelines, environmental protection act; drought management policy; disaster management plan and groundwater bill. However, a comprehensive framework for resilience planning towards water-related disruptions is essential. Another identified gap is the minimal interlink between various sectors wherein the plans formulated are non-cohesive and fragmented, addressing generic issues.

The next gap is the functional inefficiency in resources and infrastructure. Urban risks (created due to the urban processes and lack of resources or access to them) are not well understood or enacted. Even risks, such as water scarcity, are still recognized in the agricultural/rural context and not identified as disasters or risks in the urban. More in-depth work is required to define these risks and allocate resources and infrastructure to combat them. Another gap is the lack of preparedness/monitoring system to forecast the upcoming water-related risks. Although the National Disaster Management Plan (2016) signal a shift towards a more comprehensive risk reduction approach. Legal frameworks and funding are still limited to rescue and response and not risk reduction and preparedness in practice. There is a need to strengthen the regional observational system for drought monitoring to balance the existing as well as required meteorological, hydrological monitoring systems. Demand-based forecasting and the analytical methodologies for drought analysis and vulnerability assessment should be enhanced at the local and regional level. Another crucial gap is the delay in implementing and executing the schemes, which increases the damages (M= 4.23). When implementing these policies is not phased, it will lead to chaos and not serve its purpose. The history of shocks is as crucial as the future projections wherein the city needs to adapt and recover from the disruptions it has encountered.

The next gap is the non-inclusive of impact analysis and challenges in various subsystems. It provides an in-depth understanding of the implications of a proposed change, allowing for better-informed decisions. It examines the changes to identify components that may need to be established, altered, or discarded. It also identifies the time and resources required to implement resilience measures. The most crucial gap is the lack of integrated strategic policy planning encompassing all water-related disruptions (M=4.73). This will lead to the formulation of fragmented plans, which will not be suitable for a comprehensive approach. The guidelines pertain to flood management, drought management or environmental management but not an inclusive and integrated process encompassing all water-related threats to enhance resilience. Another gap is the overlapping of tasks across organizations. Decision-making and planning mechanisms are diversified across multiple organizations. The roles and responsibilities of various government entities are not clearly defined.

Water policy formulation entails identifying relevant technological solutions to availability, quality and water demands. The first stage in water policy reform would be to do detailed institutional modelling to determine who decides, what decisions can be made, and at what level. The next gap is the inadequate funding and transparency of plans detailing the funding mechanisms. Due to the extreme low recognition of water resilience and the lack of rules, the government does not give a reasonable budget in building resilience before the disaster. Financial status and water service quality are inextricably linked. Another gap is the public/stakeholder participation. The government does not make an effort to involve local stakeholders at all decision-making stages, planning, development, operation, and maintenance. It does not consider local engagement to enhance management of the present water issue, which is the consequence of a top-down process. As a governance paradigm, user engagement in water management fosters public confidence.

Table 3. Governance gaps- prioritization (n=30)

S.No	Identified Gaps	Mean	Standard Deviation	Mean Rank	Priority
1	Lack of comprehensive framework in enhancing resilience in water systems	4.47	0.51	8.72	2
2	Minimal interlink between various sectors	3.97	0.67	6.75	7
3	Functional inefficiency in resources and infrastructure	3.77	0.77	6.22	8
4	Lack of preparedness or monitoring mechanism	3.37	0.89	5.27	10
5	Time delay	4.23	0.73	7.82	3
6	Non inclusive of impact analysis and challenges in various subsystems	4.03	0.81	6.87	6
7	Lack of integrated strategic policy planning encompassing all water-related disruptions	4.73	0.45	10.02	1
8	Overlapping of tasks across organizations	3.07	0.83	3.58	11
9	Inadequate funding and transparency of plans	2.43	0.94	2.57	12
10	Lack of public/stakeholder participation	4.07	0.78	7.08	5
11	Lack of research in water resilience	4.17	0.70	7.67	4
12	Lack of incorporating technology	3.60	0.86	5.45	9

Another gap is the lack of using appropriate technology in risk reduction. Though it is included in the Master Plans, a technical acquaintance in development authorities are still inadequate. There is also a lack of using technology in an efficient water management mechanism to enhance resilience. The next gap is the lack of research in water resilience. The majority of academic research is not sufficiently practical in culminating and analyzing all the water-related risks. It either focuses only on drought / flood crisis management. Solutions to present and future water challenges must be focused on "resilience" which necessitates a multidisciplinary and trans-disciplinary approach.

