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ARTICLE

COMPETITIVE INTELLIGENCE FOR SUSTAINABLE WATER GOVERNANCE: A DATA–INTELLIGENCE–DECISION FRAMEWORK FOR SDG 6

INTELIGÊNCIA COMPETITIVA PARA A GOVERNANÇA SUSTENTÁVEL DA ÁGUA: UM FRAMEWORK DADOS–INTELIGÊNCIA–DECISÃO PARA O ODS 6

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ABSTRACT

Purpose. Ensuring clean water and adequate sanitation remains a critical global challenge. This study aims to analyse modern water supply and sanitation technologies and assess their effectiveness and potential for integration into global water management systems.

Methodology/approach. The research is based on a comprehensive analysis of scientific literature, international reports, statistical data, and case studies of technology implementation across different countries. Comparative and systemic approaches were used to evaluate technological efficiency and scalability.

Originality/Relevance. The study provides a systematic overview of innovative water management technologies in the context of sustainable development. Its relevance lies in identifying practical pathways for achieving universal access to safe water.

Key findings. The results show that digitalisation, the Internet of Things (IoT), artificial intelligence, biofiltration, and membrane technologies significantly enhance water management efficiency. The adoption of circular economy principles, particularly wastewater reuse, reduces pressure on natural water resources. However, key barriers include high implementation costs, limited financial resources, and unequal access to innovation.

Theoretical/methodological contributions. The study contributes to the development of an integrated framework for evaluating water technologies and offers methodological insights into combining technological, economic, and sustainability perspectives in water resource management.

Keywords: Clean water. Sanitation. Water management. Innovative technologies. Digitalisation. Circular economy

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RESUMO

Objetivo. Garantir água limpa e saneamento adequado continua sendo um desafio global crítico. Este estudo tem como objetivo analisar tecnologias modernas de abastecimento de água e saneamento e avaliar sua eficácia e potencial de integração em sistemas globais de gestão da água.

Metodologia/abordagem. A pesquisa baseia-se em uma análise abrangente da literatura científica, relatórios internacionais, dados estatísticos e estudos de caso sobre a implementação de tecnologias em diferentes países. Foram utilizados enfoques comparativos e sistêmicos para avaliar a eficiência tecnológica e sua escalabilidade.

Originalidade/Relevância. O estudo oferece uma visão sistemática das tecnologias inovadoras de gestão da água no contexto do desenvolvimento sustentável. Sua relevância reside na identificação de caminhos práticos para alcançar o acesso universal à água segura.

Principais resultados. Os resultados mostram que a digitalização, a Internet das Coisas (IoT), a inteligência artificial, a biofiltração e as tecnologias de membranas aumentam significativamente a eficiência da gestão da água. A adoção de princípios da economia circular, particularmente o reúso de águas residuais, reduz a pressão sobre os recursos hídricos naturais. No entanto, barreiras importantes incluem altos custos de implementação, recursos financeiros limitados e acesso desigual à inovação.

Contribuições teóricas/metodológicas. O estudo contribui para o desenvolvimento de um framework integrado para avaliação de tecnologias hídricas e oferece contribuições metodológicas ao combinar perspectivas tecnológicas, econômicas e de sustentabilidade na gestão dos recursos hídricos.

Palavras-chave: Água limpa. Saneamento. Gestão da água. Tecnologias inovadoras. Digitalização. Economia circular

1 INTRODUCTION

The availability of clean water and proper sanitation has been one of the most urgent issues in the world directly connected to the health of people, the level of their economic development, and the ecological sustainability. Although much is done by countries in order to attain Sustainable Development Goal 6 (SDG 6), there still exist uneven conditions in different regions because of climate change, urbanisation, and infrastructure constraints, and institutional inefficiencies. Water shortage, contamination and unequal distribution remains a challenge to sustainable development and social justice in most regions of the world.

Modern studies have focused on technological solutions to water management extensively such as artificial intelligence, the Internet of Things (IoT), geographic information systems, membrane technologies, and wastewater reuse systems. These researches are mainly aimed at making it more efficient, keeping an eye on the quality of water and maximising on the use of resources. Nevertheless, these are often narrowly viewed in terms of technology, neglecting to ask a more general question of how data created by these systems can be converted into actionable knowledge to be used in the decision-making process.

The critical scientific issue that has been tackled in the current study is the fact that there is a lack of incorporation of competitive intelligence and decision intelligence concepts in water management studies. Although digital technologies can be used to facilitate the collection and analysis of large volumes of data, without conceptualisation of water management systems as intelligence-driven systems to promote adaptive governance, there is no implementation. Specifically, the existing literature does not tell much about the ways data flows are translated to intelligence, how it translates into strategic choices, and how it leads to sustainable and resilient water governance.

The fact that this gap exists shows that it is necessary to shift the focus on the descriptive and technology-focused approaches to the analytical framework that relies on the logic of data to intelligence to decision. In this context, water management systems can be understood as complex socio-technical systems where digital technologies can serve not only as operational devices but as an element of intelligence infrastructures using which information is monitored in real-time, predictive analytics are employed, and informed decisions are made.

In this light, competitive intelligence is an important tool to turn disjointed information into strategic knowledge that assists in the allocation of resources, risk management as well as policy formulation. By incorporating competitive intelligence in water governance, it becomes possible to shift the institution to reactive problem-solving to proactive and adaptive management with institutional responsiveness and long-term sustainability.

Thus, this research will provide an analysis of contemporary innovative solutions to water supply and sanitation in terms of the competitive intelligence and decision intelligence and evaluate how they help to convert the data into the strategic value and promote effective governance. The research helps in developing a conceptual framework which incorporates technological, analytical and governance aspect of water management which forms the basis of intelligence-based solutions to the attainment of SDG 6.

2 LITERATURE REVIEW

2.1 Competitive Intelligence in Water Resource Management

Competitive intelligence offers a conceptual lens to understand the role of data-driven systems in facilitating strategic decision-making in complex resource management settings. When applied to water management, competitive intelligence is the process of gathering, processing and interpreting information from environmental monitoring networks, digital platforms, and institutions, to provide valuable insights. It allows organisations and governments to make informed predictions, resource allocation, and policy adjustments. The adoption of competitive intelligence in water management transforms the decision-making process from reactive to proactive and adaptive, with a focus on real-time and predictive analytics. Therefore, water management systems can be thought of as intelligence systems that improve sustainability through strategic and informed actions.

