

JAL MITRA: A Mobile Application for Real-Time Groundwater Monitoring and Resource Assessment Using DWLR Data

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Abstract - Groundwater constitutes a major component of India's water supply and is extensively used for domestic, agricultural, and industrial purposes. Effective management of this resource requires frequent observations of groundwater-level variations and timely interpretation of monitoring data. Conventional monitoring practices based on periodic measurements may not adequately represent short-term fluctuations caused by pumping, rainfall, and recharge events. This paper presents the design of a mobile-based groundwater monitoring and resource assessment system that utilizes observations obtained from Digital Water Level Recorders (DWLRs). The proposed system is intended to provide a unified interface for accessing groundwater-level observations, examining temporal variations, estimating recharge using the Water Table Fluctuation (WTF) approach, and identifying locations experiencing groundwater stress. The proposed architecture consists of DWLR devices, a communication layer, a cloud-based data repository, an application server, and a mobile client. Data preprocessing procedures such as outlier identification, missing-value treatment, and standardization are incorporated before analytical processing. The application further provides geospatial visualization, time-series analysis, recharge information, alerts, and downloadable reports. The proposed framework demonstrates how frequently collected DWLR observations can be transformed into accessible information for groundwater researchers, planners, and other stakeholders.

Keywords: Groundwater monitoring, DWLR, real-time data, mobile application, recharge estimation, time-series analysis, Water Table Fluctuation, groundwater management.

INTRODUCTION

Groundwater plays an important role in meeting the water requirements of communities and economic activities in India. Its availability, however, varies considerably with geographical conditions, rainfall, aquifer characteristics, extraction practices, and recharge processes. Increasing dependence on groundwater makes continuous assessment important for identifying changes in groundwater storage and regions experiencing sustained decline.

A major limitation of conventional groundwater monitoring is the relatively low temporal frequency of observations. Measurements collected at widely separated intervals can provide useful information about general groundwater conditions, but they may not adequately capture short-duration changes associated with intensive pumping or rainfall-

induced recharge. Consequently, the availability of high-frequency observations provides an opportunity to improve the temporal resolution of groundwater assessment.

Digital Water Level Recorders provide automated groundwater-level measurements at predefined intervals and can transmit observations through telemetry systems. Such measurements can support continuous monitoring when they are appropriately collected, validated, stored, and analysed.

The objective of this work is to develop a mobile application capable of presenting DWLR observations in an accessible form while providing analytical features for groundwater assessment. The proposed system focuses on four major activities: acquisition and preprocessing of DWLR observations, visualization of groundwater-level variations, estimation of recharge-related changes, and generation of information that can support groundwater management decisions.

The proposed application is designed to provide users with station-level information through an interactive geographical interface. Historical observations can also be examined through time-series plots, while analytical modules can be used to identify short-term and long-term variations. The overall objective is to convert continuously generated sensor observations into useful information that can be accessed through a single application.

LITERATURE SURVEY

Recent developments in groundwater monitoring have increasingly focused on the use of continuous observation data, numerical analysis, and machine learning techniques. Velhal et al. [1] presented a framework for processing and analysing Digital Water Level Recorder (DWLR) time-series data, demonstrating the usefulness of continuous groundwater observations for resource assessment and forecasting. Their work highlights the importance of systematic processing of high-frequency water-level measurements before applying analytical or predictive methods.

Groundwater recharge estimation is another important aspect of groundwater resource assessment. Sun et al. [2] investigated improvements to the Water Table Fluctuation (WTF) method, particularly for groundwater systems associated with thick vadose zones. The study demonstrates that groundwater-level fluctuations can provide useful information for estimating recharge when appropriate hydrological parameters and assumptions are considered. Similarly, Sajil Kumar et al. [11] reviewed groundwater recharge and water-balance estimation approaches with particular emphasis on Indian conditions.

