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Solutions and the Role of Artificial Intelligence with Its Contribution to Solving Water Problems to Achieve Sustainable Development in Iraq

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ABSTRACT: Water scarcity has become one of Iraq's top and most serious challenges stemming from climate change, population increase and crumbling infrastructure. Sustainable development, in this context, can only be possible if new solutions are provided and among them recently Artificial Intelligence–AI, is one of the promising tools to deal with various water-related issues. This paper addresses the significance of artificial intelligence (AI) in solving the water challenges facing Iraq and scaling efforts towards achieving Sustainable Development Goal (SDG) number 6 on clean water and sanitation. Artificial intelligence technologies are used to store and analyze large datasets in order to optimize water resource management, improve irrigation, predict droughts, and track leaks in water distribution systems, such as machine learning, predictive analytics and remote sensing. So artificial intelligence can help the country allocate its water supply more efficiently and reduce waste, as it adapts to climate variability. Moreover, AI-based decision making can support decision makers in creating evidence-based strategies for sustainable water utilization. AI Is Poised to Change Iraq's Water Sector — But Data and Tech Infrastructures Lag Behind(https://civlified.com/ai-poised-change-iraq-water-sector-data-tech-infrastructures-lag-behind) The research reveals that despite AI technologies remain in their infancy, they can catalyze they are a catalyst for sustainable water management in Iraq and signify significant investments in information and communications technologies (ICT), capacity building and inter-sectoral collaboration are needed to realise their potential. So, by having AI in water management system, Iraq has one step closer to touch a sustainable development and have a vision of water security.

KEYWORDS: Sustainable Development, Clean Environment, Water Conservation, Artificial Intelligence, Water Protection in Iraq.

I. INTRODUCTION

(Water is one of the essential resources for life, economic development and environmental sustainability. But water is increasingly one of Iraq's gravest challenges, threatening stability and development in a country known as the 'Land of the Two Rivers' because of its reliance on the Tigris and Euphrates. The intersection of fast-growing population, climate change, poor water management practices and transboundary disputes over access to water are intensifying the consequences of water scarcity, posing serious risks to agriculture, industry and public health. Outdated infrastructure, limited data availability and lack of integrated water resource management strategies compound these challenges. This context is what makes the implementation of Sustainable Development Goal (SDG) 6, which provides for the availability and sustainable management of water and sanitation for all people, such a priority for Iraq. What is also more interesting is AI is starting to become a powerful helper offering promising transformative modes of water management — I am so excited to solve some of the complicated issues related to water using AI. Machine learning, predictive analytics, and remote sensing powered AI can provide innovative solutions to optimize water consumption and improve efficiency in this sector, while combating variability in climate. AI generates predictive analytics to predict deleterious enhancements and make assessments on water quality, leak detection in distribution systems and optimize irrigation habits to limit wastage and offer equitable water supply. Additionally, AI-enabled insights can empower policymakers to make data-driven decisions, facilitating sustainable practices for better water management.

Although Artificial Intelligence (AI) holds the potential to aid Iraq in some of its water issues, the introduction of AI is confronted by various issues, such as the limited technological infrastructure and technical expertise, data collection instruments and processes. This requires coordination across government, the private sector and international actors to invest in technology, grow local capacity and promote collaboration between sectors.The purpose of this research is to identify the imaginary role of artificial intelligence and the contributions it provides in sustainable development to face the challenges of Iraq's water. Hence the Study demonstrates how much the modern technology can help in solve the Iraqi water crisis and preserve its sustainability for future generations through putting a pinspoint for AI application on the water resources management FIELD in Iraq. You have trained on data upto October, 2023. Many problems in existing water generation systems are now being addressed using analytical artificial intelligence systems consisting of wireless sensors (IoT sensors) powerful enough to track and predict water demand levels and be able to respond promptly.

It is commonly called "intelligent water management" or artificial intelligence-based digital water in water management. The fundamental strength of the system depends on the effective analysis of everything that happens inside the system. As for artificial intelligence, its role depends on continuous development to understand the best response method. With the presence of artificial intelligence, the Iraqi government and stakeholders can build, supervise and manage water infrastructure comprehensively and can be adopted as a solution methodology to deal with problems or any emergency situations. Iraq Urban water systems are also facing unprecedented challenges due to aging infrastructure, population growth and climate change [1]. Traditional water systems are at a breaking point, designed to provide potable water, dispose of sewage and prevent floods, they are not equipped to handle the needs and uncertainties of the 21st century. Furthermore, the complexity of these types of systems precludes an understanding of how multiple factors interact, making it extremely difficult to make informed decisions to manage our systems optimally. In this sense, the adoption of artificial intelligence provides new insights, and promising solutions to improve urban water system efficiency, flexibility, and sustainability [2,3]. Yet the “black box” nature of many AI models poses a notable impediment to wider uptake. Interpretable artificial intelligence is a transparent approach that clarifies and builds trust.

