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The Role of Artificial Intelligence and its Tool in Water Management

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A B S T R A C T

Water is an essential and finite resource for human survival, ecosystem health, and socio-economic development. As the global demand for clean water intensifies, sustainable water management has become an urgent priority. To ensure a reliable and long-term supply, adopting innovative methods that are environmentally sound, economically viable, and energy-efficient is critical. This paper comprehensively reviews water quality and quantity management techniques based on artificial intelligence (AI) to enhance water management efficiency. By incorporating green technologies, AI can significantly improve water resource efficiency, reduce waste, and safeguard human health and the environment. The findings highlight these technologies' importance and offer practical solutions without requiring in-depth technical knowledge.

Keywords: *Artificial Intelligence, water management, smart water grid, machine learning, modern tools*

1. Introduction

This study underscores the potential of AI and green technologies in revolutionising water management for a sustainable future [1]. Water is a valuable resource for human health and the natural environment, and it is described as the world's most important natural resource. In recent decades, it can be depicted that climate change, a rise in population, changes in water usage patterns, and socio-economic development have adversely affected the hydrological cycle and threatened human water security and aquatic biodiversity [2]. Good quality water is essential in sustaining our health and is also required for energy production, irrigation, and other recreational activities [3]. Hence, this concern must be planned and managed suitably. The availability of water resources on both surface and groundwater has been reduced due to pollution, periodic droughts, and excess consumption. Most developing countries face water-related issues in managing water resources and water pollution, which causes health issues.

Moreover, uncertain rainfall, frequent cyclones, and droughts are becoming common. Maintaining water availability and quality water balance analysis is essential in water collection and delivery systems because it determines the link between storage capacity, reuse demand and supply dependability. The designs should, in particular, be efficient not just at total capacity but also under reduced-service situations such as non-optimal, supply-limited, and unexpected conditions [4]. However, the over-reliance on supply-driven urban water supplies has been increasingly discovered and criticised, and these are regarded as wasteful and expensive supply-side solutions. It has generally led to gains in living standards for all living groups, while the same technology, on the other hand, caused environmental degradation. Positive shifts in technologies for urban use are undoubtedly possible, and we need to explore green technologies for water management. Green technologies can deliver an output that can help improve economic productivity, conserve natural resources, and limit the adverse effects on the environment and social well-being [5].

Green technology can reduce the impact of water-related issues and provide proper water quality and quantity to society and our ecosystem. Throughout the twentieth century, the term 'technology' evolved to the point where it now encompasses several technology classes. In water management, technology should increase access to resources. Therefore, artificial intelligence in water management should aim to enhance resource utilisation, quality monitoring, and practical maintenance. AI incorporates IoT integration and machine learning and facilitates forecasting demand, detecting leakages, monitoring water quality, and managing floods. This technology takes efficiency, sustainability, and resilience in water infrastructures to a new level globally [6].

Technologies for Sustainable Water Management also describes the scientific concepts and technological advancements that effectively enable green technologies to solve critical environmental challenges. The major problem for sustainable water management is that technology must be sustainable itself, which implies that procedures for treating and maintaining the world's finite water supplies must be environmentally friendly, economically feasible, and energy-efficient, where AI can play an important role [7]. Appropriate approaches will improve pollutant removal efficiency and nutrient recovery while lowering carbon emissions, reducing waste, and safeguarding human health and the environment [8]. As a result, demand management methods in integration with AI should be adopted with an emphasis on measures that make better and more effective use of limited supply. The specific definition of demand management is the adaptation and implementation of a strategy (policies and initiatives) by a water institution influencing water demand and water usage to meet objectives (such as economic efficiency, social development, social equity, environmental protection, and political acceptability) to achieve the sustainability of water supply and services [9]. Figure 1 tells us about the recent number of publications related to water management through AI, and in the past few years, the work in the same has been increasing exponentially.