Machine learning has also been increasingly applied to groundwater-level prediction. Thakur and Karmakar [3] examined advanced deep-learning approaches for predicting groundwater levels in Raipur, India. Their findings indicate that data-driven models can capture complex temporal relationships within groundwater-level observations. A hybrid deep-learning approach for groundwater forecasting was also investigated in an alluvial-fan

environment, demonstrating the potential of combining different learning strategies for improving prediction performance [4]. Shuai et al. [5] further explored the integration of physical knowledge with machine-learning methods for groundwater-level prediction.

Several review studies have examined the broader application of machine learning to groundwater prediction and monitoring. Hai et al. [6] provided a comprehensive review of machine-learning models used for groundwater-level prediction, identifying the increasing use of data-driven techniques for handling complex groundwater systems. Other systematic reviews have examined groundwater-level forecasting and the current development of machine-learning methodologies [7], [8]. Recent studies have also investigated machine learning specifically for groundwater monitoring and level prediction [9], [10].

Groundwater monitoring in India has benefited from long-term observation networks and systematic collection of groundwater-level data. Dixit et al. [12] discussed the significance of national hydrograph station networks and long-term groundwater-level monitoring in India. Such observation networks provide an important foundation for analysing temporal groundwater behaviour and supporting resource-management decisions.

Recent research has additionally explored the integration of IoT, deep learning, remote sensing, and other digital technologies in groundwater applications. Rammohan et al. [15] proposed an IoT and deep-learning framework for real-time groundwater-quality monitoring and prediction. Rahman et al. [16] discussed emerging applications of artificial intelligence in groundwater science, while other studies have investigated the integration of remote sensing, IoT, and machine learning for monitoring groundwater-related environmental changes [17]. Research on groundwater recharge and managed aquifer recharge has also emphasized the importance of suitable input data and improved modelling approaches [13]. Seasonal groundwater-level prediction using machine-learning models has further demonstrated the potential of data-driven approaches for basin-scale groundwater assessment [14].

Although these studies demonstrate significant progress in groundwater monitoring, recharge estimation, and prediction, there remains a need for an integrated application that combines continuous DWLR observations with preprocessing, temporal analysis, recharge assessment, groundwater-stress identification, geospatial visualization, and user-oriented reporting within a single platform. The proposed mobile application addresses this requirement by providing a unified interface for accessing and interpreting groundwater information generated from DWLR data.

RESEARCH GAP

Existing studies demonstrate the usefulness of DWLR data processing, recharge estimation, and groundwater forecasting. However, these functions are often addressed as

separate analytical tasks. There is a need for an integrated user-oriented platform that combines continuous groundwater observations, preprocessing, visualization, recharge-related analysis, geospatial representation, alerts, and report generation within a single application.

The proposed work addresses this integration requirement by designing a mobile application that acts as an interface between continuously generated DWLR observations and end users. The focus is therefore not only on individual analytical algorithms but also on the complete data-to-information workflow.

PROPOSED METHODOLOGY

The proposed methodology consists of a sequence of stages beginning with the acquisition of groundwater-level observations and ending with visualization and analytical outputs in the mobile application.

A. Data Acquisition

The system receives groundwater-level observations generated by DWLR installations. A DWLR generally measures groundwater-level changes through an electronic sensing mechanism and transmits the observations using an appropriate telemetry or communication system.

The proposed data flow is:

DWLR Sensor → Data Logger/Telemetry → Cloud Database → Application Server →

Mobile Application

The application server acts as an intermediate layer between the stored observations and the mobile client. This separation allows data processing and validation to be performed before information is displayed to users.

B. Data Preprocessing

Sensor-generated data may contain missing observations, abnormal readings, communication-related gaps, or values that are inconsistent with the expected groundwater behaviour. Therefore, preprocessing is required before analytical operations are performed.

The proposed preprocessing stage includes:

1. Identification of missing observations.
2. Detection of abnormal or outlying measurements.
3. Treatment of short data gaps where appropriate.
4. Conversion of measurements into a consistent reference system.
5. Organization of observations according to station and timestamp.
6. Preparation of cleaned time-series data for visualization and analysis.

