AUCTORES
Globalize your Research
Journal of Nutrition and Food Processing
Iman Hajirad*
Open Access
Research Article

Role of Artificial Intelligence in Improving Water Resource Management: From Demand Forecasting to Waste Reduction and Water Crisis Mitigation

Iman Hajirad

Department of Irrigation and Reclamation Engineering, College of Agricultural and Natural Resources, University of Tehran, Iran

Corresponding author: Iman Hajirad, Department of Irrigation and Reclamation Engineering, College of Agricultural and Natural Resources, University of Tehran, Iran.

Received date: March 17, 2025; **Accepted date:** March 31, 2025; **Published date:** April 04, 2025

Citation: Iman Hajirad, (2025), Role of Artificial Intelligence in Improving Water Resource Management: From Demand Forecasting to Waste Reduction and Water Crisis Mitigation, *J. Nutrition and Food Processing*, 8(5); **DOI:10.31579/2637-8914/305**

Abstract:

Water resource management is one of the fundamental challenges in today's world, which has become increasingly complex due to climate change, population growth, and the expansion of industrial activities. This paper examines the role of Artificial Intelligence (AI) in improving water resource management and analyzes its applications in consumption optimization, demand forecasting, water quality management, and resource waste prevention. Machine learning algorithms, neural networks, and big data processing assist decision-makers in optimizing water allocation, monitoring water quality, and predicting and managing water crises. This study demonstrates that the use of AI can significantly enhance efficiency, reduce costs, and contribute to environmental conservation.

Key words: artificial intelligence; water resources; water resources management

Introduction

Water resource management is one of the most critical challenges facing modern societies. Population growth, urbanization, industrial expansion, and climate change have exerted significant pressure on water resources, leading to a decline in both their quality and quantity. Additionally, phenomena such as droughts, floods, and increasing environmental pollution have made it more imperative than ever to improve water management and utilization methods. Traditional water resource management approaches, despite their relative effectiveness, often fail to address contemporary challenges due to the complexity of data, unpredictable variations, and the need for rapid and precise decision-making. Consequently, the integration of advanced technologies such as Artificial Intelligence (AI) has the potential to revolutionize this field (Krishnan et al., 2022). AI has emerged as a powerful tool in water resource management due to its ability to process vast amounts of data, identify complex patterns, and generate highly accurate predictions. This technology can be applied in various domains, including water quality monitoring, consumption optimization, rainfall and drought pattern forecasting, leakage detection in distribution networks, and smart irrigation management. The implementation of machine learning algorithms, neural networks, and big data processing enables more accurate decision-making, reduces water waste, optimizes consumption, and enhances the efficiency of water systems (Sun et al., 2019).

One of the most significant advantages of AI in water resource management is its ability to improve forecasting accuracy and provide rapid responses to environmental changes. For instance, machine learning models can analyze data related to precipitation levels, air temperature, soil moisture, and water reservoir levels to predict future water availability with high precision. This capability allows water resource planners and managers to make informed decisions regarding water allocation, crisis management, and mitigating the risks associated with water shortages or floods (Kamyab et al., 2023). Moreover, AI plays a crucial role in managing urban and agricultural water distribution systems. For example, AI-based systems can detect small, undetectable leaks in pipelines, preventing unnecessary water loss. In the agricultural sector, intelligent models can analyze soil data, moisture levels, and plant water requirements to determine the optimal irrigation schedule and volume, thereby preventing excessive water use (Bwambale et al., 2022; Xiang et al., 2021).

Given these applications, the use of AI in water resource management not only enhances efficiency and reduces operational costs but also contributes significantly to environmental conservation and the sustainability of water resources. This paper explores the role and impact of AI in water resource management, analyzing how this technology can be leveraged to improve efficiency, minimize water waste, and address water-related challenges. Additionally, several key AI applications in this field will be discussed.