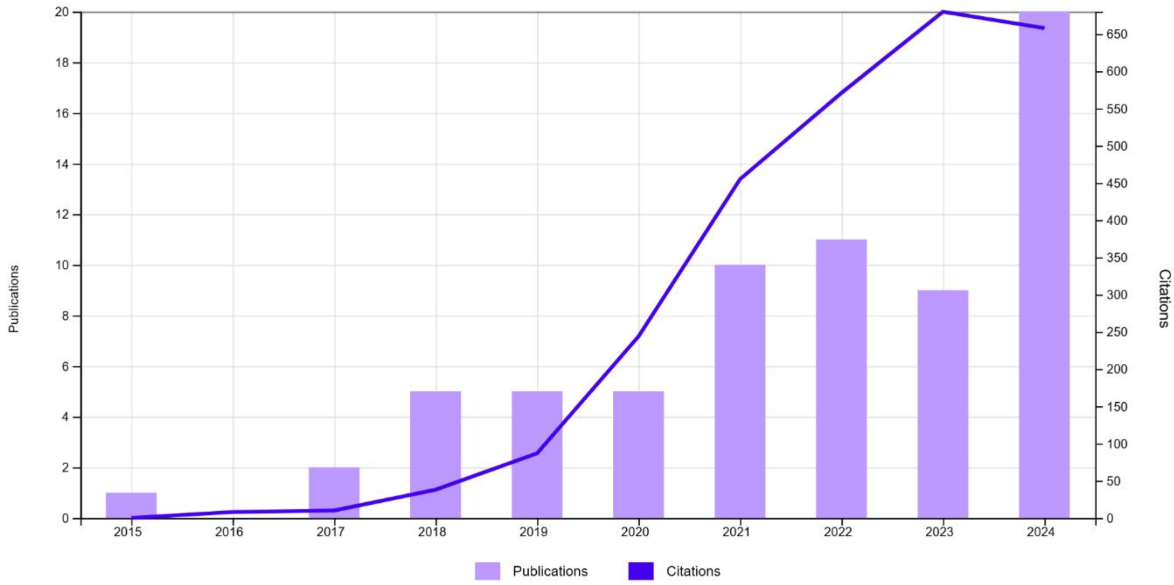

Figure 1: Total number of publications and citations in the field of AI water management

2. Tools and Salient Features of AI-driven Sustainable Technologies for Water Management

Artificial intelligence (AI), machine learning (ML), artificial neural networks (ANN), and deep learning (DL) are the typical features for developing expert artificial technology. Among them, AI represents any method that tries to replicate the results of some aspects of human cognition; ML stand for programs that perform better with experience; ANN is a machine learning algorithm, whereas DL is A type of ANN. All these features need a large amount of data to perform, which should be collected using ethical data collection methods.

AI in water management is widely used in developed or developing countries like the USA, Iran, and Australia [10]. Figure 2 shows the usability of AI and ML in water management, which can be understood as,

(i) Explanation and prediction tools are used to determine what happened in one location at one time in the water distribution network without any instrumental and sensor data [11].

(ii) Forecasting tools are used for the “what if” scenario for planning and operating the water distribution network [6].

(iii) Prescriptive tools for decision support platforms are becoming popular because they advise on the best options to solve a particular problem.

For machine learning, ANN models are flawless determining instruments for precipitation spillover forecast, stream-stream prediction, and groundwater hydrology[12].