Time-series-based methods can be investigated for handling missing observations. More advanced models such as Prophet or LSTM may be incorporated when sufficient historical data are available.

C. Groundwater-Level Trend Analysis

The application provides temporal analysis of groundwater-level observations. Short-duration changes can be examined to understand rapid fluctuations, whereas longer observation periods can be used to identify seasonal or annual patterns.

The proposed system supports:

- Daily and weekly groundwater-level variation analysis.
- Seasonal variation analysis.
- Historical trend visualization.
- Identification of sustained increases or decreases.
- Comparison of observations across monitoring stations.

For long-term trend assessment, statistical methods such as the Mann–Kendall test may be incorporated to identify statistically significant monotonic trends.

D. Recharge Estimation

Groundwater recharge can be estimated using the Water Table Fluctuation method when the required aquifer parameters and groundwater-level changes are available.

The recharge component can be expressed as:

$$\Delta R = S_y \times \Delta h$$

where:

- ΔR = estimated recharge,
- S_y = specific yield of the aquifer,
- Δh = change in groundwater-table elevation.

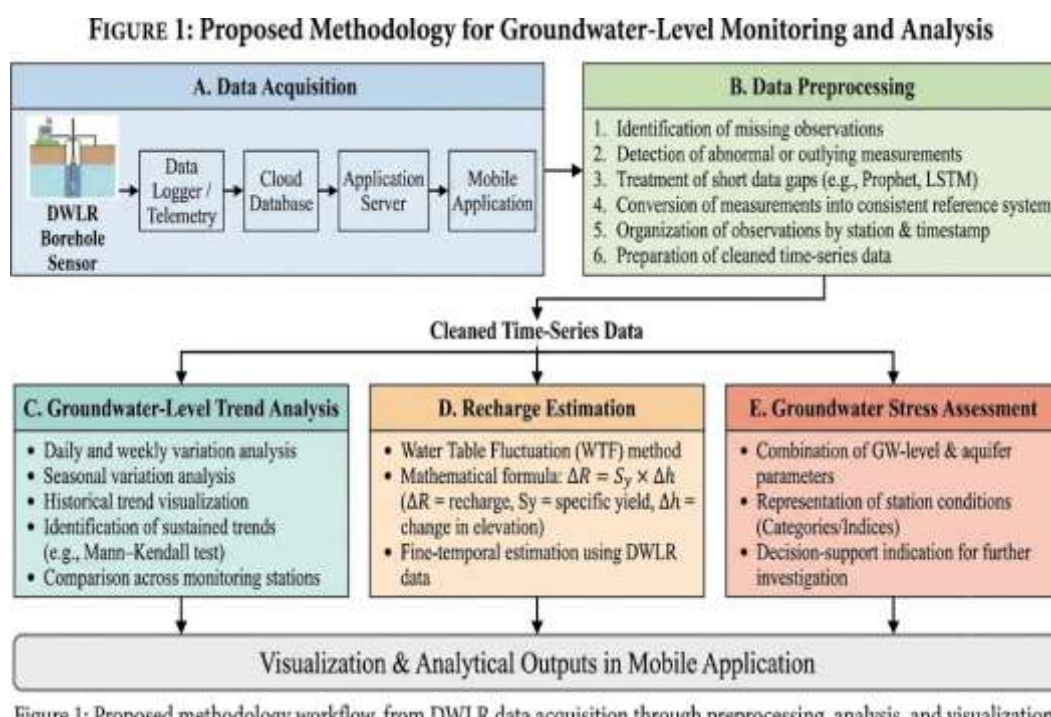
The use of high-frequency DWLR observations provides a finer temporal representation of water-level changes. However, recharge estimates depend on the availability and accuracy of aquifer parameters and on appropriate interpretation of water-level fluctuations. Therefore, the application presents recharge as an analytical estimate rather than treating every observed water-level increase as recharge.

