



Water Scarcity Management through Centralized Knowledge-Sharing Platform

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To Cite this Article

Gonuguntla Sowmya, Kallam Anusha, Kagita Sasikanth, Cherukuri Purandeswararao & K. Sujatha (2026). Water Scarcity Management through Centralized Knowledge-Sharing Platform. International Journal for Modern Trends in Science and Technology, 12(SI01), 837-842. <https://doi.org/10.5281/zenodo.19613155>

Article Info

Received: 12 March 2026; Revised: 07 April 2026; Accepted: 10 April 2026.

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KEYWORDS

IoT-Based Water Management, Real-Time Monitoring, machine learning, Smart Water Distribution System

ABSTRACT

Water management remains a major challenge for countries and communities worldwide. Issues such as water scarcity and wastage are largely caused by inefficient distribution systems, excessive consumption, and poor maintenance of water supply infrastructure. To address these problems, Internet of Things (IoT)-based water management solutions offer an effective way to monitor, control, and optimize water usage. This study proposes an embedded IoT-driven water management system designed for real-time monitoring and control of water supply networks. The system consists of multiple distributed nodes installed across the network, each integrated with sensors and actuators to measure parameters such as water level, quality, pressure, conductivity, and flow rate, while also enabling control of pumps and valves. The collected data is transmitted wirelessly to a cloud server, where it is processed and analyzed to generate actionable insights for efficient network management. Additionally, the cloud platform is configured to send SMS alerts whenever any monitored parameter exceeds predefined threshold values.

I. INTRODUCTION

Water is the most essential resource to produce agricultural and industrial goods and services. It is while only 2.7% of the world's water is available as fresh water, and only 30% of freshwater can be consumed for meeting human needs. In line with these facts, arid and semi-arid countries are not well-endowed with freshwater, and water shortage is a major limitation for their socio-economic development. Also, rapid population growth, economic development,

urbanization, industrialization, and land use change have exerted extra pressure on their freshwater resources. Meantime, the frequent and intensive droughts, which are predominantly driven by climate change dynamics, have significantly decreased the stock of freshwater resources while the demand for water consumption has increased in many arid and semi-arid regions of the world [1]. Moreover, climate change is expected to decrease freshwater supplies and increase the frequency and intensity of droughts in arid and

semi-arid areas. As a result, water scarcity would turn out to be a great concern soon.

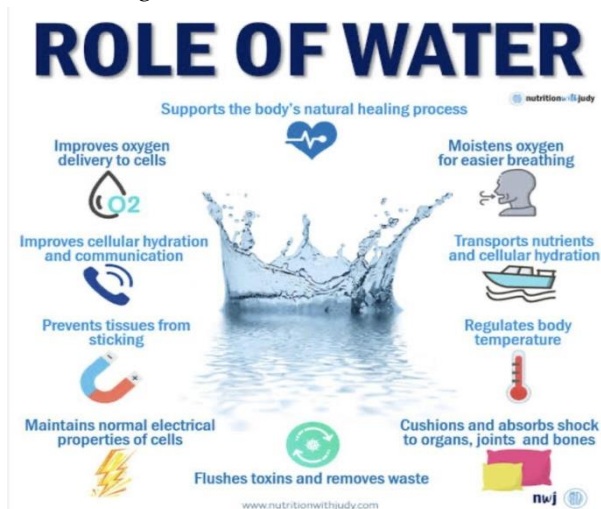


Fig. 1: How water supports human body's healing and function

Particularly, global water scarcity would affect the agricultural sector since agriculture accounts for approximately 90% of water withdrawals in developing countries that their rural economy relies on agriculture heavily. Furthermore, owing to the traditional methods of irrigation and water conveying systems, the efficiency of their irrigation systems is far lower than most developed countries, and a large fraction of scarce water is lost due to evaporation and percolation. Therefore, with the high levels of water stress, affordable use of water resources, improved productivity of farms in a sustainable way, and resilience building are imperative to mitigate the problem of water shortage in the arid and semi-arid regions of developing countries. However, resilience and adaptation are location-specific and depend on various climatic, socio-economic, and agro-ecological factors [2].