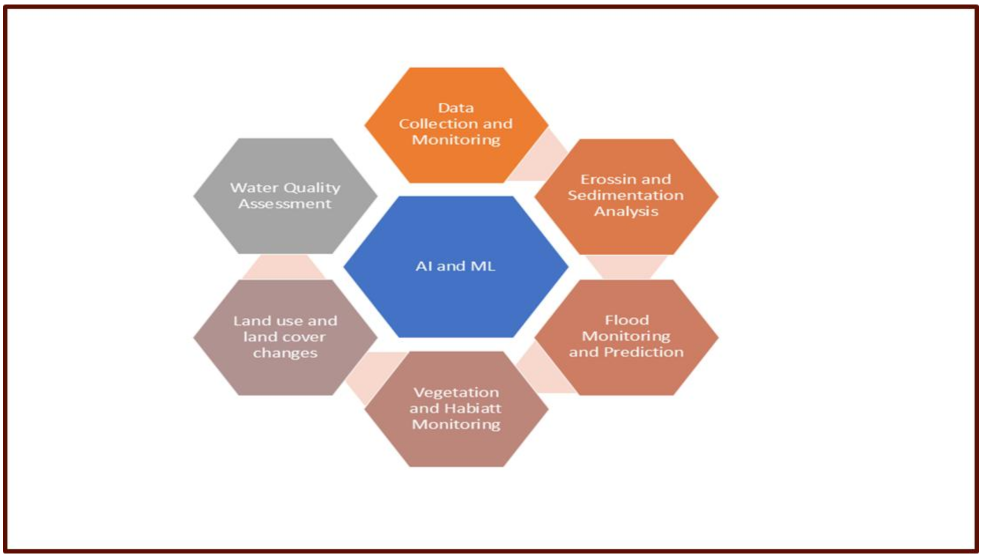

Figure 2: Different role of AL and ML in water management: Source: [14]

2.1 Remote Sensing and GIS

Remote sensing and GIS play a vital role in conserving and utilising the country's water resources. It was first used for environmental concerns between 1947 and 1971. In India, it was used for integrated water management in 1986[13]. To achieve optimum planning and operation of water resources-related projects, the latest remote sensing techniques must be combined with the traditional methods of measurement and management of water resources that will lead to sustainability[14]. The usefulness of Remote Sensing for crop classification, rainfall and snowfall estimation, soil moisture analysis, and surface and groundwater use is shown to be used for water resources planning and management in combination with GIS[15].

2.2 Geospatial Technology

This technology was first used in 1966, and for hydrological modelling, it was first used by the Maryland Department of State Planning in 1974 [16]. Geospatial success increases innovation in water management since it gives accurate information about the water monitoring system, planning, and the evaluation of the infrastructure[17]. Remote sensing, GIS, and Satellite images facilitate real-time tracking of water resources, droughts, and flood risks. This technology enhances effectiveness in planned operations, prevents time wasting, and optimises the use of resources in urban and rural areas[18]. GIS is best suited for determining a strategic plan for executing desired results applicable to different regions and objectives (e.g., determination of water-river boundaries, water quality and quantity, soil moisture, flood plains, ocean temperature, etc. [14].

3. Aspects of water management practices using AI

Past years have witnessed substantial and significant interventions for managing our Water Resources, quantitatively and qualitatively, with the help of Artificial Intelligence.

3.1. Urban Water Management

[19]and [20] studied and showed that urban water management lacks quality and loss management. The proposed smart water grid technology for managing water or ensuring water security by checking quantity and quality losses by integrating information and communication technology with water management schemes and targeting five prime research areas. (1) Platform setup between water and ICT networks (2)-Ensure both water resources are natural and produce water. (3)- Smart water flow control using bidirectional conveyance in water infrastructure. (4)- Stable management plot to deal with risk minimization for assets in water infrastructure. (5)- energy effectiveness in working and keeping up water infrastructure.

3.2 Remote Location Water Management

In most places, we fail to manage water due to the unavailability of data and accessibility to that area. [21] used ANN to manage the mountainous water supply in Cyprus. They took input parameters such as the area of the catchment, the average monthly rainfall elevation, and the slope of the location. The ANN model requires three static and changeable parameters: readjustment and re-evaluation of rainfall measuring networks and amount of precipitation, which gave reliable estimation and reduced cost.

3.3 Failure and Uncertainty Prediction of Water Infrastructure

Failure of water mains infrastructure and uncertainty in the storage of Rainwater are also issues in the water management system. [22] worked on the failure rate prediction of pipelines. They developed a model using an extreme learning machine (ELM). The study area was Greater Toronto, Canada, and used about 9500 pipeline attributes, including pipe length diameter, material, and previous failure records. That model includes pipe protection methods and is helpful in planning, budgeting, and maintenance of the water main.

