IJCRT.ORG ISSN : 2320-2882

INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)

An International Open Access, Peer-reviewed, Refereed Journal

Integrated Water Resource Management And Multiple-Use Water Services: Progress, Challenges, And Future Directions - A Review

Almas Qureshi
Assistant Professor, Acropolis Institute of Technology & Research, Indore (M.P.)

Abstract: This collection of papers explores the evolving landscape of water resource management, with a focus on Integrated Water Resources Management (IWRM) and Multiple-Use Water Services (MUS). The introduction of these concepts stems from the need to address global water crises by integrating various water uses and engaging multiple stakeholders, including local communities, researchers, and government agencies. The methodologies across the papers include comprehensive reviews of historical practices, international agreements, and the application of technological tools for climate and hydrological modeling. The findings highlight both the successes and challenges in implementing IWRM and MUS, such as the variability in progress across countries, the importance of stakeholder engagement, and the integration of local knowledge. Despite theoretical acceptance, practical implementation often faces hurdles like insufficient policies, limited resources, and the need for capacity building. The papers underscore the necessity for continuous improvement, innovative legal frameworks, and broad public participation to ensure sustainable and equitable water resource management. In conclusion, while significant strides have been made, achieving holistic and effective water management requires addressing the identified challenges, fostering international cooperation, and leveraging inclusive approaches that incorporate diverse stakeholder inputs and advanced technological solutions.

Keywords: Integrated Water Management, Multiple-Use Water services, Climate Modelling, Hydrological Modelling, Equitable Water Management

I. INTRODUCTION

The importance of water resource management is emphasized, especially in rural areas. It highlights the challenges associated with water conservation due to population growth, technological advancements, increased food consumption, and economic activities. Effective rural water resource management is essential for maintaining adequate water quality for various uses such as drinking, agriculture, and energy production. The introduction also underscores the role of a well-managed water supply network in ensuring economic stability and ecosystem health[4]. The persistent challenges of water scarcity and accessibility is discussed, emphasizing the critical role of Integrated Water Resources Management (IWRM) and water governance[1].

Despite international agreements and initiatives, many cities still struggle to manage their water resources effectively. The paper aims to provide a comprehensive analysis of water-related challenges in cities worldwide, focusing on water, wastewater, municipal solid waste, and climate change. The study uses empirical data from 125 cities and a statistical estimation model to evaluate another 75 cities, covering over 95% of the global urban population. This analysis highlights the gaps in achieving water-related Sustainable Development Goals (SDGs), particularly SDG 6 (clean water and anitation) and SDG 11 (sustainable cities and communities)[2].

The significant challenges in cities were addressed which they face in managing water resources. Urban areas often suffer from potable water scarcity, high water treatment costs, and increasing volumes of wastewater. These problems are exacerbated by urbanization and climate change, leading to the disruption of hydrological cycles and aquatic systems. Integrated Water Resources Management (IWRM) and Integrated Urban Water Management (IUWM) are proposed as solutions to these challenges. IWRM promotes the coordinated development and management of water, land, and related resources to maximize economic and social welfare without compromising ecosystem sustainability. IUWM, an extension of IWRM, emphasizes the integration of water management into urban planning, considering the entire water cycle and involving multiple institutions for effective implementation[2].

Integrated Water Resources Management (IWRM) is a holistic approach aimed at promoting coordinated development and management of water, land, and related resources to maximize economic and social welfare without compromising sustainability. The concept originated from the Dublin Statement on Water and Sustainable Development and has been a key policy framework in Africa, Asia, and Europe[3]. The significance of monitoring and managing water resources were outlined which effectively implemented to achieve sustainable development. It emphasizes the importance of Integrated Water Resources Management (IWRM) in ensuring the equitable and efficient use of water. The study aims to provide a comprehensive assessment of global progress towards implementing IWRM, based on the UN Member States' reporting[5].

Evaluation of global implementation of Integrated Water Resources Management (IWRM) is focused as part of achieving Sustainable Development Goal 6.5.1. The introduction highlights the importance of IWRM in managing water resources in a comprehensive manner, ensuring equitable distribution, sustainability, and stakeholder engagement across various sectors and regions[6]. The research paper focuses on evaluating the progress of Integrated Water Resources Management (IWRM) across various countries. The introduction outlines the global context of water resource management, emphasizing the need for integrated approaches to meet sustainable development goals. It highlights the challenges of water scarcity, governance, and the necessity for cohesive policies and practices to manage water resources effectively [7].