E. Groundwater Stress Assessment

The system can combine groundwater-level information with relevant aquifer parameters to provide an indication of groundwater stress.

Depending on the availability of validated resource data, the application can represent station conditions using categories or indices. These may assist users in identifying locations requiring further investigation.

The stress representation is intended as a decision-support feature and should not replace detailed hydrogeological assessment.



SYSTEM ARCHITECTURE

The proposed architecture consists of five principal layers.

A. Sensing Layer

DWLR devices installed at observation locations continuously collect groundwater-level measurements at predefined intervals.

B. Communication Layer

The measurements are transmitted from the field through available communication technologies such as GSM/GPRS or other supported telemetry mechanisms.

C. Data Storage Layer

Received observations are stored in a centralized database. Time-series organization is particularly suitable because each measurement is associated with a station and timestamp.

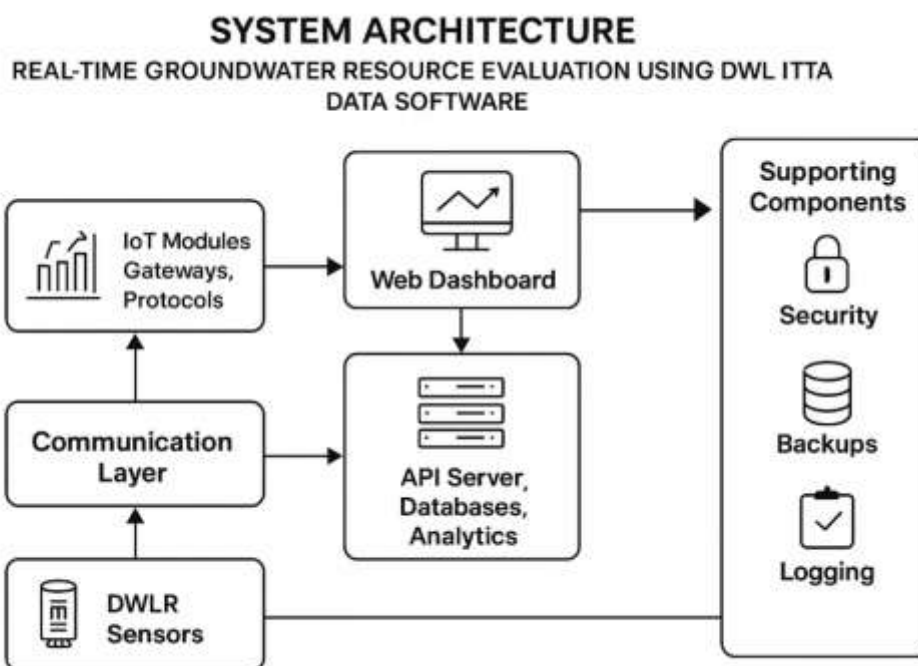
D. Application and Analytics Layer

The application server manages data retrieval, validation, preprocessing, analytical operations, and communication with the mobile client.

E. Presentation Layer

The mobile application presents processed information to users through maps, charts, dashboards, alerts, and downloadable reports.

This layered architecture separates sensor communication, storage, computation, and user interaction, allowing individual components to be modified or expanded without redesigning the complete system.



SYSTEM FEATURES

A. Interactive Geographical Map

The application provides a map-based representation of monitoring stations. Each station can be selected to obtain location-specific groundwater information.

The geographical interface allows users to identify the spatial distribution of monitoring locations and examine groundwater conditions at individual stations.

B. Time-Series Visualization

Historical groundwater-level measurements are represented using time-series graphs. Users can examine observations over different periods to understand short-term and long-term variations.

This feature provides a visual representation of groundwater behaviour rather than requiring users to interpret raw sensor records.

C. Recharge Dashboard

The recharge module presents recharge-related estimates obtained using the selected methodology and available aquifer parameters. This information can assist in examining groundwater-level responses following rainfall and recharge events.