Presently, clean water and sanitation research looks at technological, economic and social aspects of achieving SDG 6. At the same time, modern research increasingly emphasises the role of competitive intelligence as a key mechanism for transforming fragmented data into strategic knowledge within complex resource management systems. In the context of water governance, competitive intelligence can be understood as a structured process that includes data collection (via sensors, monitoring systems, and digital platforms), data processing and analysis (using artificial intelligence and analytical models), and the generation of actionable insights for decision-makers. This process enables the transition from raw environmental and infrastructural data to intelligence-based knowledge that supports strategic planning, prioritisation of investments, and adaptive management. Consequently, water management systems evolve into decision intelligence systems, where real-time and predictive analytics influence policy design, operational decisions, and long-term sustainability strategies. Therefore, the integration of competitive intelligence principles allows for a deeper understanding of how digital technologies contribute not only to efficiency but also to strategic governance and institutional resilience.

The introduction of digital technologies in terms of water resources monitoring and management is paid much attention to as they help improve their efficiency and sustainability (Kurniawan et al., 2024; Zaryouh and Fahmi, 2024). Water consumption forecasting and minimising losses (Habib et al., 2024; Lee, Jung and Jayakumar, 2024; Ryzhakova et al., 2022) can be significantly improved using the Internet of Things (IoT), Geographic Information Systems and artificial intelligence. Studies also corroborate that climate change can hurt the availability of water resources in terms of environmental challenges. Minsoc (2021) explained that this problem is particularly acute in arid regions where groundwater and surface water are rapidly depleting (Michalak et al., 2023; Onyena and Sam, 2025). However, at the same time, many countries are undertaking adaptation measures to reuse effluent wastewater and membrane technology for desalinating seawater (Stefanakis, 2024; Das et al., 2025).

Biofiliters and biochar for the adsorption of pollutants are innovative water treatment approaches such as biotechnological ones, whereas phytotechnologies use aquatic plants as a natural way of purification (Monroy-Licht et al., 2024; Jacob et al., 2024). Such technologies will diminish the negative influence of industrial and agricultural waste on water resources (Dubey, Kumar and Dutta, 2024). Finally, it studies the social aspect of access to water and sanitation in light of the unequal distribution of resources and a gender problem. Women and girls spend much time in rural, developing countries, limiting possibilities for education and economic activity (Rodríguez-Izquierdo et al., 2023; Mgwele, Bhanye and Mocwagae, 2024). Additionally, water infrastructure is underfunded, and the main obstacles to achieving SDG 6 include weak governance (Evaristo et al., 2023; Koehler, 2023).

Recent studies on natural resource management emphasise the importance of integrating environmental, technological, and institutional dimensions in addressing water-related challenges. Scholars highlight that sustainable water use depends not only on technological innovation but also on governance mechanisms, resource optimisation strategies, and adaptive management approaches under conditions of climate change and anthropogenic pressure. These findings reinforce the need to move beyond sectoral analyses toward integrated and system-oriented perspectives in water governance.

Besides technological changes, recent publications are devoted to the importance of an integrated approach to sustainable water management regarding social, economic and environmental factors. Studies indicate that not only technologies but also public policies and management decisions impact the efficiency of water systems (Boldrin, Neisse and Formiga, 2025; Dinka and Nyika, 2024). In this case, Africa, and perhaps by extension other countries, fails to achieve SDG 6 because there is a lack of infrastructure and financing, as indicated by the analysis of progress from 2015 to 2020 (Sahilu, 2022). Many regions in many parts of the world face the problem of financing innovative solutions. According to researchers, funding is often lacking to modernise water supply systems, posed as corruption and poor governance, making it hard to achieve sustainable results (Evaristo et al., 2023; Nagayev et al., 2022). Furthermore, an analysis of water reuse policies in India reveals the requirement for more active support from the state and businesses to realise the circular economy in the water sector (Dubey, Kumar and Dutta, 2024).

Decentralised water supply and sanitation systems are an important area of research that can solve the problem of unstable access to clean water in rural and remote areas (Das et al., 2025; Ametepey et al., 2024). Such systems help decrease dependence on centralised water networks and improve local resource management. Studying the use of water treatment technologies in the agricultural sphere reveals the role of energy-premised equipment in reducing water losses (Batsurovska and Dotsenko, 2022; Havrysh et al., 2020). Several studies also draw attention to the fact that water issues must be addressed using an interdisciplinary approach. As an example, it is demonstrated that it is necessary to improve water management efficiency using educational programmes by assessing the environmental competence of future water management professionals (Nagayev et al., 2022). Moreover, urbanisation is analysed, and its influence on water supply proves that urban strategies must adapt to climate change and increasing resource demand (Stracqualursi and Andreucci, 2024).

However, various challenges remain to be addressed. The second point is that integrating environmentally friendly technologies in low-income countries is inadequate for their support. Secondly, Microplastics and persistent chemical compounds constitute water that needs further research and development of effective treatment methods (Singh and Jayaram, 2022; Onyena and Sam, 2025). These days, there is a general study of the application of innovative technology to reduce water consumption and increase efficiency in water utilisation. In particular, it is seen how environmental technologies and integrated solutions are taking on a growing role in the sustainable management of water (Adeoba and Fatayo, 2024). This also includes the importance of initiatives to introduce a circular economy in water use, optimising water consumption and reuse (Moghayedi, 2024).

An important feature of all international research related to the Sustainable Development Goals (SDG 6) was the question regarding countries' readiness for their achievement. South Asia provides a powerful manifestation of inadequate funding, outdated infrastructure, and unequal access to water and sanitation that has tremendously slowed progress towards SDG 6 achievement (Danso and Otoo, 2022; Sumets et al., 2022). African countries suffer from similar problems with political, economic and climate factors preventing even progress on expanding access to clean water (Moghayedi, 2024).

However, there has been much work to develop new water management approaches, yet much work still needs to be done.

Synthesising the reviewed studies, it can be observed that existing research predominantly focuses on technological efficiency, environmental sustainability, and policy challenges, while insufficient attention is given to the transformation of data into strategic intelligence within water management systems. Although digital technologies such as IoT, artificial intelligence, and monitoring systems are widely discussed, their role as components of integrated intelligence frameworks remains underexplored. From a theoretical perspective, this gap highlights the need to conceptualise water management not only as a technological or infrastructural domain but as an intelligence-driven system where data flows, analytical capabilities, and institutional decision-making are interconnected. Thus, the theoretical contribution of this study lies in integrating competitive intelligence and decision intelligence approaches into the analysis of water governance, enabling a shift from fragmented technological perspectives to a coherent conceptual framework. Also, because their economic constraints will not allow them to adopt the latest technologies, low-income countries are still at the initial level of being ready to adopt them. Second, current methods of modern water treatment cannot eliminate all persistent pollutants, such as microplastics or pharmaceutical waste, which threaten the environment.