A comprehensive analysis of the Integrated Water Resources Management (IWRM) concept is done to trace the origins of IWRM to historical practices and international agreements, emphasizing its goal of promoting coordinated development and management of water, land, and related resources to maximize economic and social welfare without compromising ecosystem sustainability[8]. The evolution of Integrated Water Resources Management (IWRM), emphasized its significance in addressing global water crises. Historically, water management practices have evolved from local, often participatory approaches, like Spain's water tribunals, to more structured frameworks such as river basin organizations. The paper highlights the international recognition of IWRM, particularly at the United Nations Conference on Water in Mar del Plata (1977), which recommended IWRM to manage the multiple competing uses of water resources [9].

The climate change adaption in Fraser River Basin in British Columbia,in order explored strategies. The introduction highlights the importance of dealing with climate change-related issues, emphasizing the need for integrated management approaches that involve local communities, First Nations, researchers, and government agencies[10]. Multiple-Use Water Services (MUS) explores the challenges of establishing water systems that support human well-being while conserving natural ecosystems. Despite significant efforts and funding in the water sector, many systems fail, leaving the poorest populations without adequate water and sanitation. The paper introduces MUS as a holistic approach to address these issues by considering all the different water needs of rural and peri-urban poor communities, including drinking, sanitation, and agriculture[11].

The critical challenges of establishing effective water systems that cater to both human needs and the preservation of natural ecosystems is discussed and analyzed. Despite substantial investments in the water sector, many systems fail, particularly affecting the poorest communities who remain without adequate water and sanitation services. The paper introduces Multiple-Use Water Services (MUS) as a comprehensive approach to tackle these issues, aiming to address the various water needs of rural and peri-urban communities, including drinking, sanitation, and agriculture[12].

II. METHODOLOGY

The implementation of the IWRM-DMS is discussed which integrates various sensors (such as water flow sensors, pH sensors, and ultrasonic sensors) to monitor and manage water distribution and quality. The system is designed to predict water demand using historical data and machine intelligence. The IoT-based architecture facilitates continuous monitoring and efficient water distribution to meet residential, commercial, and industrial needs[4]. This approach involves evaluating the sustainability of urban water management through various indicators. It provides a comprehensive assessment of a city's water management performance.The methodology and database of cities have been updated to include recent data and improved techniques for a more accurate analysis. A statistical estimation model for the Blue City Index (BCI) has been developed to estimate IWRM performance in cities lacking comprehensive data. Cities were selected based on criteria ensuring a representative global sample, allowing the estimation model to be applied effectively. Country-level challenges are also considered, providing a broader context for understanding urban water management issues[1].

It involves a comprehensive review of IUWM definitions and global experiences. The study examines how various cities have implemented IUWM and evaluates the efficiency of these integrated approaches. The authors analyze different elements of urban water management, such as spatial planning and Stormwater management, to provide a holistic input for urban planning[2]. The review employed a thematic analysis approach to extract, code, and identify converging themes from literature. Articles were screened and selected based on predefined inclusion and exclusion criteria. The themes identified were donor effects, water scarcity, transboundary water resources, and policy approaches [3].

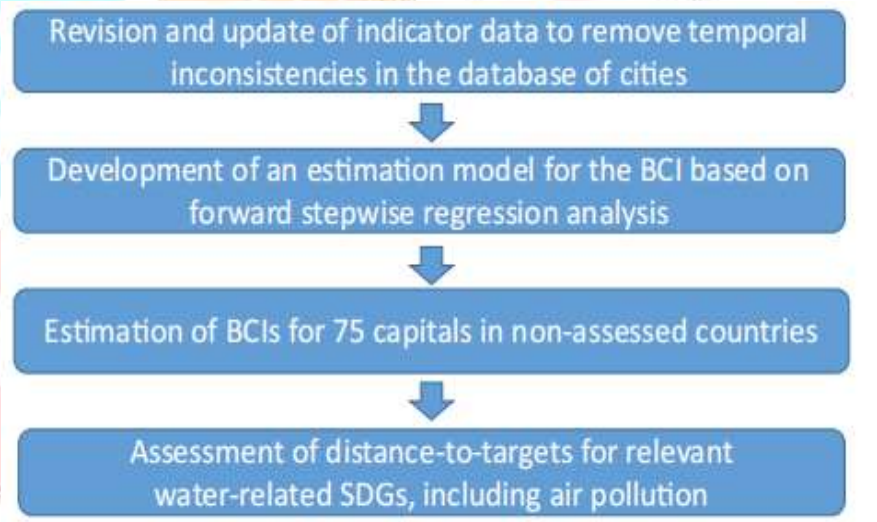

Figure: Different methods adopted in illustration of BCI Model[2]

The collected data through a detailed survey administered to UN Member States were analyzed, assessing the implementation of IWRM across four key dimensions: enabling environment, institutions and participation, management instruments, and financing. Scores for each dimension are averaged to obtain an overall IWRM implementation score for each country. The study uses a standardized approach to calculate progress and categorize countries into different levels of IWRM implementation: very low, low, medium-low, medium-high, high, and very high[5].