For the uncertainties in the storage potential of harvested rainwater and management of sewer overflow [23] Merged hydrologic execution design criteria and life cycle assessment (LCA). The study area was in Ohio (USA), Toledo combined sewer system, where two methods of RWH were compared with central grey infrastructure for handling combined sewer overflow. As a result, 4 rainwater harvesting scenarios were observed (2 RWHs, one for supplying the toilet's flushing system and the other to work as detention, and two hybrids based on combining previous with grey infrastructure). Vulnerabilities were broken down utilizing a strong Monte Carlo reproduction approach and performed by High Throughput Computing (HTC), which the Morse-Scale relapse model deciphered. As a result, if the parameter is rainfall depth, rainfall depth causes 86 percent uncertainty, while LCA parameters cause only 7% uncertainty. The result also recommends that a topography-propelled model can deliver an optimal rainwater harvesting system capacity as a component of yearly rainfall depth.

3.4 Water Quality Management

Towns and cities of developing countries struggle to get good quality water; we need infrastructure development or a shift towards new technology or management tools.[24] presented Evidential reasoning (ER) and fuzzy social choice (FSC), which are multi-parameter and output techniques for the quality assessment of Chitgar Lake. based on evaluation, the FSC model is directly beneficial for Stakeholders. Ref [25] had tried to establish a machine learning approach to predict Carlson's Trophic State Index (CTSI) of water quality of reservoir collected input parameters from the stations of twenty reservoirs in Taiwan. We used AI technologies to analyse this scenario. For variation of results, we used different software like RapidMiner Studio, Microsoft Azure Learning Studio, IBM SPSS Modeler, and WEKA. We found that the hybrid model gave the best results and could help manage the reservoir's water quality.

From past studies, it can be concluded that overexploitation of surface and groundwater resources, climatic disturbances, and lack of management strategies are the three major reasons for water scarcity in several parts of the world. Hence, immediate measures are needed for the people. So, proper water monitoring, reducing water loss strategies, and managing water resources using sustainable technologies are required for safe drinking water and multipurpose water resources to fulfill the prosperity of the people living on the planet and create a better future for the next generation. In Table 1, we can see the application of AI technology in different aspects of water management with feasible examples worldwide.

Table 1: Used AI-driven technology in various works

Application Area	**AI Techniques Used**	**Key Benefits**	**Example Projects/Case Studies**	**Reference**
Demand Forecasting	Neural Networks, Regression Analysis	Accurate demand prediction, resource allocation	Singapore Smart Water Grid	[26]
Water Quality Monitoring	Classification Algorithms, Anomaly Detection	Real-time quality monitoring, pollution prevention	California Water Quality Monitoring	[14]
Irrigation Management	Deep Learning, Reinforcement Learning	Water conservation, increased crop yield	Indian PMKSY Program	[27]
Flood Prediction	Time Series Analysis, Pattern Recognition	Early warning, damage prevention	Japan Flood Prediction Systems	[28]
Leak Detection	Image Recognition, Anomaly Detection	Reduced water loss, maintenance optimization	Thames Water, UK	[29]

3.5 Smart Water Grid

This Concept first started in 2007[19]. Smart water grid consists of a two-way real-time network with field sensors, measurement, and control devices that remotely and continuously monitor and diagnose problems in the water system, and the platform has two key components:

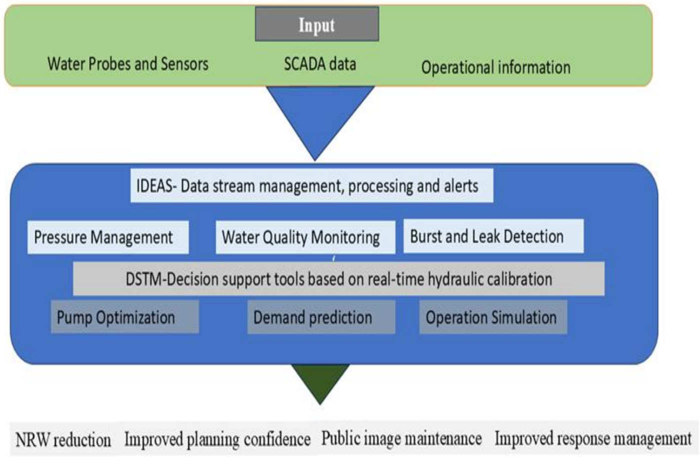

Figure 3: Process flow in Smart Water Grid, Data inferred from [19]