D. Alerts and Notifications

The system can generate alerts when predefined groundwater-level conditions are detected. For example, a rapid and persistent decline can be flagged for further examination.

Thresholds should be configured according to validated groundwater conditions rather than using a single threshold for all monitoring locations.

E. Data and Report Generation

Authorized users can obtain processed observations and generated reports for further analysis. This feature can support academic research, groundwater assessment, and external modelling.

IMPLEMENTATION FRAMEWORK

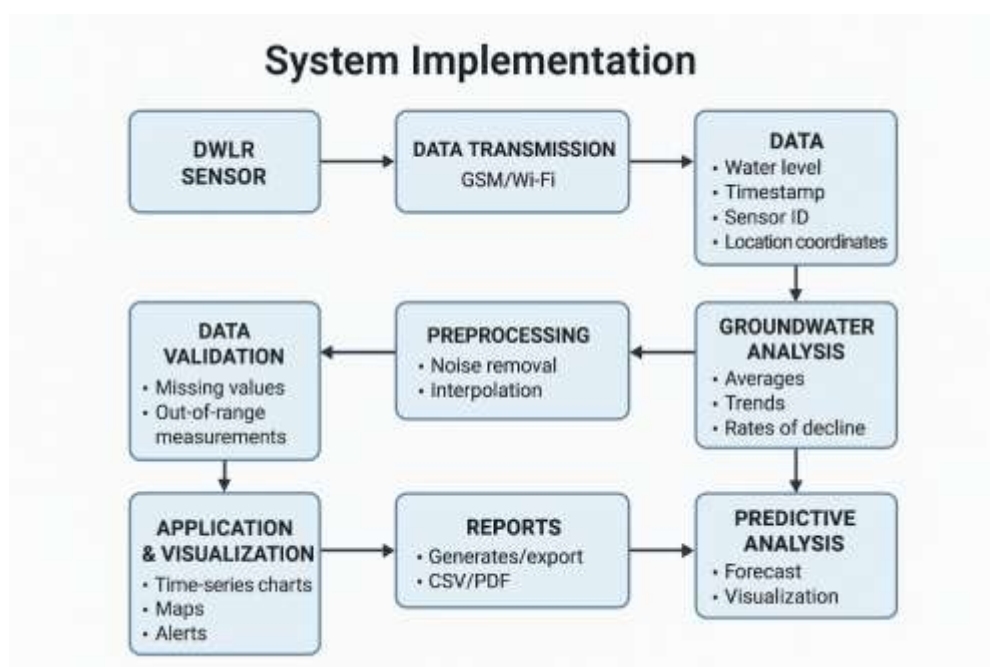
The implementation follows a client-server architecture in which the mobile application communicates with an application server through defined interfaces.

The server is responsible for receiving requests, retrieving relevant station information, processing analytical operations, and returning the required information to the mobile application.

The database stores station metadata and time-stamped groundwater observations. Analytical modules operate on validated observations to generate trend information and recharge-related estimates.

The mobile interface is designed to provide separate views for station discovery, groundwater-level visualization, analytical information, alerts, and reports.

The modular nature of the proposed architecture allows additional analytical models to be incorporated later without changing the complete application structure.



RESULTS AND DISCUSSION

The proposed mobile application provides an integrated environment for accessing and analysing groundwater observations obtained from Digital Water Level Recorders. The

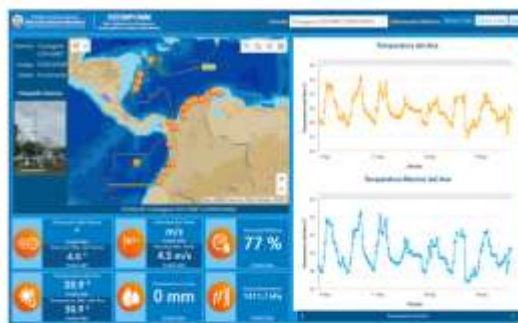
system organizes incoming groundwater-level measurements into a structured format, allowing users to examine both recent observations and historical variations through the application interface.