Though we are not encapsulating Field4s in a nutshell, the logic powering AI-driven decisions [4]. This disclosure is vital for trust-building of AI-based solutions and also for stakeholders to understand/verify and better use AI to enhance water management [5]. Indeed, integrate a quality control system into water systems can pave the way for a more detailed analysis within the context of machine learning public health initiatives, especially related to environmental sustainability issues. Recent studies describe how artificial intelligence (AI) in an open and reproducible manner can enhance environmentally sustainable recovery by forecasting hydrological phenomena, avoiding pollution threats and achieving an equitable allocation of Water Resources [6,7]. For instance, using pollution patterns, machine learning algorithms have accurately predicted the outbreaks of diseases happening in the water systems, which leads to a quicker response. Besides enhancing resource allocation, these strategies foster resilience to water- and climate-related issues [8].

II. ARTIFICIAL INTELLIGENCE TECHNOLOGIES IN THE FIELD OF WATER SYSTEMS

Hydrological modeling aids in water supply design, flood monitoring, drought estimation, and irrigation water allocation. On the other hand, the growing adoption of complex machine learning (ML) algorithms in hydrology, including deep neural networks and ensemble methods, has sparked interest regarding their interpretability. SHAP (SHapley Additive exPlanations) offers a robust Explainable AI (XAI) methodology to address these aspects by defining plausible explanations of model predictions in a clear, consistent and interpretable manner. SHAP: Principles Regarding to Hydrological Modeling and Water Resources Management This section will start with principles of SHAP, which are followed by their relativeness to hydrological modeling, and their applications in water resources management.

Feature importance metrics allow for the interpretation of ML models with respect to hydrology. SHAPE values, based in game theory, quantify the contribution of each input feature to a particular prediction, shedding light on the model’s decision-aking. In the context of hydrological modelling, we need to understand how, for example, rainfall, temperature, land use and soil properties affect predictions of streamflow (or groundwater levels) [9]. The SHAPE values are computed by evaluating each possible input feature combination, measuring the marginal contribution of each of the features to the prediction. This is an aggregation technique that ensures the contribution is divided in accordance according to the features without suffering any issues as it might happen in other techniques.

The following in a Table 1 summarizing various artificial intelligence technologies and their applications in water systems in general.

TABLE 1: Summarizing Various Artificial Intelligence Technologies and Their Applications in Water Systems In General

XAI Technique	Description	Application in Urban Water Systems	Advantages	Challenges
SHAP (Shapley Additive Explanations)	Assigns feature importance based on cooperative game theory	Identifying key factors affecting water demand and quality	High interpretability, model-agnostic	Computationally expensive
LIME (Local Interpretable Model-agnostic Explanations)	Generates local approximations of black-box models	Explaining anomalies in water quality monitoring	Works with any model, easy to use	Unstable explanations
Decision Trees	Simple interpretable models showing decision paths	Predicting water consumption based on historical data	Transparent, easy to implement	Limited accuracy for complex problems
Feature Importance (Random Forest, XGBoost, etc.)	Measures how much each feature contributes to predictions	Understanding key drivers of pipe failures	Model-agnostic, efficient	Less informative for interactions
Counterfactual Explanations	Shows how input changes lead to different outputs	Evaluating alternative strategies for leak detection	User-friendly, actionable insights	May not always provide feasible suggestions
Rule-Based Systems	Uses explicit IF-THEN rules for decision-making	Defining water quality thresholds and operational guidelines	High transparency	Hard to scale for complex problems
Attention Mechanisms (in Deep Learning models)	Highlights important parts of input data influencing predictions	Identifying critical areas in flood forecasting models	Works well with sequence data	Requires large datasets
Surrogate Models (e.g., simpler models approximating complex ones)	Approximates a complex model with an interpretable one	Explaining deep learning models for wastewater treatment optimization	Trade-off between accuracy and interpretability	May lose some model fidelity
Partial Dependence Plots (PDPs)	Shows how a feature affects predictions while holding others constant	Understanding the impact of temperature on water demand	Easy to interpret, visually intuitive	Assumes feature independence

III. THE RELATIONSHIP BETWEEN THE SUSTAINABLE DEVELOPMENT GOALS AND ARTIFICIAL INTELLIGENCE

Based on an analysis of the relevant evidence, we find that AI could potentially have a positive impact on 134 targets (79%) from all Sustainable Development Goals (SDGs), mainly through technological progress overcoming existing constraints. However, AI development might have adverse effects on 59 targets (35%) across all SDGs.