The Integrated Data and Electronic Alerts System (IDEAS), and The Decision Support Tools Model (DSTM). AI optimizes resource allocation, reduces operational costs, and enhances grid performance. It is being used in Florida, Malta, Singapore, Korea, and more. In India, the technique is practiced in Mumbai[19]. Here in table 2 outlines applications of AI in a smart water grid:

Table 2: Role of AI in smart water grid, Source: Data inferred from [33] [34] [35]

Application of AI	**Functions in smart water grid**	**Benefits**
Predictive analysis	Forecasts water demand and identifies leak risks	Reduces waste and improves efficiency
Real-time monitoring	Tracks water quality and flow rates	Ensures water safety and reliability
Automated leak detection	Detects leaks through pattern recognition	Minimizes water loss and repair costs
Demand optimization	Adjusts distribution based on usage patterns	Balances supply with consumer demand
Anomaly detection	Identifies irregularities in water usage	Prevents potential issues and theft

Significant reductions in water losses and pilferage have been reported after that. Energy efficiency helps in quality and leakage monitoring to improve water infrastructure because, in urban water management systems, leakage and quality of water are less focused.

4. Challenges of AI in water management

AI-based water management has several solutions in the pipeline, but the technologies have certain issues. Among them, data quality and accessibility are critical concerns because water data are often missing, inaccurate, or old and thus might negatively impact the AI models[19]. The fourth issue is that the cost and the difficulties in laying out sensors and monitoring systems are quite high, especially in rural areas. Applying AI to the current water systems is a complicated process requiring professional input and lots of money [30][31]. Also, regional variation in climate, regulation, and ecology makes it challenging to standardise AI models. Another issue that can be discussed is the peculiarities of data protection and the necessity of equal water distribution as a resource for all citizens [32]. Decision-making transparency is another important aspect of developing AI applications using AI technology in water management solutions.

5. Conclusion

Integrating AI into water management is feasible, which benefits current resource usage, water quality, and demand forecasting management. A significant effort is needed to fully use AI to address essential problems, including infrastructure cost, data interpretability, and data quality. A more solid, effective, and reliable solution for future water markets and strategic planning would also come from combining integrated water management techniques with comprehensive assessment instruments considering technical, environmental, social, and economic factors. Nonetheless, legislation about water quality, risk management, consumption patterns, appropriate regulations and water usage recommendations should be developed and revised regularly. By considering the multiple technologies, AI can effectively contribute to sustainable water management while bringing governments, businesses, and communities to work together. Moreover, public communications and surveys should be prioritised to ensure cost-effective implementation.

Disclosure of Interests:

The authors declare that they have no known competing interests.

References

[1] Z. Zeng, J. Liu, and H. H. G. Savenije, "A simple approach to assess water scarcity integrating water quantity and quality," *Ecol. Indic.*, vol. 34, pp. 441–449, 2013, doi: 10.1016/j.ecolind.2013.06.012.

[2] J. Liu, Q. Liu, and H. Yang, "Assessing water scarcity by simultaneously considering environmental flow requirements, water quantity, and water quality," *Ecol. Indic.*, vol. 60, pp. 434–441, 2016, doi: 10.1016/j.ecolind.2015.07.019.

[3] S. R. Krishnan *et al.*, "Smart Water Resource Management Using Artificial Intelligence—A Review," *Sustain.*, vol. 14, no. 20, pp. 1–28, 2022, doi: 10.3390/su142013384.

[4] T. C. Z. Huu Hao Ngo, Wenshan Guo, Rao Y. Surampalli, *Technologies for Sustainable Water Management and Environmental Hydraulics*. 2017.