Consequently, there is no 'one-size-fits-all' solution that can work efficiently for all developing countries. In this context, there is an emerging recognition about the fact that flexible management of water and agricultural systems requires combined efforts of different scientific disciplines, in addition to active social negotiation of diverse stakeholders. Given the complexities involved, the inclusive and flexible operational models that enable knowledge generation, integration, and sharing are needed to facilitate and support the complex negotiations.

Knowledge co-production plays a vital role in addressing climate change and water scarcity by

bringing together farmers, scientists, and policymakers to share and co-create solutions. It transforms stakeholders from passive recipients into active contributors, improving decision-making and resilience of farm households. Despite its benefits, it is still limited in many developing countries where traditional systems overlook local knowledge. Promoting inclusive and collaborative approaches can enhance sustainable agricultural practices and better adaptation to resource challenges.

2. LITERATURE SURVEY

Dai, et al. [6] proposed the two representative cases: Singapore's Smart Water Grid and selected pilot programs in Chinese cities (Shenzhen, Hangzhou, Beijing). These cases are analyzed for their level of digital integration, policy alignment, and performance outcomes, offering insights into both mature and emerging smart water implementations. Findings indicated that the transition from manual to intelligent governance significantly enhances system performance and robustness, particularly in response to climate-induced disruptions. Despite benefits such as reduced non-revenue water and improved pollution control, challenges including high initial investment, data interoperability issues, and cybersecurity risks remain critical barriers to widespread adoption. Policy recommendations focus on establishing national standards, promoting cross-sectoral data sharing, encouraging public-private partnerships, and investing in workforce development to support the long-term sustainability and scalability of smart water initiatives.

Shemer, et al. [7] proposed the Climate change, global population growth, and rising standards of living have put immense strain on natural resources, resulting in the unsecured availability of water as an existential resource. Access to high-quality drinking water is crucial for daily life, food production, industry, and nature. However, the demand for freshwater resources exceeds the available supply, making it essential to utilize all alternative water resources such as the desalination of brackish water, seawater, and wastewater. Reverse osmosis desalination is a highly efficient method to increase water supplies and make clean, affordable water accessible to millions of people.

3. SYSTEM ARCHITECTURE

The proposed Water Scarcity Management System is a centralized web-based platform designed to enhance

awareness, knowledge sharing, and community participation in sustainable water conservation. The system enables users, experts, and administrators to register and securely log in to access role-based services. Experts can upload water-saving techniques, research documents, and instructional videos, which are stored efficiently in the MySQL database and centralized file storage. Community members can browse, view, and download these resources through an interactive web interface. The platform integrates location-based services to display nearby workshops and water conservation activities. A real-time notification module keeps users informed about new expert tips, drought alerts, and important updates. The system ensures secure data handling, easy content retrieval, and scalable resource management. By digitizing the traditional manual process, the proposed system improves collaboration among stakeholders. It reduces information delay, increases accessibility, and promotes informed decision-making. Ultimately, the platform supports proactive water scarcity management and encourages sustainable water usage practices in the community.

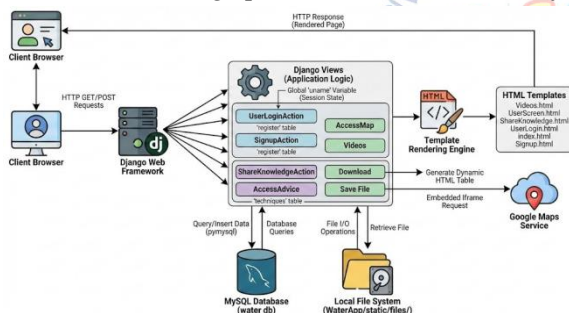


Fig2: System Architecture

4.METHODOLOGY

The proposed Water Scarcity Management through Centralized Knowledge-Sharing Platform integrates IoT-based monitoring with stakeholder-driven knowledge co-production to improve sustainable water resource management. The methodology consists of system design, data acquisition, cloud analytics, stakeholder integration, and decision-support modeling.

i. Data Acquisition

The system deploys distributed IoT nodes across water supply and agricultural networks. Each node consists of embedded controllers, water level sensors, flow meters, pressure sensors, conductivity sensors, and quality sensors. These sensors continuously measure real-time parameters such as water level, flow rate, pressure, and conductivity. The collected data is transmitted wirelessly

via GSM/Wi-Fi modules to a centralized cloud platform. Threshold values are predefined for each parameter to trigger automated SMS alerts when abnormalities occur. Water flow rate is calculated using:

$$Q = A \times v$$

where Q is the discharge (m^3/s), A is the cross-sectional area of the pipe (m^2), and v is the velocity of water flow (m/s). This equation helps determine consumption levels and detect leakages.

ii. Data Processing and Water Scarcity Index

The cloud server stores and processes incoming data using analytics algorithms. To quantify water stress levels, a Water Scarcity Index (WSI) is computed as:

$$WSI = \frac{D}{S}$$

where D represents total water demand and S represents available water supply. A higher WSI indicates severe scarcity, enabling authorities to take corrective actions.