7. CONCLUSION

Globally there exists immense stress on water resources. The present-day water crisis in India strongly indicates that the water networks aren't resilient to the deviations in the water cycle and proliferating challenges in water governance. Global policy summits and discourses are enfolding resilience as the cardinal approach in efficient water management to address the climate change impacts. According to the study findings, the peer-reviewed scholarly literature on water resilience is extremely dispersed by sector, echoing the diversification of the water system as a whole. While many works on water resilience focus mainly on creating infrastructure resilience, there is still an imprecise knowledge of the causes, behaviours, and governance contributing to resilience. This means that the identified gaps are viewed as essential only later in the resilience-building process and are not necessarily stressed or understood in early phases. The identified gaps are further tested for their credibility. The Friedman non-parametric test helped to analyze the acuteness of the data where the p-value is 0.00, less than 0.05. It also helped in prioritizing the identified gaps.

The study also revealed that the gap explaining the lack of integrated strategic policy planning encompassing all water-related disruptions is crucial. Regarding other governance aspects, a comprehensive framework, time delay in implementation, research in water resilience, and public / stakeholder engagement should be incorporated to enhance resilience towards efficient water management.

The critical point, though, is that all gaps are interdependent and may reinforce one another. In order to understand and resolve governance weaknesses, a comprehensive approach is required. It is essential to remember that one solution can help solve multiple gaps and vice versa; a single gap requires a diverse, comprehensive solution to build resilience. The paper reiterates the need to enhance resilience in our legal frameworks and policies. It implies that the country needs a resilient water system to tackle the increasing water demand and effective management. It helps to remodel to the future unforeseen vulnerabilities in the water cycle and natural hazards such as floods, droughts, etc. Further, scholars and policymakers must include governance issues into future infrastructure and technology-oriented initiatives aimed at enhancing resilience measures.

Despite the fact that this study employed a systematic evaluation of peer-reviewed literature, it has some limitations. Some critical articles were probably overlooked, while others were included in our study. This is due to the broad criteria utilised to identify relevant research articles for this assessment. Second, while searching for papers to analyse, only those written in English were considered. Studies in other languages might have provided more helpful information. Third, while the Web of Science and Scopus databases offered relevant papers for evaluation, pertinent publications from different databases may have been disregarded. Fourth, the limited number of Delphi rounds; more rounds may have resulted in a clear consensus among participants. In future study, the economic implications of resilience measures should be considered alongside climate-related disaster approaches. Another interesting research field to look forward to in the future is studying sustainable restoration techniques for resilience building in urban areas.

REFERENCES

[1] Unesco, U.W. (2020). United Nations World Water Development Report 2020: Water and Climate Change. https://www.unwater.org/publications/world-water-development-report-2020/.

[2] Marlow, D.R., Moglia, M., Cook, S., Beale, D.J. (2013). Towards sustainable urban water management: A critical reassessment. Water Research, 47(20): 7150-7161. https://doi.org/10.1016/j.watres.2013.07.046

[3] Yasin, H.Q., Breadsell, J., Tahir, M.N. (2021). Climate-water governance: A systematic analysis of the water sector resilience and adaptation to combat climate change in Pakistan. Water Policy, 23(1): 1-35. https://doi.org/10.2166/wp.2020.113

[4] Gupta, V., Jain, M.K. (2018). Investigation of multi-model spatiotemporal mesoscale drought projections over India under climate change scenario. Journal of Hydrology, 567: 489-509. https://doi.org/10.1016/j.jhydrol.2018.10.012

[5] Ali, H., Modi, P., Mishra, V. (2019). Increased flood risk in Indian sub-continent under the warming climate. Weather and Climate Extremes, 25: 100212. https://doi.org/10.1016/j.wace.2019.100212

[6] Fletcher, T.D., Andrieu, H., Hamel, P. (2013). Understanding, management and modelling of urban hydrology and its consequences for receiving waters: A state of the art. Advances in Water Resources, 51: 261-279. https://doi.org/10.1016/j.advwatres.2012.09.001