2.2 Data–Intelligence–Decision Model in Water Governance

An essential component of intelligence-driven governance is the transformation of raw data into actionable knowledge through structured analytical processes. The data–intelligence–decision model provides a conceptual framework for understanding this transformation in water management systems. At the initial stage, large volumes of data are collected from sensors, monitoring systems, and statistical databases. These data are then processed and analysed using digital tools, including artificial intelligence and predictive analytics, to generate intelligence in the form of patterns, forecasts, and risk assessments. Finally, this intelligence supports strategic and operational decision-making, enabling more efficient allocation of resources, timely interventions, and adaptive policy design. This model highlights that the value of technological systems lies not only in data generation but in their capacity to support intelligence-based governance.

3 METHODS

The research is a proposed integrative literature review and comparative analysis study to explore the innovative solution to water management in the context of competitive and decision intelligence. The methodological design is structured and transparent review protocol, which was followed to guarantee reproducibility and analytical rigour.

The search of the literature was carried out with the help of the most prominent European and American databases of scientists, such as Scopus, Web of Science, and Google Scholar. Search strategy was premised on the combinations of the following keywords, including, but not limited to, water management, SDG 6, digital technologies, artificial intelligence in water systems, water governance, and sustainable sanitation. They were searched only in publications that were published in 2020-2025 to assure akuuality and relevance of the data analyzed.

The review procedure was systematic and in multi-stage. The identification stage retrieved 312 records out of the selected databases. The screening phase involved a review of titles and abstracts to screen out irrelevant publications and this gave 148 studies. During the eligibility phase, preselected inclusion and exclusion criteria were used to evaluate the full-text articles. These inclusion criteria included: (1) SDG 6 and water management, (2) innovative or digital technology, (3) empirical or analytical evidence, and (4) publication in peer-reviewed sources or recognised international reports. The exclusion criteria were outdated publications, descriptive only material without analytical value and studies that were not directly connected to water governance. This led to the selection of 86 studies to analyze them in detail.

The research is conducted in accordance with the logic of PRISMA approach to provide the transparency of the procedure of selection. The identification, screening, eligibility, and inclusion stages were systematically used, which made it possible to reduce the dataset and decrease the selection bias. The process of literature identification, screening, eligibility assessment, and final inclusion is presented in Figure 1 according to the PRISMA framework.

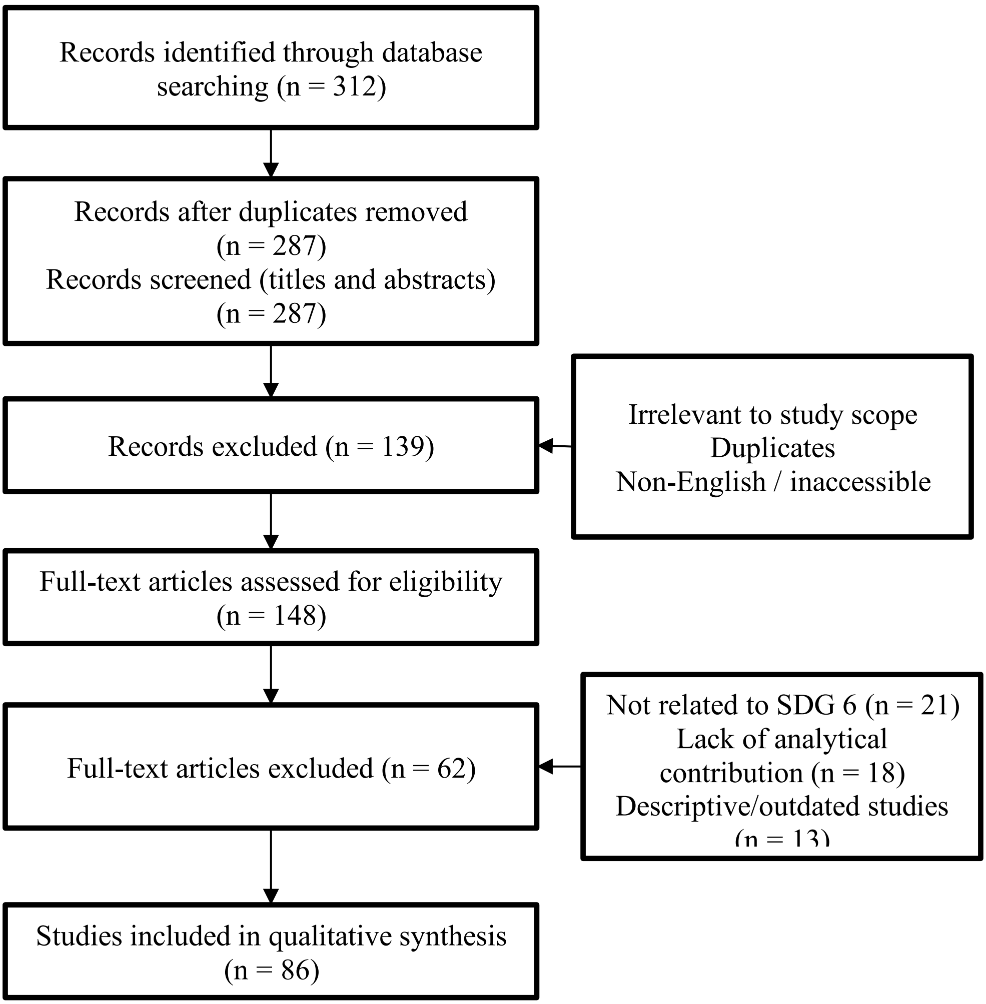

Figure 1. PRISMA flow diagram of the literature selection process
Source: developed by the author

A structured coding approach was applied to organise and interpret the selected studies, focusing on key themes related to technological solutions, governance mechanisms, and data-driven decision-making. The process of coding was aimed at defining the major themes and common ideas concerning technological solutions, governance mechanisms, data processing systems, and decision-making practices. These factors were identified into larger analytical units to be compared and synthesized conceptually.

The analytical process consisted of data extraction, cross-study comparison, and thematic synthesis to find patterns, relationships and differences between the chosen studies.

Interpretation of the findings was done in the data-intelligence-decision framework, which allowed conceptual generalisation. This methodological technique guarantees the transparency, stability, and replication of the study, as well as provides an opportunity to leave the descriptive literature review and engage in a form of analytic explanation of water management apparatus.

