Historical evolution of water resource management using adaptive governance model

Shoira Turayeva[1]; Ugiloy Yunusova[2]; Umid Mavlyanov[3]; Zilola Abdualimova[4]; Fakhriddin Niyozov[5]; Tolqin Irgashev[6]; Ikhtiyor Rakhimov[7]; Ugiloy Shukurova[8]

Received: 17 January 2025; Revised: 27 February 2025; Accepted: 18 March 2025; Published: 20 May 2025

Abstract

Nations continue confronting Water Resource (WR) related issues, including WR scarcity, contamination, and excessive groundwater use. This study examines the WR situation and asserts that governance is the root of the WR-related problems. The analysis of the existing WR policy structure reveals that the control-command methodology is a static technique, which is inadequate for addressing the uncertainties within the WR sector. An Adaptable Governance Model (AGM) is presented, emphasizing the processes of learning and involvement. The learning procedure prevents the repetition of errors, while participation guarantees an array of data, both of which are essential for effective WR-related administration.

Keywords: Water resource, Resource management, Adaptive governance, Historical evolution

1- Jizzakh State Pedagogical University, Uzbekistan. Email: shoiratorayeva@jdpu.uz, ORCID: https://orcid.org/0000-0002-4132-8163
2- Senior Teacher of the Department of Economics, “Tashkent Institute of Irrigation and Agricultural Mechanization Engineers” National Research University, Uzbekistan. Email: ubolkiboyeva@bk.ru, ORCID: https://orcid.org/0009-0005-8200-0446
3- Gulistan State University, Uzbekistan. Email: mavlyanov@list.ru, ORCID: https://orcid.org/0009-0008-4506-3394
4- Gulistan State University, Uzbekistan. Email: zilola_bdualimova@list.ru, ORCID: https://orcid.org/0009-0009-1709-9784
5- Gulistan State University, Uzbekistan. Email: niyazovfaxriddin1972@gmail.com, ORCID: https://orcid.org/0009-0001-6673-0669
6- Chirchik State Pedagogical University, Uzbekistan. Email: tolqinirgashev80@gmail.com, ORCID: https://orcid.org/0009-0001-4091-9826
7- Namangan State Pedagogical Institute, Uzbekistan. Email: ixtiyorraximov565684@gmail.com, ORCID: https://orcid.org/0009-0007-9676-6148
8- Gulistan State Pedagogical Institute, Uzbekistan. Email: ugiloy_shukurova@mail.ru, ORCID: https://orcid.org/0009-0000-3359-6427
DOI: 10.70102/IJARES/V5I1/5-1-02

Introduction

Sustainable Water Resource (WR) (Shu, Cao and Wu, 2021) management is crucial for society yet presents significant global challenges, including inadequate sanitation, depletion of WR supplies, and financial damages linked to extreme weather like hurricanes and droughts (Tuyboyov *et al.,* 2025). The persistent issue of managing WR assets has been exacerbated by the potential impacts of climate and global warming, which can alter the accessibility and distribution of clean WR alongside the demand for fluid and groundwater supplies (Gandhi, Prakruthi and Vijaya, 2024; Lukat, Pahl-Wostl and Lenschow, 2022).

Effective governance (Karimidastenaei *et al.,* 2022) is essential for enhancing the administration of WR. WR governance emerged in the academic literature alongside new methodologies of natural resource administration (Krishnan and Patel, 2023). The study delineates an apparent distinction between WR administration and governance of WR. WR administration encompasses the procedures involved in analyzing and monitoring resources and the steps formulated and executed to maintain these resources in a favorable condition (Prasanna *et al.,* 2024). WR policy is characterized as a societal role that regulates the creation and oversight of WR assets and services while offering guidance regarding an ideal situation and away from an unwelcome one (Anand *et al.,* 2024).