[7] Holling, C.S. (1973). Resilience and stability of ecological systems. Source Annu. Rev. Ecol. Syst., 4(1973): 1-23. https://doi.org/10.1146/annurev.es.04.110173.000245

[8] Pickett, S.T., Cadenasso, M.L., Grove, J.M. (2004). Resilient cities: Meaning, models, and metaphor for integrating the ecological, socio-economic, and planning realms. Landscape and Urban Planning, 69(4): 369-384. https://doi.org/10.1016/j.landurbplan.2003.10.035

[9] Perrings, C. (1998). Resilience in the dynamics of economy-environment systems. Environmental and Resource Economics, 11(3): 503-520. https://doi.org/10.1023/A:1008255614276

[10] Cutter, S.L., Burton, C.G., Emrich, C.T. (2010). Disaster resilience indicators for benchmarking baseline conditions. Journal of Homeland Security and Emergency Management, 7(1). https://doi.org/10.2202/1547-7355.1732

[11] McCandless, E., Simpson, G. (2015). Assessing resilience for peacebuilding executive summary of discussion document: Executive summary.

Geneve/Stockholm: Interpeace and Sida. http://www.interpeace.org/wp-content/uploads/2015/09/2015_09_11_FAR-Executive-Summary-2015-v3.pdf.

[12] Vale, L.J. (2014). The politics of resilient cities: Whose resilience and whose city? Building Research & Information, 42(2): 191-201. https://doi.org/10.1080/09613218.2014.850602

[13] de Oliveira, U.R., Espindola, L.S., da Silva, I.R., da Silva, I.N., Rocha, H.M. (2018). A systematic literature review on green supply chain management: Research implications and future perspectives. Journal of Cleaner Production, 187: 537-561. https://doi.org/10.1016/j.jclepro.2018.03.083

[14] Ferguson, B.C., Frantzeskaki, N., Brown, R.R. (2013). A strategic program for transitioning to a water sensitive city. Landscape and Urban Planning, 117: 32-45. https://doi.org/10.1016/j.landurbplan.2013.04.016

[15] Fratini, C.F., Geldof, G.D., Kluck, J., Mikkelsen, P.S. (2012). Three Points Approach (3PA) for urban flood risk management: A tool to support climate change adaptation through transdisciplinarity and multifunctionality. Urban Water Journal, 9(5): 317-331. https://doi.org/10.1080/1573062X.2012.668913

[16] Moghadas, M., Asadzadeh, A., Vafeidis, A., Fekete, A., Kötter, T. (2019). A multi-criteria approach for assessing urban flood resilience in Tehran, Iran. International Journal of Disaster Risk Reduction, 35. https://doi.org/101069. 10.1016/j.ijdrr.2019.101069

[17] Alves, A., Gersonius, B., Sanchez, A., Vojinovic, Z., Kapelan, Z. (2018). Multi-criteria approach for selection of green and grey infrastructure to reduce flood risk and increase CO-benefits. Water Resources Management, 32(7): 2505-2522. https://doi.org/10.1007/s11269-018-1943-3

[18] Yazdani, A., Otoo, R.A., Jeffrey, P. (2011). Resilience enhancing expansion strategies for water distribution systems: A network theory approach. Environmental Modelling & Software, 26(12): 1574-1582. https://doi.org/10.1016/j.envsoft.2011.07.016

[19] Liao, K.H. (2012). A theory on urban resilience to floods—A basis for alternative planning practices. Ecology and Society, 17(4): 48. https://www.jstor.org/stable/26269244

[20] Makropoulos, C., Nikolopoulos, D., Palmen, L., Kools, S., Segrave, A., Vries, D., Medema, G. (2018). A resilience assessment method for urban water systems. Urban Water Journal, 15(4): 316-328. https://doi.org/10.1080/1573062X.2018.1457166

[21] Greiving, S., Fleischhauer, M. (2006). Spatial planning response towards natural and technological hazards. Geological Survey of Finland, Special Paper, 42: 109-123.

[22] Voskamp, I.M., Van de Ven, F.H. (2015). Planning support system for climate adaptation: Composing effective sets of blue-green measures to reduce urban vulnerability to extreme weather events. Building and Environment, 83: 159-167. https://doi.org/10.1016/j.buildenv.2014.07.018

[23] Booher, D.E., Innes, J.E. (2010). Governance for resilience: CALFED as a complex adaptive network for resource management. Ecology and Society, 15(3): 35.