A detailed survey conducted among 186 UN member states to assess their progress in IWRM implementation from 2017 to 2020. The survey evaluated four dimensions: enabling environment, institutions and participation, management instruments, and financing. Countries were categorized into six implementation levels ranging from "very low" to "very high," based on their scores in these dimensions[6].

Figure : Different initiative for integrated water monitoring as per SDG6 [6]

INDICATORS	CUSTODIANS
6.1.1 Proportion of population using safely managed drinking water services	WHO, UNICEF
6.2.1 Proportion of population using (a) safely managed sanitation services and (b) a hand-washing facility with soap and water	WHO, UNICEF
6.3.1 Proportion of domestic and industrial wastewater flows safely treated	WHO, UN-Habitat, UNSD
6.3.2 Proportion of bodies of water with good ambient water quality	UNEP
6.4.1 Change in water-use efficiency over time	FAO
6.4.2 Level of water stress: freshwater withdrawal as a proportion of available freshwater resources	FAO
6.5.1 Degree of integrated water resources management	UNEP
6.5.2 Proportion of transboundary basin area with an operational arrangement for water cooperation	UNECE, UNESCO
6.6.1 Change in the extent of water-related ecosystems over time	UNEP, Ramsar
6.a.1 Amount of water- and sanitation-related official development assistance that is part of a government-coordinated spending plan	WHO, OECD
6.b.1 Proportion of local administrative units with established and operational policies and procedures for participation of local communities in water and sanitation management	WHO, OECD

Figure: Different indicators of SDG6 [6]

The method employed involves a comprehensive survey conducted by UNEP-DHI Centre on Water and Environment, assessing IWRM implementation in 186 countries. The survey measures progress based on four dimensions: enabling environment, institutions and participation, management instruments, and financing. These dimensions are scored and averaged to determine the overall level of IWRM implementation[7]. A detailed review of the evolution of IWRM through various international conferences and agreements, highlighting significant milestones and contributions from the 1977 United Nations Conference on Water in Mar del Plata to the World Summit on Sustainable Development in 2002 were evaluated. The authors critically analyze historical attempts to implement IWRM, examining the successes and failures to draw lessons for current and future applications[8].

The paper reviews significant milestones and developments in IWRM from the 1977 Mar del Plata conference to the 2003 Kyoto conference. It analyzes the progress and setbacks in implementing IWRM globally, drawing from various international conferences, forums, and case studies that have shaped the current understanding and practice of IWRM. The review focuses on the principles of good governance, public participation, and the integration of multidisciplinary approaches to water management[9].The methodology involves the use of climate and hydrological modeling to develop tools and resources for

climate change adaptation, including securing water resources and minimizing water-related risks. This approach aims to improve flood management strategies, understand climate change impacts on salmon migration and spawning, and update infrastructure such as dikes to handle potential inundation[10].

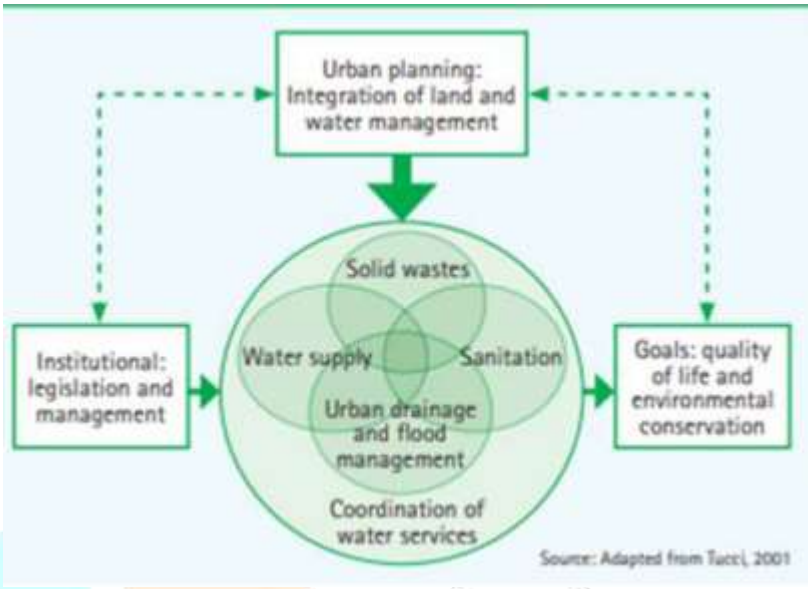

Figure: Co-ordination Framework of IUWM [4]