1. Demand Forecasting

Forecasting water demand is one of the most fundamental and critical challenges in water resource management. Water demand is influenced by various factors, including weather patterns, population growth, climate change, and industrial and agricultural needs. Without accurate and effective forecasting, planning for water supply, optimizing resource allocation, and preventing waste would not be feasible. In this regard, Artificial Intelligence (AI), utilizing machine learning algorithms, has become a powerful tool for predicting water demand (Zanfei et al., 2024). Machine learning algorithms can analyze historical data and past consumption patterns to provide more precise forecasts of future water needs. These algorithms incorporate various data sources, including precipitation levels, air temperature, seasonal variations, demographic changes, and even economic and social factors, to develop models capable of predicting water demand across different regions. For instance, by analyzing rainfall trends and climate fluctuations, AI can estimate the required water supply for the upcoming months, enabling water resource managers to plan more confidently (Perea et al., 2019). Another advantage of AI-driven water demand forecasting is its ability to simulate different scenarios and assess the impact of climate change and population growth on water demand. For example, climate variations can lead to reduced precipitation or increased temperatures, both of which directly affect water demand. AI can model these changes and predict the best possible scenarios for ensuring adequate water supply. As a result, water resource managers can allocate resources more efficiently and with greater accuracy (Shu et al., 2024).

A crucial application of water demand forecasting lies in optimizing resource usage and preventing wastage. When water demand is accurately predicted, excessive consumption during peak demand periods can be minimized. For instance, during dry seasons or low-rainfall periods, optimizing irrigation programs in agriculture and managing industrial water usage can help reduce water wastage and ensure the sustainable management of limited resources.

Additionally, water demand forecasting aids decision-making and resource allocation at both national and local levels. If forecasts indicate an increase in future demand, storage and distribution plans can be adjusted more effectively. These predictions are particularly valuable for managing water crises such as droughts and floods, enabling authorities to respond proactively to such challenges. In conclusion, leveraging AI for water demand forecasting not only enhances resource optimization but also reduces costs, prevents wastage, and promotes the sustainability of water resources (Alhendi et al., 2022).

2. Water Quality Management

Water quality management is a major concern in the field of water resources, directly affecting human health, natural ecosystems, and the efficient use of water resources. Water pollution and declining quality can result from various factors, including industrial and agricultural wastewater, urban sewage, and environmental changes. These issues necessitate continuous and precise monitoring to prevent health and environmental crises. In this regard, Artificial Intelligence (AI) can serve as an effective tool for detecting pollution and addressing water quality issues (Kamyab et al., 2023). One of the most significant applications of AI in water quality management is the analysis of data collected from various sensors and sampling processes. In many regions, sensor systems are installed to measure parameters such as pH, temperature, dissolved oxygen levels, and chemical and microbial pollutants in water. These sensors continuously collect real-time data and transmit it to databases. Using advanced algorithms, AI can process and analyze these large datasets to identify anomalies or sudden changes in water quality (Al-Adhaileh & Alsaade, 2021).

For example, machine learning algorithms can examine variations in water quality over a specific period and establish patterns of normal conditions. If an unexpected or hazardous change occurs in any of the water quality parameters, AI can simulate these changes and immediately alert water resource managers and environmental health authorities. This enables corrective actions to be taken in a significantly shorter time, reducing the risk of widespread contamination or health crises.

Moreover, AI can predict potential future pollution events by analyzing large-scale data patterns. For instance, by examining trends in water quality and environmental factors, AI can forecast pollution risks arising from heavy rainfall, rising temperatures, or industrial changes. These predictions allow managers to implement preventive measures, such as isolating contaminated sources or applying advanced water treatment techniques, before a crisis emerges (Perea et al., 2019). Additionally, AI can assist in identifying the primary sources of water pollution. By analyzing sensor data across different points in the water distribution network, AI systems can pinpoint the exact location of contamination and simulate its path. This precise identification enhances water treatment processes, ensuring that purification operations are conducted more effectively and efficiently. Overall, the use of AI in water quality management significantly enhances the ability to rapidly detect water quality issues, reduce pollution levels, and improve the performance of treatment systems. By analyzing sensor data and identifying abnormal patterns, AI enables timely and effective decision-making, ultimately preventing health and environmental crises (Sapitang et al., 2024).

3. Water Distribution Optimization

One of the major challenges in water resource management is optimizing water distribution in urban and rural networks. Water distribution systems often face issues such as leakage, pressure drops, and water loss, which can reduce efficiency and increase costs. As a result, the use of AI algorithms for optimizing these networks is increasingly expanding. These algorithms can analyze data, simulate different scenarios, and predict network conditions to improve water distribution efficiency and prevent resource wastage (Tekle et al., 2024; Boulos, 2017).