[24] Obeysekera, J., Barnes, J., Nungesser, M. (2015). Climate sensitivity runs and regional hydrologic modeling for predicting the response of the greater Florida Everglades ecosystem to climate change. Environmental Management, 55(4): 749-762. https://doi.org/10.1007/s00267-014-0315-x

[25] Stead, D. (2014). Urban planning, water management and climate change strategies: Adaptation, mitigation and resilience narratives in the Netherlands. International Journal of Sustainable Development & World Ecology, 21(1): 15-27. https://doi.org/10.1080/13504509.2013.824928

[26] Ning, X., Liu, Y., Chen, J., Dong, X., Li, W., Liang, B. (2013). Sustainability of urban drainage management: A perspective on infrastructure resilience and thresholds. Frontiers of Environmental Science & Engineering, 7(5): 658-668. https://doi.org/10.1007/s11783-013-0546-8

[27] Polonenko, L.M., Hamouda, M.A., Mohamed, M.M. (2020). Essential components of institutional and social indicators in assessing the sustainability and resilience of urban water systems: Challenges and opportunities. Science of the Total Environment, 708: 135159. https://doi.org/10.1016/j.scitotenv.2019.135159

[28] Kuil, L., Carr, G., Prskawetz, A., Salinas, J.L., Viglione, A., Blöschl, G. (2019). Learning from the Ancient Maya: Exploring the impact of drought on population dynamics. Ecological Economics, 157: 1-16. https://doi.org/10.1016/j.ecolecon.2018.10.018

[29] Head, B.W. (2014). Managing urban water crises: Adaptive policy responses to drought and flood in Southeast Queensland, Australia. Ecology and Society, 19(2): 33.

[30] Rogers, B.C., Dunn, G., Hammer, K., Novalia, W., de Haan, F.J., Brown, L., Chesterfield, C. (2020). Water sensitive cities index: A diagnostic tool to assess water sensitivity and guide management actions. Water Research, 186: 116411. https://doi.org/10.1016/j.watres.2020.116411

[31] Salas, J., Yepes, V. (2020). Enhancing sustainability and resilience through multi-level infrastructure planning. International Journal of Environmental Research and Public Health, 17(3): 962. https://doi.org/10.3390/ijerph17030962

[32] Shin, S., Lee, S., Judi, D.R., Parvania, M., Goharian, E., McPherson, T., Burian, S.J. (2018). A systematic review of quantitative resilience measures for water infrastructure systems. Water, 10(2): 164. https://doi.org/10.3390/w10020164

[33] Jiang, Y., Zevenbergen, C., Fu, D. (2017). Understanding the challenges for the governance of China's "sponge cities" initiative to sustainably manage urban stormwater and flooding. Natural Hazards, 89(1): 521-529. https://doi.org/10.1007/s11069-017-2977-1

[34] McPhearson, T., Hamstead, Z.A., Kremer, P. (2014). Urban ecosystem services for resilience planning and management in New York City. Ambio, 43(4): 502-515. https://doi.org/10.1007/s13280-014-0509-8

[35] Milman, A., Short, A. (2008). Incorporating resilience into sustainability indicators: An example for the urban water sector. Global Environmental Change, 18(4): 758-767. https://doi.org/10.1016/j.gloenvcha.2008.08.002

[36] Brown, R., Ashley, R., Farrelly, M. (2011). Political and professional agency entrapment: An agenda for urban water research. Water Resources Management, 25(15): 4037-4050. https://doi.org/10.1007/s11269-011-9886-y

[37] Simonovic, S.P., Rajasekaram, V. (2004). Integrated

analyses of Canada's water resources: A system dynamics approach. Canadian Water Resources Journal/Revue Canadienne des Ressources Hydriques, 29(4): 223-250. https://doi.org/10.4296/cwrj223

[38] Yu, C., Brown, R., Morison, P. (2012). Co-governing decentralised water systems: an analytical framework. Water Science and Technology, 66(12): 2731-2736. https://doi.org/10.2166/wst.2012.489