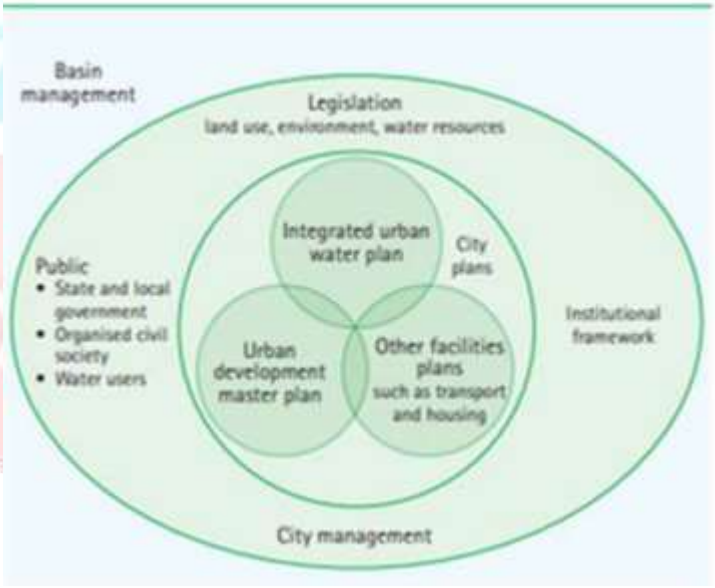

Figure: Linking Planning Framework of IUWM [4]

It includes a review of the history and background of MUS, a conceptual framework, and a detailed analysis of its practical applications. The paper examines different MUS systems, such as irrigation and domestic use modifications, community-based systems, and hybrid piped systems. It also discusses the limitations and potential risks of the MUS approach, such as exacerbating inequities and the need for effective coordination and accountability[11]. The method involves a thorough review of the historical context and background of MUS, the development of a conceptual framework, and an in-depth analysis of practical applications. The paper evaluates different MUS models, such as modifications for irrigation and domestic use, community-based systems, and hybrid piped systems. Additionally, it discusses the potential risks and limitations of MUS, such as exacerbating inequities and the need for effective coordination and accountability[12].

III. RESULTS ANALYSIS

The results section presents the outcomes of the IWRM-DMS implementation. The system showed significant improvements in efficiency (96.93%), reliability (98.24%), and overall performance (97.34%). It achieved low Mean Absolute Percentage Error (MAPE) of 21.41% and Root Mean Square Error (RMSE) of 15.12%. These metrics indicate the system's effectiveness in managing water distribution and predicting water demand. The results also highlight the system's cost-effectiveness and ability to maintain adequate water quality[4]. The model successfully estimates the IWRM performance of cities, providing valuable insights into their water management practices. The model has limitations, such as data availability and variability between cities, which must be considered when interpreting results.The model is applied to various cities, showcasing its utility in assessing different aspects of water management.A global analysis reveals widespread challenges, with many cities struggling to meet SDG targets related to water and sanitation.Country-specific challenges further illustrate the complexities of water management on a national scale[1].

IUWM solutions are while efficient and contribute to improved water management, not all elements can be integrated into a single solution. The study finds that the successful implementation of IUWM requires time, effort, and active collaboration among various stakeholders, including utilities, planners, storm water managers, and regulators[2].IWRM was initiated in 1998 by Nile basin states' water ministers to address concerns of riparian states. Kenya's national water policy and the Water Act 2002 (replaced by Water Act 2016) were significant milestones.The study covered various reforms and implementations influenced by donor effects, water scarcity, transboundary resources, and policy frameworks. Specific case studies and their outcomes were discussed.Fewer studies were included compared to East and Southern Africa, reflecting a need for more research in this region[].