4 RESULTS AND DISCUSSION

The most vital remaining challenge to sustainable development is ensuring people have access to clean water and proper sanitation. While considerable work has been completed to realise SDG 6, a large world population lacks safe drinking water and appropriate sanitation. The main challenges faced by the world in this area are as follows:

1. Water scarcity and climate change. Global water scarcity and climate change are among the main problems. Average temperatures are rising, precipitation is distributed differently, and droughts occur more often. Most of the world has a reduced water supply (Michalak et al., 2023). In the Middle East, North Africa, and South Asia, freshwater sources are being depleted at a preponderant speed over their recharging ability.

2. Pollution of water resources. There is increasing pollution of rivers, lakes and groundwater because of industrialisation, agriculture and urbanisation. There are threats to the safety of water supplies from the emission of heavy metals, pesticides, plastics, and pharmaceuticals (Jacob et al., 2024). One aspect is that an effective wastewater treatment system is not found in many developing countries, which worsens the spread of cholera and dysentery.

3. Urbanisation and population growth. On the one hand, cities and megacities are growing rapidly; on the other hand, they can exert more and more strain on water supply systems. It does not come with modern infrastructure, that is often incapable of handling a population on the rise, leading to broken water supply and improper waste disposal (Stracqualursi and Andreucci, 2024). For instance, in some African and Asian cities, people have to rely on unsafe water sources because it does not have a centralised water supply.

4. Unequal access to water and sanitation. However, there is a massive gap between water and sanitation provision in different regions and social groups. However, safe water access is a huge issue in rural areas of many African, Latin American and Asian countries, and urban populations are better off (Rodríguez-Izquierdo et al., 2023). It also has a gender element: many women and girls must collect water, which can be a labour-intensive task preventing them from going to school or finding paid employment.

5. Insufficient funding and weak water management. Investment in water infrastructure is widely under-invested and is one of the keys to the slow progress toward achieving SDG 6. Governments and municipalities sometimes cannot afford the lack of modernisation of water supply systems and installation of adequate water treatment technologies (Evaristo et al., 2023). Furthermore, poor governance, corruption, and weak legal regulations can be responsible for the wasteful use of water resources and inequitable distribution.

6. Challenges in implementing innovative solutions. Despite the many available technological solutions to increase access to water, some issues prevent implementation. Such water treatment and reuse systems are not always priced within the reach of poor countries. Moreover, the lack of skilled professionals and technological know-how contributes to the low rate of innovation adaptation (Danso and Otoo, 2022).

A range of global and local water and sanitation challenges need combined solutions, including investments in infrastructure, technological innovation, and adequate water management strategies. From an analytical perspective, the identified challenges should not be interpreted solely as isolated technical or infrastructural issues, but as components of complex socio-technical systems requiring integrated intelligence-based governance. The effectiveness of innovative technologies depends not only on their technical characteristics but on the capacity of institutions to interpret data, generate strategic knowledge, and implement informed decisions. This allows for a theoretical generalisation in which water management is conceptualised as an adaptive system driven by continuous feedback loops between data, intelligence, and decision-making processes. Consequently, the transition from descriptive identification of problems to analytical interpretation enables a deeper understanding of how technological, institutional, and informational factors interact in shaping sustainable water governance. These challenges must be addressed by collaborating with governments and international organisations, the private sector, and civil society to ensure that all have permanent access to sustainable water supplies.

Through these technologies, clean water is made accessible, the efficiency of the system water supply is improved, and the effects of human actions on soil and water bodies are minimised.

From an analytical standpoint, these technologies should be understood as interconnected elements within a broader intelligence system rather than isolated technical solutions. Their primary value lies in enabling continuous data generation, real-time analysis, and feedback mechanisms that support adaptive decision-making. This reflects a systemic transition from operational efficiency toward intelligence-driven governance, where technological performance is evaluated based on its contribution to informed and strategic decision processes.

The increasing adoption of modern solutions to renew water efficiency fulfils SDG 6 and cleans the global water deficit. In Figure 1, it is shown that innovative technologies in water supply, wastewater treatment, and water resources management are effective. The data presented in Figure 1 are derived from a synthesis of recent empirical and analytical studies (Habib et al., 2024; Zaryouh and Fahmi, 2024; Lee et al., 2024; Michalak et al., 2023; Jacob et al., 2024), which provide evidence on the performance and efficiency of different technological solutions. The figure represents a conceptual aggregation of these findings, highlighting the relative contribution of each technological group to water management effectiveness.