Conventional governance (Hrnjadović and Suljić, 2020) of resource frameworks has developed over an extended duration and is intricately linked to the technical framework. In the final quarter of the twentieth century, society began to scrutinize the wisdom of only depending on the scientifically rational method for managing and utilizing the earth's resources (Devi, Dey and Kumar, 2024). Conventional WR administration is typically termed supply control. The primary objective is to attain equilibrium between WR supply and consumption by developing freshwater supplies and extensive long-distance WR systems. Supply administration (Ngene *et al.,* 2021) relies on "endless drinking WR," disregarding the potential for WR conservation when implementing practices. The conventional decision-making approach is hierarchical and fails to accurately represent WR users' evolving needs (Pahl-Wostl, 2021).

The Adaptive Governance Model (AGM) (Tarrillo *et al.,* 2024) is lauded as a methodology for addressing intricate issues, managing unpredictability, enhancing resilience, and advancing the overall oversight of WR systems (Asif *et al.,* 2023). The principal premise of AGM articulates its immediately compelling rationale: the acquisition of knowledge and then the modification of management procedures by ongoing testing, tracking, assessment, and adjustment of policy alternatives within a cyclical framework (Tantoh *et al.,* 2021; Hu and Sinniah, 2024). Despite its appeal, and although research on additive manufacturing is extensive, experts have expressed many worries over the field's progression. The term is employed in an overly broad manner, resulting in a deficiency of understanding regarding learning proper. Experts express skepticism over the practicality of the experimental technique

in many ecological field contexts (Pahl-Wostl, 2021). There is a scarcity of empirical WR research concerning complete rounds of additive manufacturing cycles or documentation of actual deployment (Farooqi and Sharma, 2024).

Background

Resource directors overestimated the implications of feedback impacts, non-linearity, temporal delays, and individual behavior alterations, which are crucial for policy formulation. The growing acknowledgment of economic and social risks and intricate policy challenges has led to a broad reevaluation of governance and management practices. It has been apparent that numerous issues are not fundamentally linked to the foundation of resources but rather stem from governance shortcomings. The research asserted that establishing AGM is predominantly a governance challenge rather than a matter of technology since "adapting to changing conditions is constrained by societal values, perceptions, procedures, and power arrangements." The study developed a theoretical basis for effective management of WR. It formulated a plan harmonizing WR availability and demand while considering ecological, financial, and social objectives. Critics have advocated for significant paradigm adjustments in managing (Wei-Liang and Ramirez, 2023). The capacity of governance structures to manage ambiguity and unexpected events is a crucial prerequisite for sustainability in the context of escalating unpredictability resulting from climate and globalization. Various studies have indicated the necessity for adaptive control of WR supplies. Plans for adaptation in WR policy and procedure are essential to address the problems of present and future Climate Change (CC). Supply- and demand-side AGM can be implemented to secure WR supply during typical drought situations. Simultaneously, CC impacts WR-related facilities' functionality and operation, including hydroelectricity, architectural flood barriers, drainage and irrigation networks, and WR management methods. CC (Keyhanpour, Jahromi and Ebrahimi, 2021) affects flow during wet seasons, while its impact on fish habitat quantity in lower reaches is significant during dry seasons but minimal during flood seasons. The shortage of WR supplies, pervasive WR contamination, and escalating demands due to fast social and financial expansion constrain its continued growth and stability. WR supply deficiencies jeopardize global sustainability and exert worldwide repercussions if the nation can no longer maintain its capacity to provide adequate food for its vast and expanding population. Thus, enhancements in WR governance constitute a significant challenge for improved WR governance (Vakhguelt and Jianzhong, 2023).

AGM is an experimental methodology that global WR policy bodies employ to oversee and rehabilitate aquatic environments. A rigid managerial framework frequently limits the strategy's efficacy. The study examined an instance of information co-production to evaluate the relevance of border work as a theoretical framework for facilitating AGM in the WR industry. A new operational chart for a cascade hydroelectric dam has been introduced to

mitigate ecological damage during hydrological storms. A study issued a report suggesting national, local, and neighborhood policy actions and potential future adaptable freshwater administration. Managerial reform that prioritizes adaptation can enhance the availability of WR and produce socio-economic benefits by fostering an in-depth comprehension of the WR system's operations and aligning objectives and expenditures across several presently disjointed policy domains. Employing a loosely flexible governance structure, the study facilitated returns from a wooded wetland system into a substantial lowland river. This article proposes an appropriate AGM for managing WR, integrating sophisticated ideas and the current state of WR (Moreau and Sinclair, 2024). The aim is to sustain and enhance the durability of WR structures, ensuring their continued existence and flexibility to outside influences. AGM of WR entails the utilization of resources and the enhancement of management capacities.