Natural system		Land/water integration	Integration of land and "green water" (soil moisture from precipitation, used by plants via transpiration) and "blue water" (freshwater: surface and groundwater) management
		Surface water/ groundwater integration	Integration of surface water and groundwater management
		Water quantity/water quality integration	Integration of quantity and quality (water and wastewater) in water management
		Upstream/ downstream integration	Integration of upstream and downstream water-related interests
		Freshwater/marine integration	Integration of freshwater and coastal zone management
Human system	Sectoral	Cross-sectoral integration	Integration of water resource management with different public policy domains
		Inter-agency integration	Integration of public, private, and voluntary sector activity related to water resource management
	Territorial	Vertical integration	Integration between different spatial scales of water resource management
		Horizontal integration	Integration of water resource management between areas that form part of the same natural system
	Organizational	Strategic integration	Integration of water resource management with other strategies, programs, and initiatives
		Operational integration	Integration of water resource management with the delivery mechanisms in all relevant agencies
		Disciplinary/ stakeholder integration	Integration of different disciplines and stakeholders related to water resource management

Figure: Integrated Water resources Management Framework [7]

The results reveal significant variations in IWRM implementation across different countries and regions. While some countries have made substantial progress, achieving high or very high implementation levels, others are still at the low or very low implementation stages. The report highlights the need for increased efforts and targeted interventions to support countries lagging in IWRM implementation, particularly in regions facing significant water stress and management challenges[5].The results indicated varied levels of IWRM implementation globally, with some countries making significant progress while others lagged. High-scoring countries generally had well-established water management plans and robust stakeholder engagement. In contrast, low-scoring countries struggled with limited institutional capacity and inadequate

financing. Notably, the data revealed that progress in IWRM implementation is not linear and often influenced by political, economic, and social factors[6].

Significant variability in IWRM implementation across countries is analyzed. High-income countries generally show higher levels of implementation, whereas low-income countries face more challenges. The data indicate that while progress has been made since the baseline assessment in 2017, many countries are still in the early stages of implementing integrated water management practices. Notably, the report identifies regions and countries that have made substantial improvements and those that require more targeted support and interventions[7].while IWRM has gained widespread recognition and theoretical acceptance, its practical implementation faces significant challenges. The paper identifies seven critical challenges, including the need to integrate past experiences, recognize the spiritual and cultural aspects of water, and address the complexities of river restoration and fisheries management. These challenges highlight gaps in the current IWRM framework that need to be addressed to achieve sustainable water management[8].

Figure: Model for representing Integrated Water shed Management [10]

While IWRM has gained substantial traction and has been adopted in various forms worldwide, its implementation faces several challenges. These challenges include the lack of coherent policies, insufficient stakeholder engagement, limited financial resources, and the need for capacity building at local and national levels. The paper identifies seven crucial but often overlooked challenges in the current practice of IWRM, such as integrating local knowledge, ensuring sustainable financing, and addressing climate change impacts[9].Integrated watershed management strategies have been successful in addressing complex social, economic, environmental, and cross-jurisdictional issues. These strategies involve the engagement of local communities, First Nations, industry, and environmental organizations in decision-making processes. The use of models and technological advances has enhanced the understanding of the system and facilitated the development of more beneficial long-term strategies[10].

Integrated watershed management strategies have been successful in addressing complex social, economic, environmental, and cross-jurisdictional issues. These strategies involve the engagement of local communities, First Nations, industry, and environmental organizations in decision-making processes. The use of models and technological advances has enhanced the understanding of the system and facilitated the development of more beneficial long-term strategies[11].The findings highlight both the successes and challenges in implementing IWRM and MUS, such as the variability in progress across countries, the importance of stakeholder engagement, and the integration of local knowledge. Despite theoretical acceptance, practical implementation often faces hurdles like insufficient policies, limited resources, and the need for capacity building. The papers underscore the necessity for continuous improvement, innovative

legal frameworks, and broad public participation to ensure sustainable and equitable water resource management[12].

IV. CONCLUSION:

The conclusion summarizes the study's findings, reiterating the success of the IWRM-DMS in enhancing water resource management in rural areas. The system's IoT-based approach and use of various sensors for real-time monitoring have proven to be effective in reducing water demand and ensuring efficient water distribution. The study suggests that similar systems can be implemented in other rural areas to address water management challenges and improve sustainability[1].The findings highlight the need for continued efforts to achieve SDG targets, improve water governance, and implement effective IWRM practices. The paper calls for international collaboration and policy initiatives to address these global water challenges comprehensively[2].

