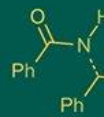


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A review on decision support systems for groundwater management

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Abstract

Groundwater provides freshwater to meet our day-to-day water and irrigation requirements. However, due to rising population, it is being depleted and deteriorating at a rapid rate. In India, the groundwater depletion is highest, therefore to meet the demands of the population its real-time monitoring is essential. Therefore, this study performs a review on decision support system (DSS) for the groundwater management. This study will act as a guide for users, researchers, stakeholders, and the government. The future scope includes incorporating Machine Learning (ML) into mobile water governance and IoT-integrated platforms.

Keywords: Groundwater, decision support system, India, groundwater management

1. Introduction

Groundwater is the invisible fresh water tapped below the Earth surface. Major population depends on it to meet their daily requirement. In India, more than 60% groundwater is being used to fulfill irrigation water requirements (CGWB, 2024) ^[5]. However, its management is perceived as challenging because of manual data collection, inadequate monitoring infrastructure, poor information accessibility, a lack of technological concern, and ineffective communication. Moreover due to absence of real-time spatial data, it becomes difficult to track its contamination levels and determine the critical areas.

The decision support system (DSS) provides solution to the above mentioned problems by integrating cutting-edge technologies, real-time monitoring, remote monitoring options, data security and its cost effectiveness in managing groundwater resources. It is used to visualise the severely affected groundwater quality zones and areas with reducing the groundwater level due to continuous mining. Further, these information can be used to suggest the crops tolerant to the water quality and groundwater recharge methods for sustainable resource management amid rising demand, climate change, and environmental concerns. The rationale behind this technology is to process vast amounts of data, analyse complex hydrogeological information and generate insightful output to manage and protect the invaluable groundwater resource for future generations. Many researchers (Khan *et al.*, 2021; Ortega, 2023) ^[9, 11] performed studies based on the decision support system for groundwater management.

Similar studies were carried out by Mamede *et al.*, (2023) ^[10] to develop a prototype for an Intelligent Water Management System for Household Use. They found that individual awareness and strategies to manage and reduce water usage were effective tool in managing water resources. Another study by Boberg *et al.*, (2023) ^[4] analysed a digital platform, ASMITAS, to collect and transfer hydrogeological data to the GeoGIS 2020 system for analysis for sustainable groundwater management in Daudkandi, Bangladesh. They concluded that by using a digital platform for data collection, management, and postprocessing can improve decision-making for arsenic mitigation at the national and local levels, leading to more sustainable groundwater management.

The DSS is valuable in maintaining the transparency of information at both local and national levels, leading to increased accountability of resources. The widespread availability of Android smartphones provides a ubiquitous framework for decentralised water governance. Android-based DSS enables farmers and policymakers to visualize water levels, forecast water availability, which helps in optimizing crop patterns on-site. Therefore, this study aims to perform review on the existing study related to decision support system.

It can effectively to assist researchers, farmers, and stakeholders in making well-informed decisions regarding groundwater resources.

2. Material and Methods

This section includes a detailed literature review on the decision support system.

2.1 Decision Support System (DSS) for Groundwater Management

Pierce *et al.*, (2016) ^[13] evaluated the DSS application by incorporating groundwater modules to inform researchers and practitioners about designing, developing, and deploying DSS for use in groundwater management. They detected that the groundwater decision support system can provide alternative means for water resource management from the adaptive management of water resources. Further, they observed that the groundwater allocation and management strategies were not efficient and lead to over-abstraction. To tackle these issues, the DSS was used to evaluate complex data sets, which consist of hydrogeologic, economic, legal, and environmental elements for the calculation of available yield of aquifers, estimate risk, and improve groundwater management policies.

Aliyari *et al.*, (2018) ^[2] developed a software DSS-SMGW-01 for sustainable groundwater management. Their software was effective in controlling groundwater exploitation in managing subunits, combined with water resource management and consumption. They used seven indices, such as GDR, DG, GV, GAD, NBPD, LP, and EMP, to estimate their influence on the aquifer and socio-economic conditions. Moreover, they compared the results obtained by the DSS with the indices. They concluded that their system can be able to function in other areas by changing the database.

Gallardo *et al.*, (2020) ^[6] used models and decision support systems in Europe to provide irrigation to vegetable crops for their nutrient management. They considered the effects of climate change and growing social pressure to reduce nutrient contamination of water bodies. Their findings shows that, DSS is important tool to optimize irrigation and nutrient management.

Patil *et al.*, (2020) ^[12] developed a Smartphone and IoT-based system for integrated farm monitoring. They focused on an integrated farm monitoring system using Smartphone applications and the Internet of Things. They mentioned that farmers can remotely monitor the soil moisture, leaf wetness duration, pH level, temperature, and humidity in the environment using their system. They observed that the system quickly analyses the weather and soil conditions in a particular area where the plant is present and gives new insights to manipulate the decision-making. Their approach was deployed and tested in the fields of Islampur, Maharashtra. They proposed a cost-effective and productive system for farmers.