AGM can holistically address WR's sustainable, financial, social, and environmental dimensions while constantly refining comments to resolve planning challenges and facilitate sustainable growth for decision-makers involved in relevant plans. Managers must accept ambiguity and pursue chances for learning via experimenting (Chapagain *et al.*, 2024). Navigating the ambiguities in interpersonal and political connections with innovation endorsed by various groups is essential. Flexible governance is a crucial element in addressing the issue of WR supply.

Proposed AGM based WR Management

The long-term oversight of intricate adaptive structures has challenges due to varying temporal, geographical, and social scales, nested structures, unavoidable uncertainty, multidimensional conversations, and emergent features. The deficiencies of the existing framework have led to growing criticism of the Command-Control (CC) system, as it detaches itself from the demands and situations at lower tiers in adapting to evolving surroundings. It creates lock-in circumstances, a term from economics that denotes the prevalence of proven technologies despite their lower performance attributable to dependency on paths. This planning framework is susceptible to unexpected events and crises due to the rigidity of management institutions.

The growing recognition of CC effects necessitates that WR policy adopt greater flexibility to address uncertainties and unforeseen events. The eco-hydrological structure has experienced significant alterations in recent decades, attributed to warming temperatures and the development of cascade dams for energy generation. In recent decades, an increasing body of research has advocated establishing AGM to improve capacity and optimize WR-related practices and regulations.

The AGM is derived from the Complex Adaptive Framework (CAF), a sophisticated, nonlinear, self-organizing entity capable of adapting to CC. The primary characteristic of the AGM is its learning capacity. This system can acquire knowledge from experiences and prevent the recurrence of identical errors.

A CAF comprises numerous fundamental components (i.e., agents) that continuously interact with one another by defined regulations. These people constantly engage, acquire knowledge, and gain expertise from such conduct—for instance, the immunity system, the stock marketplace, economics, etc. The modular system architecture and decentralized governance enhance the adaptability and resilience of a system.

AGM is employed to address complex and challenging resource issues. In contrast to conventional management approaches, AGM is predominantly marked by significant uncertainty and limited management. The essential distinction between AGMs and traditional management is that AGM relies on experimentation, with managers continuously modifying approaches to address the demands of an unpredictable outside setting. The method is circular due to feedback mechanisms. The conventional management strategy typically employs administrative directives and fails to assess the complexity of systems, resulting in management delay in a linear procedure. Under an AGM, WR safety would be perpetually assessed and redefined to align with the demands of an ever-evolving environment instead of being treated as a fixed objective or conclusion (Figure 1).