The preprocessing stage improves the usability of the collected data by identifying incomplete, inconsistent, or unsuitable observations before further analysis. The processed time-series data can subsequently be used to identify groundwater-level fluctuations and temporal patterns. Graphical representation of these variations enables users to observe changes over different time periods and supports interpretation of groundwater conditions at individual monitoring locations.

The application also incorporates groundwater recharge assessment based on groundwater-level fluctuations and the Water Table Fluctuation approach. In addition, groundwater-stress conditions can be identified using predefined groundwater-level thresholds. These analytical functions provide users with information that can support monitoring and resource-management activities.

Geospatial visualization enables monitoring locations to be viewed according to their geographic position. This provides a convenient way to examine groundwater conditions across different areas rather than analysing individual observation points independently. The alert mechanism can notify users when groundwater levels approach or exceed predefined limits, thereby supporting timely attention to potentially critical conditions.

Overall, the proposed system demonstrates how continuous DWLR observations can be transformed into accessible groundwater information through data preprocessing, time-series analysis, recharge assessment, visualization, and alert generation. The present implementation establishes the functional framework for real-time groundwater monitoring. Further evaluation using larger datasets and measured performance indicators can be used to quantify prediction accuracy, processing efficiency, and system response time.



ADVANTAGES

The proposed system provides the following advantages:

1. Provides centralized access to groundwater observations.
2. Supports visualization of high-frequency groundwater-level data.
3. Reduces dependence on manual interpretation of individual observations.
4. Provides both spatial and temporal views of groundwater conditions.
5. Supports recharge-related analysis using groundwater-level fluctuations.
6. Enables configurable groundwater-level alerts.
7. Provides processed information in a mobile-accessible format.
8. Creates a foundation for future groundwater forecasting models.
9. Facilitates sharing of processed observations and reports among authorized user

LIMITATIONS

The accuracy of groundwater assessment depends on the quality and completeness of DWLR observations. Communication failures, sensor errors, missing observations, and inconsistent station metadata can affect the analytical outputs.

Recharge estimation also depends on parameters such as specific yield and the suitability of the Water Table Fluctuation method for the particular hydrogeological setting. Therefore, automated estimates should be interpreted together with relevant field and hydrogeological information.

Similarly, groundwater-stress classification requires appropriate threshold values and reliable resource-assessment data. A uniform classification scheme may not be suitable for all aquifer conditions.

These limitations indicate that the application should be considered a decision-support system rather than a replacement for detailed hydrogeological assessment.

FUTURE ENHANCEMENTS

The proposed system can be further enhanced by incorporating additional environmental and hydrological datasets such as rainfall, temperature, soil characteristics, land-use information, and surface-water conditions. Integrating these variables with DWLR observations can provide a broader basis for analysing groundwater behaviour.

Machine-learning and deep-learning models can also be incorporated to develop groundwater-level forecasting capabilities. Different predictive models can be evaluated using historical DWLR time-series data, with appropriate performance measures used to compare their effectiveness.

Future versions of the application can include advanced GIS-based spatial analysis, automated report generation, customized user alerts, and improved visualization of groundwater trends. Integration with additional IoT-based monitoring devices can further expand the range of parameters available to the system.

The system can also be evaluated using larger datasets collected over longer periods and from multiple geographic regions. Such evaluation would help assess the robustness,

scalability, and practical applicability of the proposed framework under different groundwater conditions.

CONCLUSION

The proposed mobile application provides an integrated approach for monitoring and assessing groundwater conditions using Digital Water Level Recorder data. By combining continuous groundwater-level observations with data preprocessing, time-series analysis, recharge assessment, groundwater-stress identification, geospatial visualization, and alert generation, the system converts raw monitoring data into information that can be more easily interpreted by users.