[5] M. & N. Bhardwaj, "The advantages and disadvantages of questionnaires," *J. Basic Appl. Eng. Res.*, vol. 2, no. 22, pp. 1957–1960, 2015.

[6] H. Kamyab *et al.*, "The latest innovative avenues for the utilization of artificial Intelligence and big data analytics in water resource management," *Results Eng.*, vol. 20, no. October, 2023, doi: 10.1016/j.rineng.2023.101566.

[7] A. U. Egbemhenghe *et al.*, "Revolutionizing water treatment, conservation, and management: Harnessing the power of AI-driven ChatGPT solutions," *Environ. Challenges*, vol. 13, no. October, 2023, doi: 10.1016/j.envc.2023.100782.

[8] Y. A. Hajam, R. Kumar, and A. Kumar, "Environmental waste management strategies and vermi transformation for sustainable development," *Environ. Challenges*, vol. 13, no. June, 2023, doi: 10.1016/j.envc.2023.100747.

[9] DOSH, "From the Director General," *Dep. Occup. Saf. Heal.*, 2017.

[10] T. D. Fletcher *et al.*, "SUDS, LID, BMPs, WSUD and more – The evolution and application of terminology surrounding urban drainage," *Urban Water J.*, vol. 12, no. 7, pp. 525–542, 2015, doi: 10.1080/1573062X.2014.916314.

[11] Z. Li, H. Liu, C. Zhang, and G. Fu, "Real-time water quality prediction in water distribution networks using graph neural networks with sparse monitoring data," vol. 250, no. August 2023, 2024.

[12] M. Drogkoula, K. Kokkinos, and N. Samaras, "A Comprehensive Survey of Machine Learning Methodologies with Emphasis in Water Resources Management," *Appl. Sci.*, vol. 13, no. 22, 2023, doi: 10.3390/app132212147.

[13] A. K. Taloor, P. K. Thakur, and M. Jakariya, "Remote sensing and GIS applications in water science," *Groundw. Sustain. Dev.*, vol. 19, no. December, 2022, doi: 10.1016/j.gsd.2022.100817.

[14] C. Kundan, M. Umank, M. Padam, and J. Omar, "Discover Geoscience Integration of remote sensing data and GIS technologies in river management system," *Discov. Geosci.*, 2024, doi: 10.1007/s44288-024-00080-8.

[15] S. Panda, B. R. Maram, and K. Shirisha, *Remote Sensing in Agriculture : Applications in Crop Monitoring ,* no. July. 2023.

[16] S. Shekhar, S. Feiner, and W. G. Aref, "From GPS and virtual globes to spatial computing - 2020," *Geoinformatica*, vol. 19, no. 4, pp. 799–832, 2015, doi: 10.1007/s10707-015-0235-9.

[17] S. Talukdar, M. W. Naikoo, J. M. Islamia, and S. Ahmed, "Recent Trends in Application of Geospatial Technologies and AI for Monitoring and Management of Water Resources," no. July, 2024, doi: 10.1007/978-3-031-61121-6.

[18] A. Shastry, E. Carter, B. Coltin, R. Sleeter, S. Mcmichael, and J. Eggleston, "Remote Sensing of Environment Mapping floods from remote sensing data and quantifying the effects of surface obstruction by clouds and vegetation," vol. 291, no. March, 2023.

[19] D. Vekaria and S. Sinha, "ai WATERS : an artificial intelligence framework for the water sector," 2024, doi: 10.1007/s43503-024-00025-7.

[1] Z. Zeng, J. Liu, and H. H. G. Savenije, "A simple approach to assess water scarcity integrating water quantity and quality," *Ecol. Indic.*, vol. 34, pp. 441–449, 2013, doi: 10.1016/j.ecolind.2013.06.012.

[2] J. Liu, Q. Liu, and H. Yang, "Assessing water scarcity by simultaneously considering environmental flow requirements, water quantity, and water quality," *Ecol. Indic.*, vol. 60, pp. 434–441, 2016, doi: 10.1016/j.ecolind.2015.07.019.