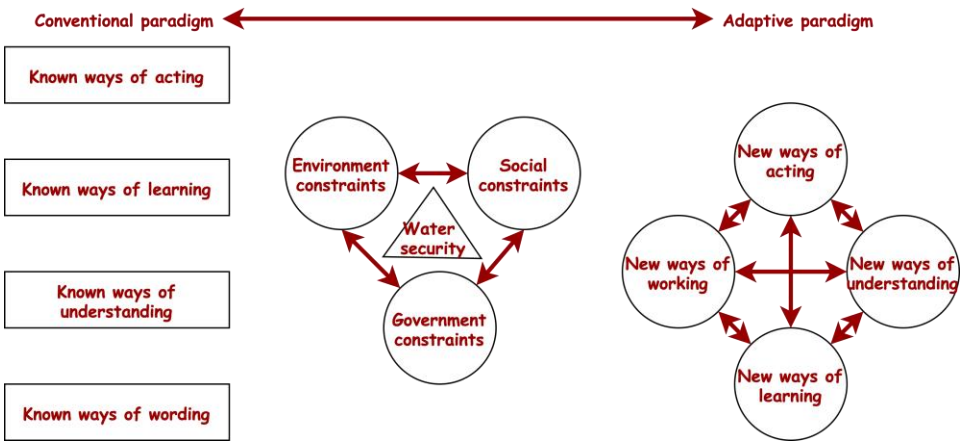

Figure 1: Traditional and AGM analysis

Training Cycles in Country: An AGM

AGM is an organized method that enhances procedures and operations through continuous learning derived from the results of actions and initiatives. The study advocates for flexible governance as a cohesive paradigm to guide policies that enhance the preservation of transboundary watersheds in an uncertain future while equipping the interconnected social-ecological systems to address unforeseen change agents. The study identifies four characteristics of AGM: (1) reestablishing the connection between humans and the environment; (2) amalgamating different viewpoints and forms of information; (3) advancing adaptable and integrative administration objectives; and (4) employing polycentric organizations and analytical deliberation methods. The research characterized the governance structure as an expansive concept that includes structural attributes and dynamic processes at both the rule-making and practical levels, facilitating the

formulation and implementation of WR policies.

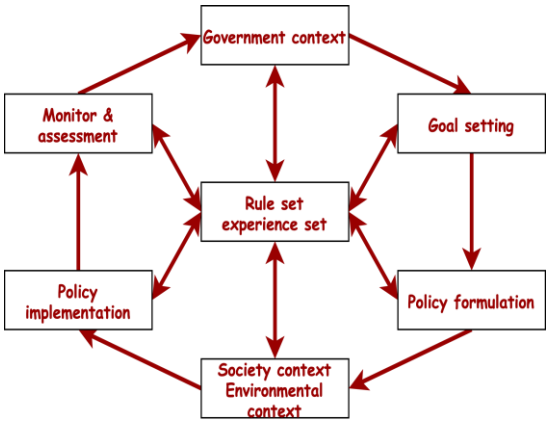

Figure 2. Learning cycle

Based on the literature and empirical research, the essence of AGM is the learning cycle, as seen in Figure 2. The entire process comprises six stages in the field of WR administration: governmental context, goal establishment, policy design, social environment and ecological context, policy execution, tracking, and evaluation. The learning process is integrated into two components:

(a) The Perpetual Cycle

The entire procedure constitutes a perpetual cycle. All policies are not immutable, permitting modification and adaptation. The present framework is founded on the optimal setting, enhancing the established objective by available knowledge and facts. Once established, change is less likely to occur. Data integrity is contentious; some scholars have questioned its feasibility, stating that the WR structure is exceedingly sensitive and unpredictable. Although it is feasible to gather all the data, the substantial task cannot be completed under the present circumstances. CAF states that the WR network is characterized by significant complexity and volatility. Optimization represents an unattainable ideal paradigm. The execution will progressively diverge from the initial approach, and the original strategy will become ineffective in the event of significant catastrophes.

The ongoing loop could effectively mitigate this issue. This does not imply an absence of errors; owing to the continuing nature of the process instead of a linear approach, the problems recognized can be rectified in due course. Monitoring and evaluation are other components. Incorporating a wider array of interests provides access to diverse expertise essential for comprehensively evaluating a resource management issue and identifying novel strategies to address it.

This loop signifies the management strategies for the administration of WR, which will be perpetually monitored and assessed with the involvement of diverse stakeholders, environmental factors, and societal influences throughout the execution of relevant regulations, thereby leading to more tailored management decisions.

Established Regulations and Experiential Framework

The rule set and the experience set influence the adaptation process. It is a compilation of acquired expertise and validated principles. The iterative process facilitates experimentation and failure while established norms and lessons learned prevent repeating the same mistake.

Each participant or relevant agency might contribute new ideas and innovative methods to the collection while extracting pertinent knowledge to

support their decisions. It is an adaptive and supplementary process. For instance, without a rule set and a knowledge set, the ongoing loop repetitively commits the same errors; without the continual loop, the rule set and knowledge set can't be developed and refined.