AI algorithms can optimize water pressure and flow in distribution networks by analyzing data collected from sensors and monitoring systems. For example, smart systems can use real-time pressure data from different network points to identify areas with significant pressure drops or potential leaks and automatically adjust pressure levels in these areas. This prevents water loss within the network and ensures optimal resource distribution. Additionally, these algorithms can analyze consumption patterns at different times of the day to propose effective scheduling for water distribution, reducing strain on the system during peak demand hours (Cosgrove & Loucks, 2015). Another key application of AI in water distribution optimization is leak detection and management. Leaks in distribution networks are a major cause of water loss, increasing costs and negatively impacting the environment. AI algorithms can accurately simulate leak locations by analyzing pressure and flow data, allowing system managers to detect leaks early. These simulations help decision-makers take preventive measures before serious system failures occur.

Optimizing water distribution through AI not only reduces water loss but also lowers energy and operational costs. Water distribution systems often require extensive pumping to maintain adequate pressure, leading to high energy consumption. By optimizing pressure and flow, AI can help reduce excessive energy use and lower the costs associated with water pumping and distribution. Ultimately, AI-driven water distribution optimization enhances the efficiency and sustainability of water systems (Jain & Singh, 2023). By leveraging AI algorithms, managers can access tools for faster and more informed decision-making regarding resource allocation and network pressure regulation. These advancements improve water distribution, reduce costs, and maximize resource utilization, ultimately contributing to the sustainable management of global water resources.

4. Water Resource Management

Water resource management is a critical challenge, especially in times of crises and climate change. Efficient water resource allocation is necessary to prevent excessive consumption and wastage. AI, with its ability to analyze vast datasets, simulate various scenarios, and predict outcomes, serves as an advanced tool in this field, playing a key role in balancing water supply and demand (Chang et al., 2023). One of the most significant applications of AI in water resource management is the use of advanced models for predicting and analyzing complex water-related data. These models can process information such as precipitation levels, groundwater reserves, temperature, soil moisture, climate variations, and water consumption to provide more accurate predictions about future water availability. This enables water managers to make informed decisions regarding resource allocation and prevent overexploitation (Ghobadi & Kang, 2023).

AI-driven simulations can help managers adopt the best strategies under different conditions. For instance, using water consumption data from various regions and forecasting future climate conditions, different management scenarios for drought or excessive rainfall can be simulated. These simulations allow decision-makers to take preventive actions before crises occur, mitigating irreversible damage.

Moreover, AI algorithms can analyze long-term water consumption patterns to optimize resource distribution. By identifying trends in agricultural, industrial, and domestic water use, AI can provide recommendations for reducing consumption during peak demand periods. For example, predictive AI models can forecast water demand in different sectors and propose strategies to minimize wastage and enhance efficiency.

AI also plays a crucial role in identifying and managing water crises. In regions with limited water resources, AI algorithms can predict potential future shortages and assist in planning optimal irrigation schedules, storage strategies, and distribution adjustments (Mahardhika et al., 2023; Ay & Özyıldırım, 2018). By leveraging AI-driven predictions, managers can implement strategic measures during critical periods and prevent water-related disasters. Given these advantages, AI-powered water resource management significantly improves efficiency, prevents resource waste, and optimizes consumption across various sectors. This technology enhances precision in water planning, reduces management costs, and ensures the sustainability of water resources for future generations.

5. Flood and Drought Prediction

Flood and drought prediction is one of the most crucial applications of AI in water resource management. These natural disasters can have severe impacts on water resources, agriculture, infrastructure, and human lives. Given climate change and weather fluctuations, accurate and effective forecasting of these crises is essential. AI, with its ability to process vast datasets and simulate various scenarios, enhances flood and drought prediction, thereby mitigating their adverse effects (Adikari et al., 2021).

AI, particularly through machine learning algorithms, can analyze climatic and historical data, including precipitation levels, temperature, soil moisture, river water levels, and other environmental factors. These algorithms can identify complex patterns that were previously difficult for humans to recognize. For example, by analyzing historical flood and drought data, AI can detect risk patterns and critical timeframes, predicting when and where these events might occur (Kikon & Deka, 2022). One advantage of AI in flood and drought prediction is its ability to simulate different conditions and assess the impact of climate changes. As temperature rises or precipitation patterns become more erratic, predicting floods or droughts becomes more challenging. AI algorithms can simulate these variations and evaluate their effects on water resources and the environment. Such forecasts help local and governmental authorities plan preventive measures and timely responses to crises (Kikon & Deka, 2022). Additionally, precise AI-driven predictions play a vital role in water resource management. For instance, predicting droughts enables planners to optimize water reserves before dry periods begin and allocate resources more efficiently. In the case of floods, early warnings can facilitate the evacuation of high-risk areas, strengthen infrastructure, and issue timely alerts to communities. AI can also enhance water resource monitoring by leveraging satellite data and remote sensing. Through satellite image analysis, AI can model real-time water trends and drought developments, forecasting which regions might be affected by floods or droughts (Oluwatobi et al., 2017).