The application provides a centralized interface through which groundwater observations can be viewed and analysed over different time periods and locations. The integration of DWLR data with analytical and visualization functions can support continuous observation of groundwater-level behaviour and assist in identifying locations that require further attention.

The proposed framework also provides a foundation for extending groundwater monitoring through predictive analytics, additional environmental datasets, and advanced machine-learning techniques. Future development can focus on improving forecasting capabilities, integrating rainfall and land-use information, expanding spatial analysis, and evaluating the system using larger real-world datasets. Such improvements can further enhance the usefulness of digital tools for sustainable groundwater monitoring and resource assessment.

REFERENCES

- [1] A. Velhal, T. Bhor, C. Harde, and V. Pawara, "Groundwater Resource Evaluation Using Digital Water Level Recorder (DWLR) Time-Series: An Integrated DWLR Processing, Analysis, and Forecasting Framework," *International Journal of Sciences and Innovation Engineering*, vol. 2, no. 9, pp. 1206–1211, 2025.
- [2] J. Sun, X. Yan, S. Li, W. Wang, W. Liu, and Z. Li, "Improving the water table fluctuation method to estimate groundwater recharge below thick vadose zones," *Hydrological Sciences Journal*, vol. 69, no. 14, pp. 2044–2056, 2024.
- [3] S. Thakur and S. Karmakar, "Predicting Groundwater Levels Using Advanced Deep Learning Models: A Case Study of Raipur, India," *Transactions of the Indian National Academy of Engineering*, vol. 10, no. 3, pp. 551–558, 2025.
- [4] "Advanced groundwater level forecasting with hybrid deep learning model: Tackling water challenges in Taiwan's largest alluvial fan," *Journal of Hydrology*, vol. 655, Art. no. 132887, 2025.

- [5] G. Shuai, J. Huang, and S. Xu, "Accurate groundwater level predictions: integration of physics-driven and machine learning approaches," *Applied Water Science*, vol. 16, Art. no. 203, 2026, doi: 10.1007/s13201-026-02862-6.
- [6] T. Hai, M. M. Hameed, T. et al., *Neurocomputing*, vol. 489, pp. 271–308, 2022, doi: 10.1016/j.neucom.2022.03.014.
- [7] *Environmental Modelling & Software*, vol. 168, Art. no. 105788, 2023. Useful for discussing ANN, ANFIS, SVR, deep learning and hybrid models.
- [8] *Water Research*, vol. 252, Art. no. 121249, 2024, doi: 10.1016/j.watres.2024.121249.
- [9] *Environmental Modelling & Software*, vol. 192, Art. no. 106549, 2025, doi: 10.1016/j.envsoft.2025.106549.
- [10] *Applied Computing and Geosciences*, vol. 28, Art. no. 100303, 2025..
- [11] P. J. Sajil Kumar, M. Schneider, and L. Elango, *Sustainability*, vol. 14, no. 1, Art. no. 340, 2022, doi: 10.3390/su14010340.
- [12] M. Dixit, M. Arora, H. P. Jayaprakash, and V. R. Achutha, *Groundwater for Sustainable Development*, 2024, doi: 10.1016/j.gsd.2024.101313.
- [13] U. Khan and A. Baba *Environmental Earth Sciences*, vol. 85, Art. no. 294, 2026, doi: 10.1007/s12665-026-13033-w.
- [14] I. M. Ali, M. A. Hussein, S. K. Tiwari, et al., *Discover Sustainability*, 2026, doi: 10.1007/s43621-026-04584-w.
- [15] B. Rammohan, P. Partheeban, S. Balaraman, F. J. J. Joseph, et al *Journal of Water Process Engineering*, 2025, Art. no. 109052, doi: 10.1016/j.jwpe.2025.109052.
- [16] M. Rahman, A. Raihan, S. M. Rahman, et al *Advances in Space Research*, vol. 77, no. 4, 2026,
- [17] *Desalination and Water Treatment*, 2025, Art. no. 101403, doi: 10.1016/j.dwt.2025.101403.