Nations employ numerous methods for managing WR that might be regarded as established principles or experiential knowledge. Executives ought to categorize these management principles and knowledge into a structured repository. Effective policy implementation and WR administration can be achieved through these strategies. These regulations and experiences serve as the foundation for advancements in WR handling and the benchmark for evaluating WR governance requirements, which are constantly altering to establish new rules and practices.

Distinct Framework of AGM

The research advocates for flexible governance as a theoretical foundation for the holistic management of WR, offering a paradigm for incorporating stakeholder input into freshwater resource management while addressing uncertainty.

A structure for the AGM of WR assets is constructed, as illustrated in Figure 3. This governance framework comprises multiple stakeholders who collaboratively establish WR management objectives, considering complex variables such as hydrological circumstances, assets, environmental aspects, and regional socioeconomic circumstances. They employ hydrological, socio-economic, and optimum distribution algorithms to validate and enhance these objectives. Following the establishment of progressive management goals, the framework implements WR system building, a stringent oversight of WR structure, a river-belonging structure, and further measures to direct and enhance regional WR consumption and conservation. Due to the impact of implementing different measures, the framework employs distinctive and cohesive continuous tracking and dynamic evaluation to compare assessment outcomes with managerial goals, facilitating self-adaptive acquiring to identify modifications and strategies, which are utilized as input criteria for the subsequent decision-making phase. Relevant groups are undertaking a new phase of WR management goals and are considering additional elements.

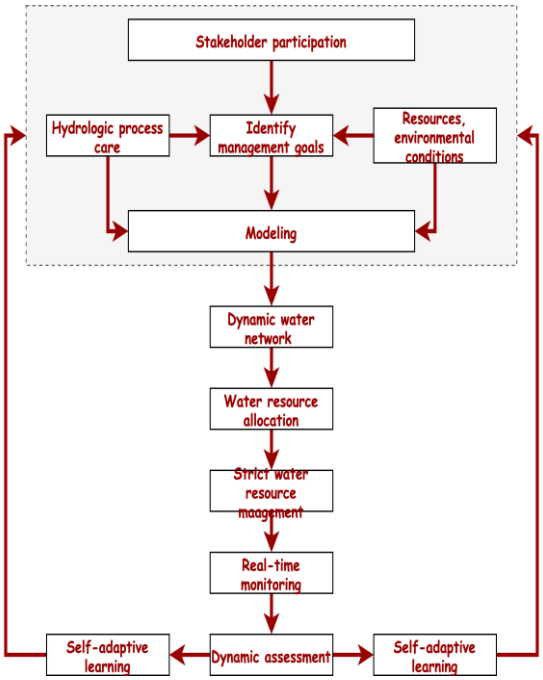

Figure 3: Water resource AGM

Discussion

A complex link exists among governability, governance, and public administration. All three entities engage in WR administration, and effective

management is contingent upon their coordination and collaboration. Governability offers legal and policy assurances for overseeing WR supplies; public management is equally essential. The primary governance entity must be societal governing bodies, with the government overseeing WR via these organizations. The primary entities for governing consist of private or public organizations or a collaboration between the two.

Governance entails the collaboration among governability and civil society, the partnership between governmental and non-governmental entities, the interaction between private and public organizations, and both coercive and open collaboration. Governance encompasses more topics than administration, with a more significant number of players. The governing body's practical and orderly administration of WR assets necessitates adherence to legislative frameworks, legal support, and integration with public administration and safeguarding efforts.

WR Management

WR directors must know extensively about prior management instances and events, considering financial, social, ecological, and other relevant variables. The workers acquire continuous monitoring information regarding WR assets and develop intelligent management platforms and systems to assist administrators in setting and adjusting objectives in actual time depending on various influences while handling WR.

Sectors Utilizing WR

All departments must enhance awareness regarding the judicious utilization of WR assets, optimize the effectiveness of WR use, and coordinate their WR consumption data with other divisions. They should document WR consumption in real time and offer managerial input to facilitate the dissemination of WR data on resources across various levels. The agency's external WR consumption adjustment indicates that the WR management structure can promote an equitable distribution of WR assets and optimize the overall advantages.