Kabuya *et al.*, (2021) ^[7] presented initial findings from a current groundwater monitoring app experiment. They found that numerous groundwater databases, as well as sparse or unreliable groundwater information and monitoring systems, exist. They observed that the main challenge was Groundwater monitoring for the water administrative authorities in Southern Africa, especially in the Congo. This has made it difficult to make decisions and conserve groundwater, especially since there are no

restrictions on the number of boreholes that permit holders can dig and report to water authorities. According to the preliminary findings, they found that there was no precise monitoring mechanism for the Regideso catchment, which caused the abstraction rate to fluctuate. They observed that research work was necessary to develop an application or an MS Excel monitoring spreadsheet that uses the factor scores and rankings. They created an analysis application for groundwater sustainability in Regideso for the groundwater level monitoring and assessment to regularly modify the sustainability yield of the Regideso catchment.

To improve agriculture and farming livelihoods, (Khan *et al.*, 2021) ^[9] integrated web-and mobile-based applications for groundwater management. However, since groundwater managers, farmers, and researchers do not directly address the need for immediate on-the-ground decision-making, there is a need for an intuitive platform that combines socioeconomic, physical, and science-based groundwater information with other data and processes. They developed computational systems like Web-based DSS that use data and models interactively to aid in the formulation, analysis, and selection of management strategies.

Arshad *et al.*, (2022) ^[3] implemented an intelligent agriculture decision support system based on LoRaWAN for maximum crop yield. To optimize output and achieve sustainability, their work suggests a clever Decision Support System (DSS) that reduces water seepage waste in agribusiness and improves per-hectare production through realtime monitoring. Their system uses networking-based DSS, cloud-based decision support layers, and integrated sensors to suggest precautions for the highest possible sustainable yield.

Akbar *et al.*, (2022) ^[1] employed Geographic Information System (GIS)-Principal Component Analysis (PCA) modeling for groundwater and related health hazards in Abbottabad, Pakistan. They observed that the city of Abbottabad was located along the China-Pakistan Economic Corridor route and has experienced anthropogenic developmental activities in the past three decades and cross-border migration from Afghanistan. As a result, water quality degradation and groundwater contamination occurred, and water was not fit for drinking purposes in the Khyber Pakhtunkhwa (KPK) province, Pakistan. So, they performed research on groundwater quality, modeling the groundwater data using PCA and geospatial modeling for health risk and exceedance parameters. The sampling locations of study areas were acquired using the geographic coordinates of the Global Positioning System (GPS) Essentials application. The Android-based GPS application, commonly known as GPS Essentials, was frequently used to gather geographic coordinates. They conducted laboratory analyses for the groundwater quality parameters after the sampling process. They found that the communities living in the study area were exposed to harmful carcinogenic metals like As and Pb, and the people were prone to health risks after consumption of unfit water.

Kabuya *et al.*, (2022) ^[8] studied apps for intelligent groundwater monitoring and evaluations in Kimbanseke of the Regideso Catchment. Numerous groundwater databases and sparse or unreliable groundwater information and monitoring systems exist. The mandatory critical data that is needed for an efficient water use monitoring system needs to be submitted by water clients. Decision-making and groundwater conservation have become difficult due to this

and the need to restrict the number of boreholes dug by permit holders to the water authorities. It is necessary to consider an application for groundwater level monitoring and assessment to modify the sustainable yield for the Kimbanseke catchment regularly.

Ortega (2023) ^[11] used a Digital Twin for Ground Water Table Monitoring. The Digital Twin served as a platform for researchers and stakeholders to investigate various scenarios and evaluate the effects of changing different parameters, acting as a decision support system. This platform made planning and decision-making based on well-informed simulation results possible. The suggested approach uses digital twin technologies, real-time sensor data, interactive visualization, and machine learning techniques to bridge the gap between GWT monitoring and decision-making. The research will support the creation of an efficient groundwater management and control system and enable sustainable urban water management techniques.

3. Conclusion

The Decision Support System proves to be an effective tool in the assessment and visualization of data in real time. The DSS provides platform to manage the water resources efficiently. It helps in managing the areas which are exploited due to over-abstraction of groundwater. In some cases, it was found that DSS can be effective in analysing the weather and soil conditions. Moreover, the digital twin technologies integrate DSS with real-time sensor data for interactive visualization. Furthermore, the cloud-based decision support system integrates sensor data with the web platform to efficiently visualize the data. The Android-based GPS application proves to be helpful in analysing groundwater quality parameters and detect the contamination level in the groundwater samples.

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