For effective urban water management, it is essential to adopt IUWM as a core component of urban planning. This approach ensures the sustainable management of water resources, addresses the challenges posed by urbanization and climate change, and improves the overall quality of life in urban areas[3].While IWRM has seen varying levels of success across different regions, common challenges include the influence of donors, policy implementation issues, and managing transboundary water resources. The success of IWRM largely depends on localized adaptation and effective governance structure[4].

Although there has been notable progress in IWRM implementation globally, there is still a considerable way to go to meet the targets set for sustainable water management. The findings underscore the necessity of continuous monitoring, capacity building, and enhanced international cooperation to accelerate the adoption and effectiveness of IWRM practices worldwide[5].

While there has been notable progress in IWRM implementation since 2017, significant gaps remain. The paper calls for increased efforts to address these gaps, particularly in low-scoring countries, through enhanced capacity building, financial support, and stakeholder engagement. It stresses the need for a concerted global effort to accelerate IWRM implementation to meet the SDG targets by 2030[6]. The importance of continued efforts and international cooperation to enhance IWRM implementation globally is analyzed. It calls for increased investment, capacity building, and knowledge sharing to address the gaps identified. The paper emphasizes that achieving the sustainable development goals related to water resources requires a concerted effort from all stakeholders, including governments, private sectors, and civil society. The findings suggest that while progress is evident, much work remains to be done to ensure comprehensive and effective water management practices worldwide[7].

Although IWRM is a well-established concept, the main hurdle lies in its practical application. Effective implementation requires overcoming theoretical and practical challenges, incorporating lessons from past experiences, and addressing the diverse and context-specific nature of water management issues. The authors argue that without addressing these challenges, IWRM risks becoming an idealistic but impractical concept[8].The importance of addressing these challenges to fully realize the potential of IWRM in resolving water-related issues. It calls for a more inclusive approach that incorporates technological advancements, stakeholder participation, and adaptive management strategies to ensure sustainable and equitable water resource management[9].

While not all management initiatives in the Fraser River Basin have been entirely successful, the system serves as an exemplary model of integrative management and community engagement. Success emerges when integrated watershed management is utilized to address diverse issues through collaborative efforts. The study emphasizes the need for continuous improvement, innovative legal systems, and broad public participation to advance holistic sustainable watershed management[10].While MUS offers a promising approach to water management, it requires clear definitions, actionable roadmaps, and strong accountability measures. The paper recommends better knowledge sharing, improved data collection, and supportive legislation to create an enabling environment for successful MUS projects. These steps are crucial to avoiding past failures and ensuring sustainable progress in meeting the water needs of the global poor[11].

While significant strides have been made, achieving holistic and effective water management requires addressing the identified challenges, fostering international cooperation, and leveraging inclusive approaches that incorporate diverse stakeholder inputs and advanced technological solutions[12].

REFERENCES

[1] Grison, C., Koop, S., et al., 2023. Integrated water resources management in cities. Water resources Management, 37: 2787-2803.
[2] Nagata, K., Shoji, I., et al., 2022. Practicality of Integrated Water resources(IWRM) in different context. International Journal of water resources and management, 38(5): 897-919.
[3] Hadžič, E., Milišič, H., et al., 2022. Water resources management in Urban areas. 30.
[4] Ahmed,S.S., Bali, R.,et al. 2021. Improved Water resources management framework for water sustainability and security. 201(2): 111527.
[5] Dirwai, L.T., Kanada, K.E., et al., 2021. Water resources management: IWRM strategies for improved water management. A Systematic review of case studies of East, west and Southern Africa. https://doi.org/10.1371/journal.pone.0236903.
[6] Progress on Integrated water resources management, 2021. Global Indicator 6.5.1 updates and accelaration needs.
[7] Kumar, P.C., 2018. Water resources issues and management in India. Journal of Scientific & Engineering Research, 5(9):137-147.
[8] Rahman, M.M. and Varis, O., 2017. Integrated Water resources Management:Evolution, prospects and future challenges. Sustainability: Science, Practice and Policy, 1(1): 15-21.
[9] Wang, G., Mang, S., et al., 2016. Integrated watershed management: Evolution, development and Emerging trends. Springer, 27(5): 967-994.
[10] Loucks, P.D., and Crosgrove, J.W., 2015. Water management:Current, Future challenges and research directions. Water resources research, 51: 4823-4839.
[11] Srinivasan, V., Akudago, A.J., et al., 2011.Integrated water resources management: A Global review.
[12] Falkenmark, M., Villareal-Gonžalez, F., et al., 2000. Integrated water resources management.