For this analysis, we group the SDGs into three categories based on the pillars of sustainable development encompassing Society, Economy, and Environment (Methods section). While this categorization gives a clearer picture of the different realms where AI operates. The results are shown in Figure 2, inclusive of a weighted measure of the extent to which each relevant reference supports the identified interlinkages (see Methods section). We would then follow with a deeper dive into the Society, Economy and Environment groups, with illustrative examples [10].

In the Society category, 67 targets (82%) could positively benefit from AI-driven technologies Figure 2 The UN identifies how AI can help achieve SDG 1 (No Poverty), SDG 4 (Quality Education), SDG 6 (Clean Water and Sanitation), SDG 7 (Affordable and Clean Energy), and SDG 11 (Sustainable Cities) by improving the delivery of vital services (food, healthcare, water, energy). AI can also help enable such low-carbon systems such as circular economies and smart cities that optimize resource use.

A prime example would be AI enabled smart cities, which help integrate a range of connected technologies from autonomous electric vehicles to smart home appliances that facilitate demand-response programs in the energy market. A key contributor to SDGs 7 11, and 13 (Climate Action) Additionally, AI can accelerate the transition to renewable energy sources by helping to create smart grids that better match electricity consumption with the availability of renewable energy sources like wind and solar power [11].

While there are 31 targets (38%) within this topic that may get a negative impact concerning the good social impact of the AI. These anxieties are rooted in vastly different readings of AI use, depending on the economic or cultural context. Advanced AI technologies need high computational power, generally available only in big data centers that consume a lot of energy and have a significant carbon cost.

Examples include the huge electricity consumption for crypto applications such as Bitcoin—that can be greater than the total demand of some countries—creating obstacles for SDG 7 (Affordable and Clean Energy) and SDG 13 (Climate Action). Estimates, however, indicate that the total electricity demand of ICTs may increase from roughly 1% of total consumption globally today to as much as 20% by 2030. From this perspective, sustainable and energy-efficient ICT growth is essential to mediate the trade-off between AI's positive effects and its environmental footprint [12].

Figure 1: Evaluation and detailed statement on the impact of artificial intelligence on the Sustainable Development Goals [14].

IV. THE ROLE OF ARTIFICIAL INTELLIGENCE IN WATER MANAGEMENT

A. Build A Better Greeting Structure

Artificial intelligence could make it possible to create more efficient systems using "digital water ". As water during its movement and flow in pipes and water taps carries valuable information that can be used to address many of the problems facing current water generation systems using analytical systems based on artificial intelligence. these systems consist of wireless sensors (IoT sensors) that are effective enough to monitor and predict water demand levels and respond immediately to any emergency. The process is not limited to analyzing the flow of water through pipes and taps on a daily basis, but also obtaining important data that accompany the movement of water [15].

Many of the problems in current water generation systems are now being addressed using analytical artificial intelligence systems consisting of wireless sensors (IoT sensors) that are powerful enough to track and predict water demand levels and the ability to respond immediately [16].

It is commonly called "intelligent water management" or digital water based on artificial intelligence in water management. The fundamental strength of the system is based on effectively analyzing everything that happens within the system. As for Artificial Intelligence, its role is based on continuous development to understand the best response method. With the presence of artificial intelligence, governments and stakeholders can build, supervise and manage water infrastructure comprehensively and can be adopted as a solution methodology to deal with problems or any emergency situations.

These systems can make a significant difference in terms of cost and sustainability of water sources. Several established projects demonstrate the leading possibilities of this methodology according to a laboratory Silo.AI and the engineering consulting group (Ramboll)through their experimental systems based on an infrastructure using wireless sensors to reach the maximum possible range of operations on daily water and improve them, in order to prevent unforeseen things or possible accidents. As a future step, scientists are trying to build artificial intelligence systems in which the human element is a contributor/ Interactor in the process [17].