[3] S. R. Krishnan *et al.*, "Smart Water Resource Management Using Artificial Intelligence—A Review," *Sustain.*, vol. 14, no. 20, pp. 1–28, 2022, doi: 10.3390/su142013384.

[4] T. C. Z. Huu Hao Ngo, Wenshan Guo, Rao Y. Surampalli, *Technologies for Sustainable Water Management and Environmental Hydraulics*. 2017.

[5] M. & N. Bhardwaj, "The advantages and disadvantages of questionnaires," *J. Basic Appl. Eng. Res.*, vol. 2, no. 22, pp. 1957–1960, 2015.

[6] H. Kamyab *et al.*, "The latest innovative avenues for the utilization of artificial Intelligence and big data analytics in water resource management," *Results Eng.*, vol. 20, no. October, 2023, doi: 10.1016/j.rineng.2023.101566.

[7] A. U. Egbemhenghe *et al.*, "Revolutionizing water treatment, conservation, and management: Harnessing the power of AI-driven ChatGPT solutions," *Environ. Challenges*, vol. 13, no. October, 2023, doi: 10.1016/j.envc.2023.100782.

[8] Y. A. Hajam, R. Kumar, and A. Kumar, "Environmental waste management strategies and vermi transformation for sustainable development," *Environ. Challenges*, vol. 13, no. June, 2023, doi: 10.1016/j.envc.2023.100747.

[9] DOSH, "From the Director General," *Dep. Occup. Saf. Heal.*, 2017.

[10] T. D. Fletcher *et al.*, "SUDS, LID, BMPs, WSUD and more – The evolution and application of terminology surrounding urban drainage," *Urban Water J.*, vol. 12, no. 7, pp. 525–542, 2015, doi: 10.1080/1573062X.2014.916314.

[11] Z. Li, H. Liu, C. Zhang, and G. Fu, "Real-time water quality prediction in water distribution networks using graph neural networks with sparse monitoring data," vol. 250, no. August 2023, 2024.

[12] M. Drogkoula, K. Kokkinos, and N. Samaras, "A Comprehensive Survey of Machine Learning Methodologies with Emphasis in Water Resources Management," *Appl. Sci.*, vol. 13, no. 22, 2023, doi: 10.3390/app132212147.

[13] A. K. Taloor, P. K. Thakur, and M. Jakariya, "Remote sensing and GIS applications in water science," *Groundw. Sustain. Dev.*, vol. 19, no. December, 2022, doi: 10.1016/j.gsd.2022.100817.

[14] C. Kundan, M. Umank, M. Padam, and J. Omar, "Discover Geoscience Integration of remote sensing data and GIS technologies in river management system," *Discov. Geosci.*, 2024, doi: 10.1007/s44288-024-00080-8.

[15] S. Panda, B. R. Maram, and K. Shirisha, *Remote Sensing in Agriculture : Applications in Crop Monitoring ,* no. July. 2023.

[16] S. Shekhar, S. Feiner, and W. G. Aref, "From GPS and virtual globes to spatial computing - 2020," *Geoinformatica*, vol. 19, no. 4, pp. 799–832, 2015, doi: 10.1007/s10707-015-0235-9.

[17] S. Talukdar, M. W. Naikoo, J. M. Islamia, and S. Ahmed, "Recent Trends in Application of Geospatial Technologies and AI for Monitoring and Management of Water Resources," no. July, 2024, doi: 10.1007/978-3-031-61121-6.

[18] A. Shastry, E. Carter, B. Coltin, R. Sleeter, S. Mcmichael, and J. Eggleston, "Remote Sensing of Environment Mapping floods from remote sensing data and quantifying the effects of surface obstruction by clouds and vegetation," vol. 291, no. March, 2023.

[19] D. Vekaria and S. Sinha, "ai WATERS : an artificial intelligence framework for the water sector," 2024, doi: 10.1007/s43503-024-00025-7.