Additionally, water quality is monitored using electrical conductivity (EC), estimated as:

$$EC = \frac{1}{R}$$

where R is the electrical resistance of water. Conductivity values help assess salinity and contamination levels.

iii. Knowledge Co-Production and Decision Support

Beyond technical monitoring, the platform incorporates a centralized knowledge-sharing module where farmers, policymakers, researchers, and local stakeholders can exchange insights. Data visualizations, trend reports, and predictive analytics support collaborative decision-making. Machine learning models analyze historical consumption patterns to forecast shortages and recommend optimized irrigation scheduling.

iv. Alert and Control Mechanism

When monitored parameters exceed predefined thresholds, automated alerts are sent via SMS to administrators and stakeholders. Actuators control pumps and valves to regulate supply in real time, reducing wastage.

This integrated methodology combines IoT sensing, mathematical modeling, cloud analytics, and stakeholder knowledge co-production to enhance resilience, optimize water usage, and mitigate water scarcity effectively.

5. DESIGN AND CONSTRUCTION

The design of the proposed Water Scarcity Management System is based on a centralized knowledge-sharing platform integrated with IoT-enabled monitoring

infrastructure. The system follows a multi-layered architecture consisting of sensing, communication, cloud processing, and application layers. At the sensing layer, distributed embedded nodes are installed at key points within the water supply network and agricultural fields. Each node is equipped with water level sensors, flow meters, pressure sensors, conductivity sensors, and water quality monitoring devices. These sensors continuously collect real-time data related to water availability, usage, and quality. The design ensures low power consumption, scalability, and adaptability to both rural and urban environments.

The construction phase involves assembling microcontrollers (such as Arduino or ESP-based boards), integrating sensors and actuators, and configuring wireless communication modules like GSM or Wi-Fi for data transmission. The collected data is transmitted securely to a centralized cloud server where it is stored and processed. A web-based dashboard is developed to visualize real-time parameters, historical trends, and scarcity indicators. Automated SMS alert systems are configured to notify stakeholders when threshold limits are exceeded. Additionally, control mechanisms are implemented to regulate pumps and valves remotely. The construction ensures reliability, real-time responsiveness, and seamless integration between hardware, cloud analytics, and stakeholder knowledge-sharing modules for efficient water resource management.

6. RESULTS AND DISCUSSION

The proposed centralized water scarcity management system demonstrates significant improvements in efficiency, accessibility, and data reliability compared to traditional approaches. The system enables experts and users to share and access water conservation knowledge through a structured and user-friendly platform. Experimental observations indicate faster data retrieval, smooth file handling, and real-time updates, ensuring that newly added information is immediately available to users. The integration of a centralized MySQL database eliminates redundancy and maintains consistent data across the system.

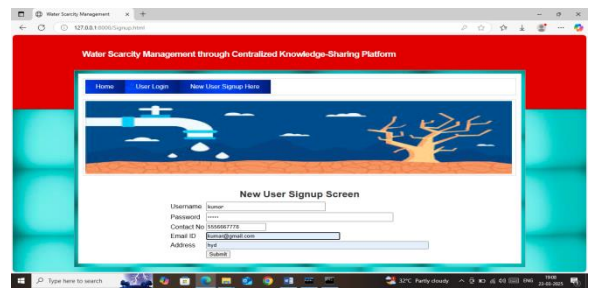


Fig 3: User Registration Module

The system interface begins with Figure 2, where new users can securely sign up by providing necessary details. This ensures that only authenticated users can access and contribute to the platform.