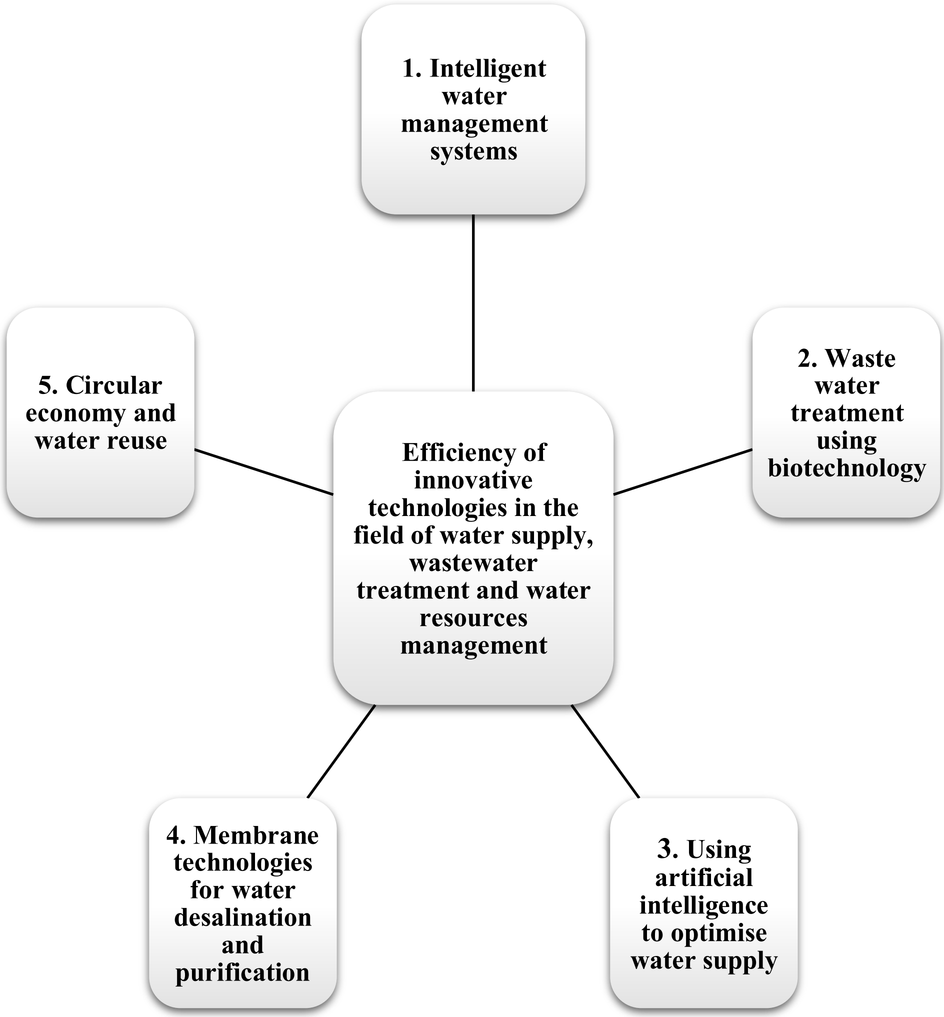

Figure 1. Efficiency of innovative technologies in water supply, wastewater treatment and water resources management
Source: developed by the author based on Habib et al. 2024; Zaryouh and Fahmi, 2024; Lee, Jung and Jayakumar, 2024; Michalak et al. 2023; Jacob et al. 2024

Over and above, let us look seriously at how innovative technologies discharge their effectiveness in water delivery, wastewater treatment and management.

1. The development of digital technologies gives rise to intelligent systems monitoring and managing water resources. The Internet of Things (IoT) has enabled real-time water quality and pollution and water flow monitoring, enhancing water management (Zaryouh and Fahmi, 2024). For example, Morocco is applying innovative systems for automated monitoring of water reservoirs and targeted use of the water quantity.

2. Recently, water treatment using biofilters and bioorganisms started to be popular due to their safety to the environment and efficiency. Research proves that the adsorption of industrial wastewater using biochar dramatically enhances the efficiency of

industrial wastewater treatment (Jacob et al., 2024 [24]). Indicators for eco-engineering include phytotechnologies, such as using aquatic plants such as Eichhornia crassipes in bioremediation, which can also drastically reduce the concentration of toxic materials in water.

3. Today, water consumption is increasingly being predicted with artificial intelligence (AI) and machine learning, leak prediction is becoming more intuitive through machine learning, and water treatment processes are being automated using machine learning. The AI-based algorithms can recover 20–30 per cent of the water loss in urban water supply systems through the discovery of anomalies in the early stage (Habib et al., 2024). In light of this, the promise of using AI is highest for cities in arid regions where it is necessary to distribute water efficiently.

4. As nations with high potential demand for reliable water supply have been shown from this research, modern membrane filters such as nanofiltration and reverse osmosis can produce drinking water from highly contaminated sources. Countries with a shortage of fresh water, like Saudi Arabia and the UAE, use such systems for a large part of their drinking water, of which a significant amount is desalinated seawater (Stefanakis, 2024). At the same time, the latest graphene membranes outperform all prior membranes; those based on graphene exhibit dramatically increased energy efficiency in filtration processes.

5. Circular economy approaches are being developed to minimise water loss and pollution. EU countries are implementing projects to reuse treated wastewater for irrigation, industrial production, and even as an additional source of drinking water (Dubey, Kumar and Dutta, 2024). This approach helps to significantly reduce the consumption of natural water resources and reduce environmental pollution.

Numerous studies have proven the effectiveness of modern innovations in water supply, wastewater treatment and water management. From an analytical perspective, these results can be interpreted through the data–intelligence–decision framework, where technological systems act as data generators, analytical tools transform this data into intelligence, and governance structures utilise this intelligence for informed decision-making. In order to give a structured interpretation of the results, applied analytical model was used basing on data-intelligence-decision framework. In this model, technologies are considered based on their contribution to three interrelated processes namely: data generation (e.g., sensors, IoT systems), data processing and intelligence formation (e.g., artificial intelligence and analytical platforms), and decision-making support (e.g., governance mechanisms and policy implementation). With the help of this model, it is possible to evaluate the role of various technologies in transforming the raw data into actionable intelligence and strategic decisions in a systematic manner. This interpretation shifts the focus from technological efficiency to intelligence-based management. Innovative technologies, biological purification methods, membrane filters and artificial intelligence open new opportunities to solve global water supply problems. Further development of these technologies will help reduce water shortages and improve the quality of life worldwide.

Growing demand for water resources and decreasing availability require introducing the latest technologies to improve water management efficiency. Innovative technologies, such as artificial intelligence (AI), the Internet of Things (IoT) and automated monitoring systems, can improve water management, reduce water losses, optimise treatment processes and ensure more sustainable use of water resources. The introduction of these technologies has the potential to be applied globally, but their effectiveness depends on the infrastructure, level of digitalisation and financial capabilities of countries. Importantly, these technologies should be interpreted not only as operational tools but as elements of integrated intelligence systems.

Their ability to collect, process, and analyse large volumes of data enables the transition from reactive to proactive water management. In this context, digital infrastructures support decision intelligence by providing predictive insights, facilitating strategic planning, and enhancing governance efficiency. Table 1 below summarises the leading innovative technologies, their characteristics and potential benefits for water management. In order to reinforce the comparative aspect of the analysis, the identified technologies have been evaluated systematically on a variety of criteria, such as efficiency, scalability, cost implications, and suitability to various institutional contexts. This comparison shows that digital technologies which include artificial intelligence and Internet of Things are highly adaptable and scalable, especially in urban settings whereas membrane and biofiltration technologies are more effective in cleaning water but demand more financial resources. Conversely, the approaches to the circular economy have a high potential of long-term sustainability but require regulatory and institutional backing. The comparative analysis shows that the success of water management solutions depends on a situation and is defined by the relationship between the technological capacities and the governance systems.The data included in Table 1 are compiled from multiple peer-reviewed sources and analytical reports, allowing for a comparative evaluation of technological functions and their practical implications. The table reflects a systematisation of heterogeneous data into a structured format to support analytical interpretation within the proposed intelligence-based framework.