WR Utilizer

As the fundamental unit of WR utilization, every citizen should cultivate knowledge of methods to conserve WR, encourage others to preserve watersheds, safeguard the marine ecosystem, and adhere to rules about WR handling, such as the river ownership system. Users must identify and address any WR issues promptly.

Conclusion

The increasing demand for WR in farming, manufacturing, domestic use, and ecology has rendered the current supply insufficient. The condition is exacerbated by WR pollution to the environment. The research examined the situation of managing WR and underscored the importance of considering complexity within the management framework and developing AGM.

This study analyzes the deficiencies of the existing management framework. Despite numerous amendments and corrections to the existing CC management, its shortcomings have

become evident. It resulted in public loneliness, state organization, and the disjunction between WR consumption and conservation. The WR structure is a CAF characterized by complexity, nonlinearity, and self-organization; hence, the research proposes AGM to address existing shortcomings.

The research developed a viable alternative WR management framework incorporating learning and engagement. The existing CC administration should be supplanted by flexible governance. AGM relies on the learning cycle, which facilitates the acquisition of knowledge from the past and the ability to modify actions based on the prevailing circumstances. An inflexible approach is incapable of addressing emergencies and unforeseen events. The involvement of various stakeholders, including managers, WR-utilizing sectors, and individual WR users, enhances the decision-making process for WR executives, industries, and consumers.

The benefits of the AGM of WR include 1) collaboration among many stakeholders, 2) a robust organizational structure, and 3) the enhancement of how decisions are made. The AGM targets the intricate WR structure, executing a continuous cycle of identification, monitoring, assessment, response, and adjustment of various actions. Modifying the WR structure involves continuously adjusting the organization of WR strategies and allocation plans, thereby facilitating the creation, utilization, and conservation of WR assets while consistently aligning with organized and sustainable progress across financial, social, environmentally friendly, and other dimensions.

References

Anand, J., Hemasundari, M., Kavitha Selvaranee, J., and Michael Mariadhas, J., 2024. Role of Strategic Human Resource Management and the Development of Information Systems for the Enhancement of Libraries. *Indian Journal of Information Sources and Services, 14*(2), pp.78–84. https://doi.org/10.51983/ijiss-2024.14.2.12

Asif, Z., Chen, Z., Sadiq, R. and Zhu, Y., 2023. Climate change impacts on water resources and sustainable water management strategies in North America. *Water Resources Management*, *37*(6), pp.2771-2786.

Chapagain, K., Babel, M.S., Karthe, D. and Stamm, J., 2024. Integrated assessment of water–energy–food nexus: Conceptual framework and application to the Ping River basin, Thailand. *International Journal of Water Resources Development*, *40*(2), pp.284-318. https://doi.org/10.1080/07900627.2023.2252529

Devi, P., Dey, S.R. and Kumar, P., 2024. Integration of water resources management in rural areas. In *Water Resources Management for Rural Development* (pp. 139-152). Elsevier. https://doi.org/10.1016/B978-0-443-18778-0.00013-1

Farooqi, A. and Sharma, S., 2024. Marriage Patterns and Household Formation: Insights from Historical Demography. *Progression journal of Human Demography and Anthropology*, *2*(2), pp.17-21.

Gandhi, N., Prakruthi, B. and Vijaya, C., 2024. Effect of Industrial Emissions on Haematological and Biochemical Parameters of Channa

striata Fresh Water Fish. *International Journal of Aquatic Research and Environmental Studies*, *4*(1), pp.115-119. http://doi.org/10.70102/IJARES/V4I1/10

Hrnjadović, J., and Suljić, N., 2020. Unevenness of Water Consumption in Settlement on the Case of Doboj. *Archives for Technical Sciences*, *1*(22), pp.35–42.