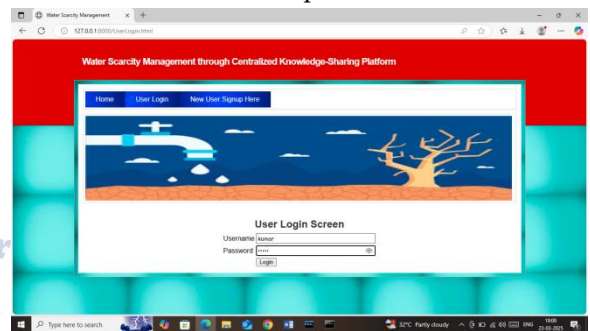


Fig 4: User Login Interface

The secure access mechanism is further illustrated in Figure 4, which allows registered users to log in and utilize system features.

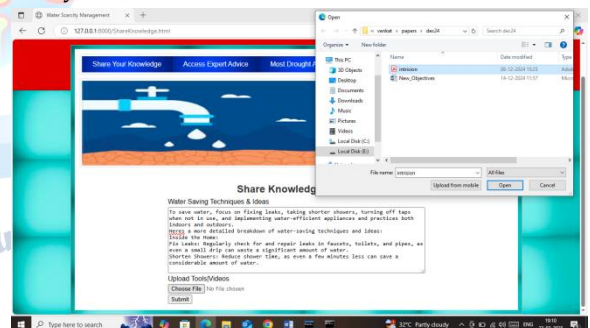


Fig 5: Knowledge Sharing Module

The knowledge-sharing capability is presented in Figure 5, where users can upload water conservation techniques along with supporting files such as documents, images, and videos.

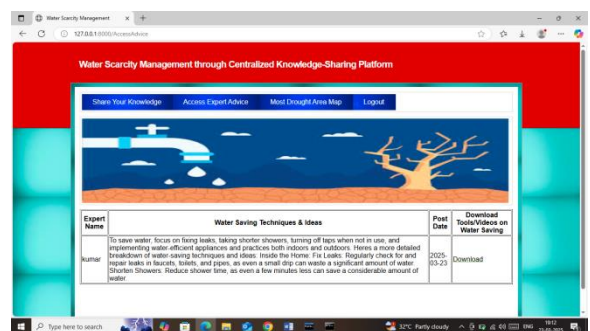


Fig 6: Expert Advice Module

This promotes collaboration and collective learning among users. The expert guidance feature is shown in Figure 6, providing users with reliable recommendations and downloadable resources related to water management practices.

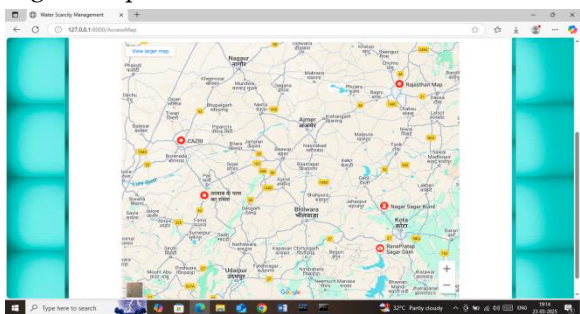


Fig 7: Drought Area Visualization Map

The analytical and visualization component is depicted in Figure 7, which highlights regions affected by water scarcity. This map-based representation helps users and authorities understand the severity of drought conditions and take informed decisions.

7. CONCLUSION

The project successfully demonstrates a robust, web-based system that centralizes expert knowledge and makes it accessible to the broader community. By integrating features such as expert-verified techniques, downloadable resources, and interactive maps of drought-prone areas, the platform effectively bridges the gap between water conservation experts and community users. Performance improvements, such as optimized database queries, secure session management, and efficient file handling, have enhanced the system's responsiveness and scalability, ensuring smooth user experience even as the volume of shared knowledge grows. Moreover, the inclusion of real-time knowledge sharing fosters collaborative learning, empowering users to not only access information but also contribute practical techniques, thereby creating a dynamic ecosystem for sustainable water management.

FUTURE SCOPE

The future scope includes integrating AI-driven recommendations to provide personalized water-saving techniques and using IoT sensors for real-time monitoring of water usage. Expanding to mobile applications with offline access and adding multimedia tutorials can enhance accessibility and engagement. Multi-language support and analytics dashboards can

further improve community participation and track the effectiveness of conservation practices.

Conflict of interest statement

Authors declare that they do not have any conflict of interest.

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