Ultimately, AI-based predictions significantly reduce damages caused by floods and droughts. These forecasts enable proactive measures, helping water resource and crisis managers effectively allocate resources and minimize the consequences of these natural events. Thus, AI-driven flood and drought prediction not only mitigates risks and damages but also strengthens the resilience of water systems against climate change.

6. Climate Data Analysis

Climate change is one of the greatest challenges in global water resource management. Rising temperatures, shifting precipitation patterns, prolonged droughts, and changes in river systems and groundwater sources significantly impact water availability. In this context, climate data analysis using artificial intelligence (AI) serves as a powerful tool for better understanding the effects of climate change on water resources and developing effective strategies for optimal water management (Huntingford et al., 2019; Leal Filho et al., 2022).

AI can collect and analyze climate data from various sources, including weather stations, satellites, and climate prediction models. This data includes precipitation levels, air temperature, soil moisture, wind patterns, river conditions, and groundwater levels. Machine learning algorithms can process this complex data and identify patterns that help predict the impacts of climate change on water resources (Kadow et al., 2020). For example, AI algorithms can analyze temperature and rainfall trends in a specific region and predict whether these changes will lead to water shortages, increased drought risk, or altered precipitation patterns. These forecasts enable water resource managers to plan for potential water crises and implement better strategies for water supply during dry or wet periods. Another application of AI in climate data analysis is the simulation of different scenarios. Based on projected climate variations, AI can generate multiple scenarios to examine the potential effects of climate change on water resources. For instance, in scenarios predicting rising temperatures and reduced rainfall, AI can estimate the extent of water resource depletion, helping decision-makers allocate water resources more efficiently (Dewitte et al., 2021; Chen et al., 2023). AI-driven climate data analysis can also identify vulnerable areas at risk due to climate change. It allows for the early detection of regions that may experience significant changes in water availability, enabling proactive planning. For example, areas expected to face higher temperatures and lower precipitation might require enhanced water storage systems, changes in agricultural irrigation practices, or more efficient water-use strategies (Chen et al., 2023).

Ultimately, AI-powered climate data analysis supports better decision-making in water resource management policies. It provides managers with scientific insights and accurate predictions, enabling them to develop operational plans for addressing water crises, expanding new water sources, and protecting existing resources. By leveraging AI, water management can become more sustainable and efficient, enhancing resilience against climate change impacts.

7. Water Systems Management

Water systems management is a critical and complex aspect of water resource administration. Traditionally, irrigation, storage, and water distribution operations were conducted manually using conventional methods, which were not only time-consuming but also inefficient. With technological advancements, particularly in artificial intelligence (AI), it is now possible to manage water systems intelligently and autonomously.

These smart systems can accurately regulate irrigation, storage, and water distribution based on real-time needs, significantly improving water consumption efficiency (Krishnan et al., 2022).

One of the primary applications of AI in water systems management is optimizing irrigation processes in agriculture. AI-based systems can automatically determine the precise amount and timing of irrigation for each region. These systems use various data sources, such as soil moisture, weather forecasts, plant type and water requirements, and other environmental conditions, to intelligently adjust water distribution. This not only enhances agricultural productivity but also prevents water wastage, ensuring efficient use of water resources (Jenny et al., 2020; Farig et al., 2025). In urban and industrial sectors, smart systems can autonomously manage water distribution settings. For instance, in urban water distribution networks, AI can regulate water flow at different points based on consumption data and demand forecasts. These systems can automatically detect consumption variations or pipeline leaks and adjust pressure and distribution accordingly. This helps reduce water wastage and improve service quality for consumers (Satpathy et al., 2025).

AI also plays a crucial role in water storage management. In reservoirs and dams, smart systems can monitor water levels in real-time and calculate optimal storage conditions. By utilizing precise weather forecasts and environmental data, these systems can make informed decisions on whether to store or release water. This prevents water loss and helps mitigate potential water crises in the future (Martyushev, 2025).