Table 1 – Key innovative technologies for water management

Technology	How it works	Main advantages
Artificial intelligence (AI)	Analysing large data sets to predict water consumption and detect anomalies.	Reduced water consumption, early detection of leaks, increased efficiency of water supply (Habib et al., 2024).
Internet of Things (IoT)	Sensors for real-time monitoring of water quality and level.	Operational control and response, optimisation of water distribution (Zaryouh and Fahmi, 2024).
Geographic information systems (GIS)	Visualisation and analysis of water resources data using satellite technologies.	Effective water network planning and ecosystem management (Lee, Jung and Jayakumar, 2024).
Automated control systems	Control of pumping stations, wastewater treatment and water supply regulation.	Energy saving and increased productivity of water systems (Michalak et al., 2023).
Smart water quality sensors	Monitoring the level of contamination and determining the chemical composition of water in real-time.	Prompt detection of hazardous substances, improving water supply safety (Jacob et al., 2024).

Source: developed by the author based on Habib et al. (2024), Zaryouh and Fahmi (2024), Lee, Jung and Jayakumar, 2024, Michalak et al. (2023), Jacob et al. (2024)

Introducing innovative technologies in the water sector can significantly improve water use efficiency. Tools based on artificial intelligence, the Internet of Things, geographic information systems, and automated sensors can reduce water losses and improve the quality of water treatment and distribution. The further development of these technologies will contribute to more sustainable use of water resources and adaptation to climate change, which is especially important in growing water scarcity (Kniaz et al., 2023).

The issue of clean water and adequate sanitation remains a global challenge in achieving Sustainable Development Goal 6 (SDG6). Despite significant progress in many countries, some areas remain critical. Given the existing challenges, innovative technologies such as the Internet of Things (IoT), artificial intelligence (AI), biofiltration, and membrane technologies have significant potential to improve water management efficiency. Introducing innovative technologies can help reduce water losses, improve water quality and ensure sustainable water supply even under challenging conditions (Table 2).

Table 2 – Examples of effective implementation of innovative technologies in the water sector

Country	Technology	Implementation results
Morocco	Intelligent systems based on IoT	Reducing water losses, optimising water distribution
Australia	Artificial intelligence for monitoring water networks	Reduction of water losses in urban networks by 20-30%, early detection of water leaks
Singapore	Integrated NEWater system (water recycling)	Reduce dependence on water imports, build resilience to droughts
Israel	Drip irrigation	Saving up to 50% of water, increasing yields in agriculture
Netherlands	"Green dams and managed drainage	Flood protection, sustainable water management

Source: developed by the author based on Habib et al. 2024; Zaryouh and Fahmi 2024; Lee, Jung and Jayakumar, 2024; Michalak et al. 2023; Jacob et al. 2024

The introduction of innovative technologies in the water sector demonstrates a high potential for improving the efficiency of water network management and minimising water losses. In order to have a more systematic assessment of the effectiveness of the technologies, key performance indicators were chosen using the reviewed studies such as water loss reduction rates, energy efficiency, treatment effectiveness, and cost-efficiency. To give an example, AI-based systems prove to be able to decrease water losses by 2030, whereas membrane technologies prove to have a high purification rate under conditions of the worst contamination. IoT-monitors help to ensure control in real-time and early detection of anomalies and enhance the efficiency of operations. The metrics can offer evidence basis to the evaluation of the work of various technological solutions, as well as the comparative analysis can be approached more objectively. However, the effectiveness of these technologies varies depending on institutional capacity, data integration mechanisms, and governance structures. This suggests that technological innovation alone is insufficient without the presence of analytical capabilities that transform data into actionable intelligence. Therefore, the results indicate that the key determinant of successful water management lies in the ability to integrate technological, informational, and decision-making components into a coherent intelligence framework. Case studies from Morocco, Australia, Singapore, Israel, and the Netherlands show that the use of IoT, AI, and integrated systems can significantly improve the quality of water supply, even in regions with challenging climatic conditions (African Business, 2023; UN-Water, 2023a, 2023b). These examples can serve as a basis for adapting similar technologies in developing countries, ensuring the achievement of SDG 6 at the global level.

Singapore and Ghana have shown significant progress towards achieving Sustainable Development Goal 6 (SDG 6), which aims to provide all access to clean water and sanitation by 2030 (UN-Water, 2023a, 2023b). Despite a few natural water resources, Singapore has also established an approach to water management that integrates water importation, local catchments, treated water (NEWater) and desalination, commonly called the Four National Taps. The country will maintain a sustainable and reliable water supply in this approach. Singapore also actively participates in innovative and research-related water technologies, partnering with international partners and involving the private sector in water infrastructure development. Educational campaigns are important to facilitate public awareness of water conservation and efficient use (UN-Water, 2023a).

It has also worked hard through institutional reform, financing, public participation, natural resource management and good monitoring to improve access to safe water and sanitation, especially in rural areas. Specialised water management agencies have been created to make water management more efficient, and public funds, international investment and donor support have been attracted to develop water infrastructure. Active engagement of communities in decision-making on and managing water projects was also an important factor that enhanced the ownership and sustainability of the initiatives. Groundwater use and protection of wetlands have been used to achieve a stable water supply, and water quality and sanitation monitoring systems have facilitated sound decision-making and development strategy adjustments (UN-Water, 2023b).

The two countries show that SDG 6 can be delivered through an integrated approach, innovation, good governance, and active public participation. Technological solutions combined with funding and local community participation are required to significantly improve the efficiency of the water sector in Singapore and Ghana (African Business, 2023).

The problem of both efficient use of water resources and sustainable development of water supply and sanitation is one of the key challenges of the modern world. SDG 6 aims to ensure access to clean water and adequate sanitation for all, but achieving this goal requires a comprehensive approach. The environmental, economic and social aspects are interconnected: water pollution and climate change affect water availability, financial barriers hinder infrastructure modernisation, and unequal access to water resources leads to social tensions.

It is crucial to examine the dynamics of investment in the sustainable water sector in different regions of the world (Figure 2) to illustrate the interconnection of these factors.