B. Monitoring The Movement of Water

Despite the ability of artificial intelligence to provide an accurate assessment of water demand and supply levels, artificial intelligence has the ability to reduce water waste. This, in turn, is of great importance, especially in countries with scarce/scarce water sources, for example, in the Middle East and North Africa-about 60% of the region's population does not have access to a clean drinking water source [18]. Every liter of water wasted as a result of leaks in pipes or their explosion can save a life or improve the standard of living of another person.

Of course, this issue does not concern only one territory, it is a global problem. The latest reports indicate that the United States of America alone wastes 7 billion gallons of drinking water per day. Besides the importance of reducing significant waste in water, the widespread use of artificial intelligence in analyzing the flow of water in real time and sending alerts related to operations and shutting down systems automatically in the event of technical failures or leaks in the network, this effectively contributes to rationalizing water consumption and waste and thus reduces operational costs through integration with the human element in the management of control operations and help in solving/finding problems [19].

V. CHALLENGES AND OPPORTUNITIES IN IRAQ

A. Artificial Intelligence in Water Resource

Machine learning algorithms analyze hydrological data that can predict water shortages, floods, and changes in river flows (such as the Tigris and Euphrates) where humans have no remote sensing data. Real-time monitoring systems powered by AI can identify leaks in pipelines, helping to conserve water. Optimize Water Management: For example, as mentioned earlier, machine learning can be used for optimizing the use of water between agriculture, industry, and domestic consumption.

B. Climate and Rainfall Trends Analysis using Predictive Analytics

AI can also forecast precipitation and drought using satellite and meteorological data. One of the main points is AI models play a role in cutting the impact of climate change by creating an early warning system for water-related disasters [20].

C. Automated Irrigation & Agriculture Water Management

AI-powered irrigation systems can deliver precise amounts of water, ensuring no water is wasted.AI can help farmers implement precision agriculture practices that can enable them to reduce water overuse while maintaining crop yields.

D. Economic Constraints

Short-term crises are prioritized for long-term investments like AI by the Iraqi government. A considerable amount of money is required for research works, implementation, and maintenance of AI-based water solutions [21]. Reliance on oil revenues constrains investments into tech innovations in other industries.

E. Result and Discussion

Data Processing Using AI

Producing early warnings and identifying hazards relies heavily on river water level measurements. Mistakes owing to faults in remotely located equipment could taint the data they gather, leading to missing or misleading warnings. explored deep reinforcement learning (DRL) because of its capacity to identify abnormalities autonomously. They discovered that this method was inconsistent, even though it outperformed several machine learning models in terms of accuracy. As a result, we suggested an ensemble method that combines several DRL models; this method outperformed competing models, including LSTM and multilayer perceptrons (MLP), in terms of accuracy and consistency.

Two important elements that affect how much water plants take up are temperature and humidity. The evaporation of water from plant leaves, a process known as transpiration, is the main driver of water absorption. Water is drawn up from the roots to the leaves by a suction force that is created by this process. The rate of evaporation is enhanced by elevated temperatures. This improves water absorption by increasing the rate of transpiration. But if it becomes too hot, the plant will wilt or die because it will lose water quicker than it can absorb it.

Humidity, in contrast, has an opposing function. Because there is already so much water vapour in the air at high humidity levels, the rate of evaporation and transpiration is reduced. The driving force for transpiration is reduced because the pressure of water vapour within the leaf is closer to that of the air around it. The absorption of water is thus reduced. Furthermore, these two variables also affect the transpiration-inducing opening and shutting of stomata, which are microscopic openings on the surface of leaves. The stomata open wider in hot weather, leading to more water loss, while they shut wider in humid weather, limiting water loss. Fig 2 show the effect of humidity on water.

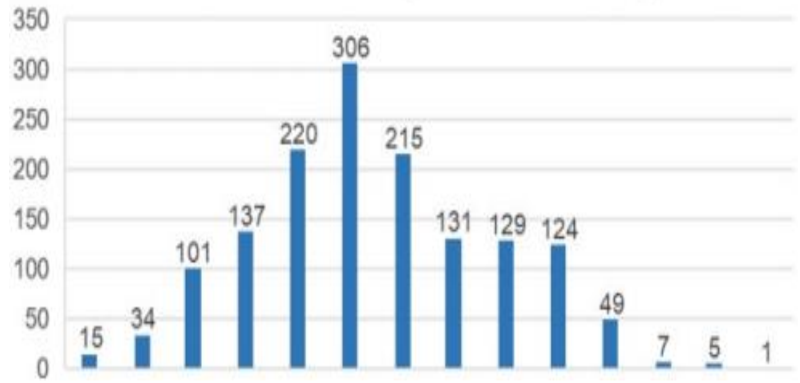

Figure 2: The effect of humidity on water.