Additionally, these smart systems can identify leaks and infrastructure issues within water networks. Using machine learning algorithms, AI can automatically detect minor leaks or system faults and notify relevant authorities. This capability minimizes maintenance and repair costs while preventing further water losses. Ultimately, integrating AI-driven smart systems in water resource management not only optimizes water consumption but also reduces costs, preserves natural resources, and enhances efficiency across all sectors. By leveraging accurate data and advanced analytics, these systems empower water resource managers to make better decisions and ensure the sustainable use of water resources (Al-Raeei, 2025).

Results and Discussion

The results demonstrated that artificial intelligence (AI) can effectively contribute to water demand forecasting, optimizing water distribution, and identifying potential contamination in urban and agricultural water systems. The use of advanced algorithms for data analysis led to more accurate predictions of future demand and improved the efficiency of distribution systems. Moreover, intelligent systems were able to simulate various conditions and assess the impact of climate change on water resources. The findings indicate that AI can help in the timely identification of water crises such as droughts and floods, preventing damages caused by these events.

Conclusion

AI, with its high potential, can significantly improve water resource management and enhance their sustainability. By leveraging advanced technologies, AI can optimize water consumption, accurately forecast demand, and identify potential crises. Through these predictions, water managers can make timely and effective decisions, managing water resources more efficiently. Furthermore, AI can reduce water waste and improve its distribution across various regions, ultimately enhancing the performance of water systems and lowering costs. Investment in AI technologies can lead to sustainable water supply and improved quality of life in different communities. This technology, by optimizing consumption and reducing waste, contributes to achieving higher productivity of water resources and provides effective solutions in addressing water crises. Ultimately, AI not only aids in more effective water resource management but also enhances the resilience of water systems against future challenges.

Recommendations

To improve water resource management, it is recommended that governments and relevant organizations prioritize the adoption of AI. Investment in data infrastructure and the use of machine learning algorithms can help optimize resource allocation and forecast water crises. Additionally, training and upgrading the skills of personnel, especially in the agricultural and water sectors, is essential. The development of smart monitoring systems globally can help reduce pollution and maintain water quality.

Resources

1. Krishnan, S. R., Nallakaruppan, M. K., Chengoden, R., Koppu, S., Iyapparaja, M., Sadhasivam, J., & Sethuraman, S. (2022). Smart water resource management using Artificial Intelligence—A review. Sustainability, 14(20), 13384.
2. Sun, A. Y., & Scanlon, B. R. (2019). How can Big Data and machine learning benefit environment and water management: a survey of methods, applications, and future directions. Environmental Research Letters, 14(7), 073001.
3. Kamyab, H., Khademi, T., Chelliapan, S., SaberiKamarposhti, M., Rezania, S., Yusuf, M., ... & Ahn, Y. (2023). The latest innovative avenues for the utilization of artificial Intelligence and big data analytics in water resource management. Results in Engineering, 20, 101566.
4. Bwambale, E., Abagale, F. K., & Anornu, G. K. (2022). Smart irrigation monitoring and control strategies for improving water use efficiency in precision agriculture: A review. Agricultural Water Management, 260, 107324.
5. Perea, R. G., Poyato, E. C., Montesinos, P., & Díaz, J. A. R. (2019). Optimisation of water demand forecasting by artificial intelligence with short data sets. Biosystems engineering, 177, 59-66.
6. Shu, J., Xia, X., Han, S., He, Z., Pan, K., & Liu, B. (2024). Long-term water demand forecasting using artificial intelligence models in the Tuojiang River basin, China. Plos one, 19(5), e0302558.
7. Xiang, X., Li, Q., Khan, S., & Khalaf, O. I. (2021). Urban water resource management for sustainable environment planning using artificial intelligence techniques. Environmental impact assessment review, 86, 106515.
8. Alhendi, A. A., Al-Sumaiti, A. S., Elmay, F. K., Wescaot, J., Kavousi-Fard, A., Heydarian-Forushani, E., & Alhelou, H. H. (2022). Artificial intelligence for water–energy nexus demand forecasting: a review. International Journal of Low-Carbon Technologies, 17, 730-744.
9. Zanfei, A., Lombardi, A., De Luca, A., & Menapace, A. (2024). AI-Forecast: an innovative and practical tool for short-term water demand forecasting. Water Supply, 24(4), 1352-1363.
10. Hmoud Al-Adhaileh, M., & Waselallah Alsaade, F. (2021). Modelling and prediction of water quality by using artificial intelligence. Sustainability, 13(8), 4259.
11. Sapitang, M., Dullah, H., Latif, S. D., Ng, J. L., Huang, Y. F., Malek, M. B. A., ... & Ahmed, A. N. (2024). Application of integrated artificial intelligence geographical information system in managing water resources: A review. Remote Sensing Applications: Society and Environment, 101236.
12. Tekle, S. L., Bonaccorso, B., & Naim, M. (2024). Simulation-based optimization of water resource systems: a review of limitations and challenges. Water Resources Management, 1-24.
13. Cosgrove, W. J., & Loucks, D. P. (2015). Water management: Current and future challenges and research directions. Water Resources Research, 51(6), 4823-4839.
14. Jain, S. K., & Singh, V. P. (2023). Water resources systems planning and management (Vol. 51). Elsevier.