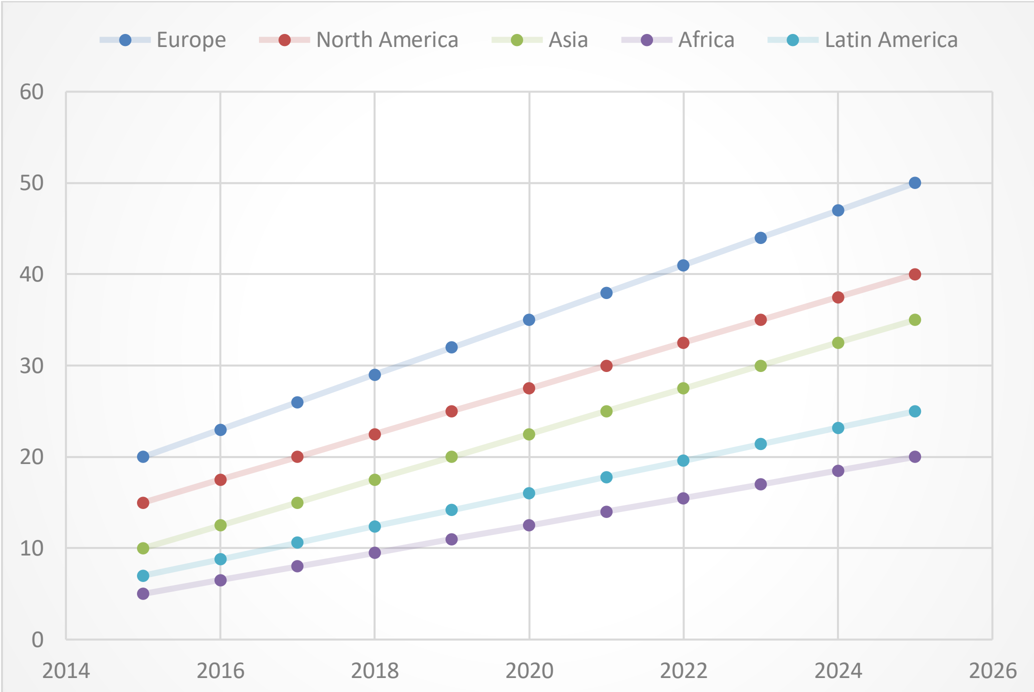

Figure 2. Addressing the environmental, economic and social aspects of sustainable water supply and sanitation
Source: developed by the author based on Boldrin, Neisse and Formiga, 2025; Dinka and Nyika, 2024; Dubey, Kumar and Dutta, 2024; Evaristo et al. 2023; Koehler, 2023

The graph demonstrates investment dynamics in the sustainable water sector in different world regions for 2015-2025. The general trend shows a gradual increase in funding in all regions, but the pace of this growth varies significantly. ***Europe*** demonstrates the most significant investments among all regions. In 2015, funding totalled $20.0 billion; by 2025, it will have grown to $50.0 billion, an increase of $30.0 billion in ten years. The average annual increase in investment is $3.0 billion, indicating steady and progressive growth. ***North America*** also shows a significant increase in investment, from 15.0 billion in 2015 to 40.0 billion in 2025. The total increase is $25.0 billion, with an average annual increase of $2.5 billion. This indicates active financing of sustainable water supply programmes, although the growth rate is somewhat lower than in Europe. ***Asia*** started with $10.0 billion in 2015 and reached $35.0 billion in 2025. This represents an increase of $25.0 billion in ten years, similar to North America. However, the peculiarity is the faster growth after 2020, when investments began to increase significantly due to the active implementation of water treatment and redistribution technologies. ***Africa*** remains the region with the lowest investment volumes, although it also shows positive dynamics. In 2015, funding was only $5.0 billion; by 2025, it will have increased to $20.0 billion. This is an increase of $15.0 billion in ten years, a significant relative increase (four times the initial value). However, the average annual increase is only $1.5 billion, significantly less than in developed regions. ***Latin America*** is showing growth rates similar to those of Africa. In 2015, investments amounted to $7.0 billion, and in 2025 - $25.0 billion. The overall increase of $18.0bn shows a slightly faster pace than Africa, but the region still lags behind Europe, North America and Asia. The average annual increase is $1.8 billion.

When analysing the general trends, the most significant funding is concentrated in economically developed regions - Europe and North America. At the same time, Asia is showing strong growth, which indicates that water infrastructure is improving in many countries in this region. Africa and Latin America remain relatively underfunded, requiring additional attention from international investors and governments to ensure equal access to clean water and sanitation.

Innovative solutions in water management play a key role in ensuring the sustainable use of water resources, especially in climate change, urbanisation and growing water scarcity. Different countries have adopted different approaches to water management, depending on their economic capacities, climatic conditions and level of technology development. Successful international practices include introducing digital technologies, bioengineering water treatment methods, circular economy in water supply, and integrated water management strategies.

Table 3 shows a comparison of the leading innovative solutions in the field of water management used in different countries of the world.

Table 3 – Comparison of international experience in implementing innovative solutions in water management

Country	An innovative solution	Main advantages	Possibility of adaptation in other countries
Singapore	Integrated NEWater system - reuse of treated wastewater	Reducing dependence on water imports, resilience to droughts	High (requires significant investment in technology)
Israel	Drip irrigation to minimise water losses	Saving up to 50% of water, increasing yields	High (effective for arid regions)
Netherlands	Use of green dams and managed drainage technologies	Flood protection, sustainable water management	Average (depending on climatic conditions)
Australia	Intelligent systems for monitoring and forecasting water resources	Reducing water losses, improving water network management	High (can be used in urban networks)
Germany	Use of biofilters and natural water purification systems	Reduced use of chemicals, improved water quality	High (environmentally friendly solution)

Source: developed by the author based on Michalak et al. (2023), Stefanakis (2024), Jacob et al. (2024), Zaryouh and Fahmi (2024), Habib et al. (2024)

International experience in water management demonstrates a wide range of approaches that can be adopted in different countries depending on climatic, financial and technological capabilities. For example, the NEWater water reuse system in Singapore can be implemented in large metropolitan areas where there is a need to reduce dependence on natural water sources. Israel's drip irrigation technology is an effective solution for arid regions such as the Middle East and Africa.

However, adapting some technologies, such as intelligent monitoring or biofilter technologies, would have more potential as they do not require extensive maintenance of existing water infrastructure. Projects that require significant investments can be challenging to transfer to low-income countries, given that they are costly.

Water management is effective for environmental sustainability, social well-being and economic development. In order to achieve this goal, appropriate strategies, encompassing legislative initiatives, technological innovations, appropriate water use, and active participation by society, must be developed comprehensively. Water conservation and management measures taken by the public, private and civil society sectors will be much more effective when they cooperate.

These measures will not only make water management more efficient but also improve environmental sustainability, enhance water sector sustainability, and promote equal access to clean water for every social group. These recommendations should be adapted to different regional and economic conditions to achieve Sustainable Development Goal 6 (SDG6).

1. *We should introduce new technologies for water resources monitoring and management.* Authorities should encourage water consumption and quality to be monitored through digital technology, such as smart sensors, satellite monitoring and artificial intelligence. Such a policy aims to minimise water losses from networks, facilitate management of networks and react promptly to emergencies.