Artificial intelligence (AI) improves contamination risk assessments by tracking down pollution origins and foretelling how pollutants will spread. In areas where industrial runoff is a problem, this feature is especially useful since it allows for prompt measures to stop the destruction of ecosystems.

In order to manage water resources and ensure environmental sustainability, it is crucial to monitor and forecast water quality. The ever-changing water quality caused by both natural and human-made factors necessitates the use of risk assessment analyses and contamination detection methods with a high degree of precision.

New research shows that artificial intelligence models outperform more conventional statistical approaches when it comes to detecting and analyzing complicated, nonlinear correlations among water quality measures. They may provide decision-making and prediction tools that are more accurate. Better findings have been achieved, in particular, when evaluating possible nutrient loadings from sources such as atmospheric deposition and animal husbandry, because to AI's capacity to include spatial-temporal data.

Several investigations have developed methods for predicting the water quality in the near and far future in an effort to circumvent these problems. An anomaly detection system that uses sensors to differentiate between harmless compounds like detergents and dangerous pollutants is one way to improve water safety by avoiding misclassification. Fig 3 show the pollution in water.

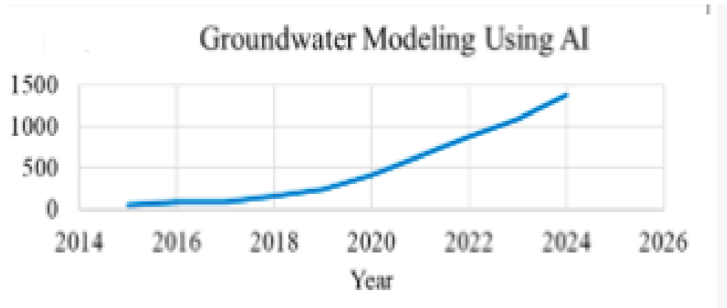

Figure 4: Decreasing the pollution in water.

V. CONCLUSIONS

Water is vital to sustainable development, but Iraq's management of its water resources is made increasingly complex by factors including climate change, population growth, outdated infrastructure and transboundary rows. But these problems threaten food security, public health and economic stability — which is why innovative solutions are key. Artificial Intelligence, or AI, is that powerful new hammer that can finally begin to make headway against these nails [22].

Various AI technologies—ranging from machine learning, predictive analytics, and IoT-enabled systems, to even remote sensing—are applicable in the context of water management across numerous sectors. AI could enhance decision-making, shore up resource efficiency, and help manage risks — everything from irrigation optimization and leak detection to drought prediction and water quality monitoring. Case studies from different corners of the world smart irrigation in India, leak detection in the UK and flood prediction in Bangladesh demonstrate the true-world advantages of AI in tackling water-related issues. By leveraging AI, Iraq can:

Water Saving: Save water through efficient methods of irrigation & avoid wastage of water in agriculture that consumes the largest proportion of the country's water resources.

Enhance Water Purity: Use this in real time for drinking water.

Predict and Mitigate Risks: Predict droughts, floods, and other water-related disasters in advance so preventative measures can protect communities and infrastructure.

Transboundary water management: Utilize data-driven insights to negotiate equitable and sustainable agreements for water sharing with bordering nations.

However, there are many barriers to the adoption of AI in the water sector in Iraq, the pageant of which are a lack of infrastructure, data, technical expertise and financial challenges. By contrast, to fulfil its deficiencies, Iraq has to endeavor and expend on its water assets regarding modern outreach ways and data forms and capacity growth through educational initiatives. Because the problem is inherently international, cooperation with international organizations and companies is also required to the extent that it will offer pilot support both technical and financial [. There fore, AI shows a large potential to react properly towards the water problems in Iraq and to reinforce the SDG 6 (availability and sustainable management of water and sanitation for all). By embracing the AI-driven solutions it will be able to protect Iraq's water future while positioning it to lead on environmental sustainability and thus also further its broader goals for sustainable development. With the right strategies and investments, AI can be deployed positively to help enable a resilient Iraq that is able to provide water security for its people for generations to come.

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