[20] M. Mutchek and E. Williams, "Moving Towards Sustainable and Resilient Smart Water Grids," *Challenges*, vol. 5, no. 1, pp. 123–137, 2014, doi: 10.3390/challe5010123.

[21] L. S. Iliadis and F. Maris, "An Artificial Neural Network model for mountainous water-resources management: The case of Cyprus mountainous watersheds," *Environ. Model. Softw.*, vol. 22, no. 7, pp. 1066–1072, 2007, doi: 10.1016/j.envsoft.2006.05.026.

[22] A. M. A. Sattar, Ö. F. Ertuğrul, B. Gharabaghi, E. A. McBean, and J. Cao, "Extreme learning machine model for water network management," *Neural Comput. Appl.*, vol. 31, no. 1, pp. 157–169, 2019, doi: 10.1007/s00521-017-2987-7.

[23] H. Tavakol-Davani, S. J. Burian, D. Butler, D. Sample, J. Devkota, and D. Apul, "Combining Hydrologic Analysis and Life Cycle Assessment Approaches to Evaluate Sustainability of Water Infrastructure," *J. Irrig. Drain. Eng.*, vol. 144, no. 11, p. 05018006, 2018, doi: 10.1061/(asce)ir.1943-4774.0001340.

[24] S. Malakpour, E. Reza, K. Mohammad, and R. Nikoo, "Developing water quality management policies for the Chitgar urban lake : application of fuzzy social choice and evidential reasoning methods," *Environ. Earth Sci.*, 2016, doi: 10.1007/s12665-015-5065-4.

[25] J. Chou, C. Ho, and H. Hoang, "PT CR," *Ecol. Inform.*, no. 2017, 2018, doi: 10.1016/j.ecoinf.2018.01.005.

[26] "Managing the water distribution network with a Smart Water Grid," *Smart Water*, vol. 1, no. 1, pp. 1–13, 2016, doi: 10.1186/s40713-016-0004-4.

[27] S. P. Wani *et al.*, "Pradhan Mantri Krishi Sinchai Yojana: Enhancing Impact through Demand Driven Innovations," no. December, pp. 1–52, 2016, [Online]. Available: http://oar.icrisat.org/9758/.

[28] A. Kawamura, H. Amaguchi, J. Olsson, and H. Tanouchi, "Urban Flood Runoff Modeling in Japan: Recent Developments and Future Prospects," *Water (Switzerland)*, vol. 15, no. 15, 2023, doi: 10.3390/w15152733.

[29] B. Schäfer *et al.*, “Machine learning approach towards explaining water quality dynamics in an urbanised river,” *Sci. Rep.*, vol. 12, no. 1, pp. 1–15, 2022, doi: 10.1038/s41598-022-16342-9.

[30] M. Javaid, A. Haleem, I. Haleem, and R. Suman, “Advanced Agrochem Understanding the potential applications of Arti fi cial Intelligence in Agriculture Sector,” vol. 2, no. September 2022, pp. 15–30, 2023.

[31] A. S. Albahri *et al.*, “A systematic review of trustworthy artificial intelligence applications in natural disasters ARES SR FA,” vol. 118, no. June, 2024.

[32] S. Elias, J. Krogstie, A. Kaboli, and A. Alahi, “Environmental Science and Ecotechnology Smarter eco-cities and their leading-edge arti fi cial intelligence of things solutions for environmental sustainability : A comprehensive systematic review,” vol. 19, 2024.

[33] S. W. Lee, S. Sarp, D. J. Jeon, and J. H. Kim, “Smart water grid: the future water management platform,” *Desalin. Water Treat.*, vol. 55, no. 2, pp. 339–346, 2015, doi: 10.1080/19443994.2014.917887.

[34] Y. Ye, L. Liang, H. Zhao, and Y. Jiang, “The System Architecture of Smart Water Grid for Water Security,” vol. 154, pp. 361–368, 2016, doi: 10.1016/j.proeng.2016.07.492.

[35] K. E. Y. Points, H. Jenny, and E. G. Alonso, “ADB BRIEFS,” vol. 5, no. 143, 2020.