[39] Oneda, T.M.S., Barros, V.G. (2021). On stormwater management master plans: comparing developed and developing cities. Hydrological Sciences Journal, 66(1): 1-11. https://doi.org/10.1080/02626667.2020.1853131

[40] Simonovic, S.P., Fahmy, H. (1999). A new modeling approach for water resources policy analysis. Water Resources Research, 35(1): 295-304. https://doi.org/10.1029/1998WR900023

[41] Almoradie, A., de Brito, M.M., Evers, M., Bossa, A., Lumor, M., Norman, C., Hounkpe, J. (2020). Current flood risk management practices in Ghana: Gaps and opportunities for improving resilience. Journal of Flood Risk Management, 13(4): e12664. https://doi.org/10.1111/jfr3.12664

[42] Kim, H., Son, J., Lee, S., Koop, S., Van Leeuwen, K., Choi, Y.J., Park, J. (2018). Assessing urban water management sustainability of a megacity: Case study of Seoul, South Korea. Water, 10(6): 682. https://doi.org/10.3390/w10060682

[43] Ahmad, S., Prashar, D. (2010). Evaluating municipal water conservation policies using a dynamic simulation model. Water Resources Management, 24(13): 3371-3395. https://doi.org/10.1007/s11269-010-9611-2

[44] Du, T.L., Bui, D.D., Buurman, J., Quach, X.T. (2018). Towards adaptive governance for urban drought resilience: The case of Da Nang, Vietnam. International Journal of Water Resources Development, 34(4): 597-615. https://doi.org/10.1080/07900627.2018.1438886

[45] Mees, H.L., Driessen, P.P., Runhaar, H.A. (2014). Legitimate adaptive flood risk governance beyond the dikes: the cases of Hamburg, Helsinki and Rotterdam. Regional Environmental Change, 14(2): 671-682. https://doi.org/10.1007/s10113-013-0527-2

[46] Simonovic, S.P., Li, L. (2004). Sensitivity of the Red River Basin flood protection system to climate variability and change. Water Resources Management, 18(2): 89-110. https://doi.org/10.1023/B:WARM.0000024702.40031.b2

[47] Ahmad, S., Simonovic, S.P. (2004). Spatial system dynamics: New approach for simulation of water resources systems. Journal of Computing in Civil Engineering, 18(4): 331-340. https://doi.org/10.1061/(asce)0887-3801(2004)18:4(331)

[48] Cimellaro, G.P., Tinebra, A., Renschler, C., Fragiadakis, M. (2016). New resilience index for urban water distribution networks. Journal of Structural Engineering, 142(8): C4015014. https://doi.org/10.1061/(ASCE)ST.1943-541X.0001433

[49] Bagheri, A., Darijani, M., Asgary, A., Morid, S. (2010). Crisis in urban water systems during the reconstruction period: A system dynamics analysis of alternative policies after the 2003 earthquake in Bam-Iran. Water Resources Management, 24(11): 2567-2596. https://doi.org/10.1007/s11269-009-9568-1

[50] Wu, G., Li, L., Ahmad, S., Chen, X., Pan, X. (2013). A dynamic model for vulnerability assessment of regional water resources in arid areas: A case study of Bayingolin, China. Water Resources Management, 27(8): 3085-3101. https://doi.org/10.1007/s11269-013-0334-z

[51] Dai, L., van Rijswick, H.F., Driessen, P.P., Keessen, A.M. (2018). Governance of the sponge city programme in China with Wuhan as a case study. International Journal of Water Resources Development, 34(4): 578-596. https://doi.org/10.1080/07900627.2017.1373637

[52] Madani, K., Mariño, M.A. (2009). System dynamics analysis for managing Iran’s Zayandeh-Rud river basin. Water Resources Management, 23(11): 2163-2187. https://doi.org/10.1007/s11269-008-9376-z

[53] King-Okumu, C., Jillo, B., Kinyanjui, J., Jarso, I. (2018). Devolving water governance in the Kenyan Arid Lands: from top-down drought and flood emergency response to locally driven water resource development planning. International Journal of Water Resources Development, 34(4): 675-697. https://doi.org/10.1080/07900627.2017.1357539

[54] Ministry of Water Resources, (2011). National water policy. Econ. Polit. Wkly., 46(3): 592-600. https://doi.org/10.1177/0019556120030336