Hu, X. and Sinniah, S., 2024. The Role of Green Risk Management Approaches in Promoting Green and Sustainable Supply Chain Management. *Natural and Engineering Sciences*, *9*(2), pp.33-54. https://doi.org/10.28978/nesciences.1569144

Karimidastenaei, Z., Avellán, T., Sadegh, M., Kløve, B. and Haghighi, A.T., 2022. Unconventional water resources: Global opportunities and challenges. *Science of the Total Environment*, *827*, p.154429. https://doi.org/10.1016/j.scitotenv.2022.154429

Keyhanpour, M.J., Jahromi, S.H.M. and Ebrahimi, H., 2021. System dynamics model of sustainable water resources management using the Nexus Water-Food-Energy approach. *Ain Shams Engineering Journal*, *12*(2), pp.1267-1281. https://doi.org/10.1016/j.asej.2020.07.029

Krishnan, M., and Patel, A., 2023. Circular Economy Models for Plastic Waste Management in Urban Slums. *International Journal of SDG's Prospects and Breakthroughs*, *1*(1), pp.1-3.

Lukat, E., Pahl-Wostl, C. and Lenschow, A., 2022. Deficits in implementing integrated water resources management in South Africa: The role of institutional interplay. *Environmental science & policy*, *136*, pp.304-313.

Moreau, I. and Sinclair, T., 2024. A Secure Blockchain-Enabled Framework for Healthcare Record Management and Patient Data Protection. *Global Journal of Medical Terminology Research and Informatics*, *2*(4), pp.30-36.

Ngene, B.U., Nwafor, C.O., Bamigboye, G.O., Ogbiye, A.S., Ogundare, J.O. and Akpan, V.E., 2021. Assessment of water resources development and exploitation in Nigeria: A review of integrated water resources management approach. *Heliyon*, *7*(1). https://doi.org/10.1016/j.heliyon.2021.e05955

Pahl-Wostl, C., 2021. Adaptive and sustainable water management: from improved conceptual foundations to transformative change. In *Global Water Resources* (pp. 175-193). Routledge.

Prasanna, D.S.J.D., Punitha, K., Shrividya, G., Haval, A.M. and Vij, P., 2024. An Optimized and Cost-Effective Resource Management Model for Multi-Tier 5G Wireless Mobile Networks. *Journal of Wireless Mobile Networks, Ubiquitous Computing, and Dependable Applications*, *15*(3), pp.136-149. https://doi.org/10.58346/JOWUA.2024.I3.010

Shu, R., Cao, X. and Wu, M., 2021. Clarifying regional water scarcity in agriculture based on the theory of blue, green and grey water footprints. *Water Resources Management*, *35*, pp.1101-1118.

https://doi.org/10.1007/s11269-021-02779-6

Tantoh, H.B., Simatele, D.M., Ebhuoma, E., Donkor, K. and McKay, T.J., 2021. Towards a pro-community-based water resource management system in Northwest Cameroon: Practical evidence and lessons of best practices. *Geo Journal*, *86*, pp.943-961. https://doi.org/10.1007/s10708-019-10085-3

Tarrillo, S.J.S., Rosas, R.G.N., Vásquez, E.J.F., Reyes, E.M.A., Canales, H.B.G., Medina, A.O.B., Luna, R.D.O., and Bulnes, J.L.L., 2024. The Impact of Internet Security Awareness among Undergraduates in Learning Management System. *Journal of Internet Services and Information Security, 14*(3), pp.256-264. https://doi.org/10.58346/JISIS.2024.I3.015

Tuyboyov, O., Turdikulova, B., Davlatova, R. and Norov, S., 2025, February. The role of AI-driven intelligent tutoring systems in enhancing mechanical engineering education. In *AIP Conference Proceedings* (Vol. 3268, No. 1, p. 070038). AIP Publishing LLC. https://doi.org/10.1063/5.0257379

Vakhguelt, V. and Jianzhong, A., 2023. Renewable Energy: Wind Turbine Applications in Vibration and Wave Harvesting. *Association Journal of Interdisciplinary Technics in Engineering Mechanics*, *1*(1), pp.38-48.

Wei-Liang, C. and Ramirez, S., 2023. Solar-Driven Membrane Distillation for Decentralized Water Purification. *Engineering Perspectives in Filtration and Separation*, *1*(1), pp.16-19.