2. *Find mechanisms of economic incentives for sustainable use of water.* Financial instruments, such as tax breaks or subsidies, may be introduced to price comparatively lower financial penalties on the water reuse technologies companies introducing can assist them in reducing water pollution. Other than that, we should also seek to introduce fines for excess water consumption and pollution so that they can conserve their resources.

3. *Strengthening regulations will also help implement strict water quality standards.* Government agencies should maintain effective control over the implementation of environmental standards and liability for violations in the water supply and sewerage sector. Initiating international water quality standards will improve water bodies' biological status and safeguard public health.

4. *An active public engagement and educational campaigns about responsible water use.* Progress can indeed be made with the aid of civil society organisations to raise public awareness of water issues. Educational programmes, information campaigns, and water conservation initiatives will help create a culture of rational water use at the household and business levels.

An integrated approach to water management requires cooperation between the government, businesses and the public. Introducing modern technologies, economic incentives, effective legislation and information campaigns can significantly improve the state of water resources and promote their sustainable use. To achieve real change, it is necessary to ensure constant monitoring, adaptation of strategies and active participation of all stakeholders.

The study results confirm that ensuring access to clean water and proper sanitation remains a global challenge, especially in developing countries. In contrast to purely descriptive interpretations, this study emphasises the role of analytical and intelligence-based mechanisms in addressing these challenges. The findings indicate that effective water management depends on the integration of data systems, analytical tools, and governance structures, which together enable informed and adaptive decision-making. Beyond confirming existing challenges, the findings contribute to theoretical generalisation by demonstrating that water management systems can be understood as intelligence-driven adaptive systems. This perspective highlights the role of information flows, analytical capabilities, and institutional decision-making in determining system performance, moving beyond purely descriptive or technological interpretations. At the same time, the analysis of modern technological solutions shows their significant potential to improve water management. It is important to compare the data obtained with the research of other authors, which allows us to assess the effectiveness of different approaches.

Ensuring access to clean water and sanitation (SDG 6) is closely linked to broader socio-economic development outcomes. However, beyond policy-oriented interpretations, the findings of this study highlight that these interconnections are mediated by intelligence-driven processes. In particular, the effectiveness of water management systems depends on the ability to collect, process, and interpret data in order to support adaptive decision-making. This perspective shifts the focus from descriptive SDG interlinkages to an analytical understanding of how information flows and institutional capacities influence governance outcomes. As a result, sustainable development in the water sector can be better explained through the integration of data, intelligence, and strategic decision-making mechanisms.

At the same time, SDG 2, "Ending hunger", also directly depends on effective water management. Agriculture is the leading consumer of water, and introducing technologies such as drip irrigation (as in Israel) allows for optimised water use and increased yields, contributing to food security. The relationship with SDG 3, Good health and well-being, is manifested through reducing diseases caused by contaminated water. For example, access to safe water and adequate sanitation reduces the risk of infectious diseases such as cholera and dysentery, especially in rural and urban slums (Jacob et al., 2024; Ryzhakova et al., 2022).

The social aspect of access to water is important for achieving SDG 5 on gender equality, as in many cultures, women and girls are responsible for collecting water. This limits their access to education and opportunities for economic activity. Improving water infrastructure promotes gender equality by freeing women's time for other activities, including education and work (Mgwele, Bhanye and Mocwagae, 2024). It is also worth noting that effective water management supports SDG 10, "Reduce inequality", as access to clean water reduces the gap between rural and urban communities and between the poor and the rich. The introduction of innovative technologies, such as intelligent water monitoring systems and membrane treatment technologies, helps to ensure equal access to water resources for all social groups (Evaristo et al., 2023).

Thus, achieving SDG 6 improves the state of the water sector and contributes to socio-economic development, improving the population's quality of life and strengthening environmental sustainability. From a theoretical perspective, these findings extend beyond the SDG-oriented interpretation and support the conceptualisation of water management systems as intelligence-driven governance structures. The results demonstrate that the effectiveness of water policies and technologies is determined not only by resource availability or infrastructure development, but by the capacity to generate, interpret, and utilise data as strategic intelligence. This establishes a direct link between empirical observations and the theoretical framework of competitive intelligence, where information flows, analytical capabilities, and institutional decision-making form an integrated system. Consequently, water governance can be understood as a dynamic process of continuous intelligence generation and adaptation, rather than a static implementation of sustainability goals. An integrated approach to water management, which considers the interconnections with other SDGs, can become the basis for developing effective policies and innovative solutions at the global level.

5 FINAL CONSIDERATIONS

This study contributes to the field of competitive intelligence by conceptualising water management systems as intelligence-driven governance structures in which data, analytical processes, and decision-making mechanisms are systematically integrated. Unlike traditional approaches that focus primarily on technological efficiency, this research demonstrates that the effectiveness of innovative water solutions depends on their capacity to function within data–intelligence–decision frameworks that support strategic and adaptive governance.

The findings indicate that digital technologies such as artificial intelligence, the Internet of Things (IoT), and monitoring systems should be interpreted not only as operational tools but as core components of decision intelligence systems. Their value lies in enabling continuous data collection, analytical processing, and the generation of actionable insights, which directly influence resource allocation, infrastructure planning, and policy design. In this context, water management evolves into an intelligence-driven system characterised by feedback loops, predictive capabilities, and institutional adaptability.

From a theoretical perspective, the study advances the integration of competitive intelligence and decision intelligence into the domain of sustainable water governance. It proposes a shift from descriptive and technology-oriented models toward a systemic analytical framework that links technological innovation with information processing and strategic decision-making. This contributes to a more comprehensive understanding of how sustainability objectives, including SDG 6, can be achieved through intelligence-based governance rather than isolated technical interventions.

From a practical standpoint, the results suggest that policymakers and institutions should prioritise not only the implementation of innovative technologies but also the development of analytical capacities and data integration mechanisms. Effective water governance requires the establishment of intelligence infrastructures that enable real-time monitoring, predictive analysis, and evidence-based decision-making. Without such capabilities, the potential of technological innovations remains limited.

The study has several limitations. It is based on secondary data and literature sources, which may not fully capture the variability of local implementation contexts. Additionally, the effectiveness of intelligence-driven approaches may differ depending on institutional capacity, economic conditions, and technological infrastructure. Future research should focus on empirical validation of intelligence-based water management models, including case studies and quantitative assessments of decision-making effectiveness.

Overall, this research highlights that the transition toward sustainable water management is not solely a technological challenge but an intelligence challenge. Integrating competitive intelligence into water governance systems provides a foundation for more adaptive, resilient, and strategically informed management of water resources.

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