15. Boulos, P. F. (2017). Smart water network modeling for sustainable and resilient infrastructure. Water Resources Management, 31(10), 3177-3188.
16. Chang, F. J., Chang, L. C., & Chen, J. F. (2023). Artificial intelligence techniques in hydrology and water resources management. Water, 15(10), 1846.
17. Ghobadi, F., & Kang, D. (2023). Application of machine learning in water resources management: a systematic literature review. Water, 15(4), 620.
18. Mahardhika, S. P., & Putriani, O. (2023, June). Deployment and use of Artificial Intelligence (AI) in water resources and water management. In IOP Conference Series: Earth and Environmental Science (Vol. 1195, No. 1, p. 012056). IOP Publishing.
19. Adikari, K. E., Shrestha, S., Ratnayake, D. T., Budhathoki, A., Mohanasundaram, S., & Dailey, M. N. (2021). Evaluation of artificial intelligence models for flood and drought forecasting in arid and tropical regions. Environmental Modelling & Software, 144, 105136.
20. Kikon, A., & Deka, P. C. (2022). Artificial intelligence application in drought assessment, monitoring and forecasting: a review. Stochastic environmental research and risk assessment, 36(5), 1197-1214.
21. Oluwatobi, A., Gbenga, O., & Oluwafunbi, F. (2017). An artificial intelligence based drought predictions in part of the tropics. Journal of Urban and Environmental Engineering, 11(2), 165-173.
22. Huntingford, C., Jeffers, E. S., Bonsall, M. B., Christensen, H. M., Lees, T., & Yang, H. (2019). Machine learning and artificial intelligence to aid climate change research and preparedness. Environmental Research Letters, 14(12), 124007.
23. Leal Filho, W., Wall, T., Mucova, S. A. R., Nagy, G. J., Balogun, A. L., Luetz, J. M., ... & Gandhi, O. (2022). Deploying artificial intelligence for climate change adaptation. Technological Forecasting and Social Change, 180, 121662.
24. Kadow, C., Hall, D. M., & Ulbrich, U. (2020). Artificial intelligence reconstructs missing climate information. Nature Geoscience, 13(6), 408-413.
25. Dewitte, S., Cornelis, J. P., Müller, R., & Munteanu, A. (2021). Artificial intelligence revolutionises weather forecast, climate monitoring and decadal prediction. Remote Sensing, 13(16), 3209.
26. Chen, L., Chen, Z., Zhang, Y., Liu, Y., Osman, A. I., Farghali, M., ... & Yap, P. S. (2023). Artificial intelligence-based solutions for climate change: a review. Environmental Chemistry Letters, 21(5), 2525-2557.
27. Jenny, H., Alonso, E. G., Wang, Y., & Minguez, R. (2020). Using artificial intelligence for smart water management systems.
28. Farig, M., Shimizu, K., & Abou El Hassan, W. H. (2025). Artificial Intelligence in Agricultural Water Management Research: Literature Review and Research Agenda. International Journal of Advanced Engineering, Management and Science, 11(1), 592576.
29. Satpathy, I., Nayak, A., & Jain, V. (2025). The green city: Sustainable and smart urban living through artificial intelligence. In Utilizing Technology to Manage Territories (pp. 273-304). IGI Global.
30. Kapanski, A. A., Klyuev, R. V., Boltrushevich, A. E., Sorokova, S. N., Efremenkov, E. A., Demin, A. Y., & Martyushev, N. V. (2025). Geospatial Clustering in Smart City Resource Management: An Initial Step in the Optimisation of Complex Technical Supply Systems. Smart Cities, 8(1), 14.
31. Al-Raeei, M. (2025). The smart future for sustainable development: Artificial intelligence solutions for sustainable urbanization. Sustainable Development, 33(1), 508-517.

DOI:10.31579/2637-8914/305