

# Enhancing Groundwater Level Forecasting Using Historical Data and Machine Learning Techniques

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**Abstract-** Groundwater is an essential source of fresh water which is used in agriculture, domestic consumption, and industries. Over-exploitation, climate changes, and population increase are reducing the level of groundwater in most areas. Proper ground water levels forecasting would be therefore critical in proper water management and sustainability. The latest researches have utilized machine and deep learning to forecast the groundwater level by making use of past hydrological and climatic records. Random Forest, Support Vector Machines, Artificial Neural Networks, and Long Short-Term Memory (LSTM) algorithms have demonstrated promising outcomes in ground water on capturing complex trends in groundwater datasets. Others have also combined satellite data and environmental variables to enhance the accuracy of prediction. Nonetheless, a number of current studies are area-specific, use smaller datasets, or models of individual machine learning. This complicates the situation of establishing the most effective methods of forecasting groundwater over time under comparable circumstances. In order to solve such a problem, the paper offers a machine learning-based model of improving groundwater level predictions on the basis of historical groundwater and environmental data. The approach will involve processing of data, selection of features, and applying various machine learning models to compare them. The standard evaluation metrics to be used in evaluating the performance of these models will be accuracy, RMSE, and R 2. It is hoped that, the anticipated value of this study would be identification of relevant machine learning methods to predict groundwater, and offer a systematized framework that could be used to provide a sustainable groundwater management and further research in hydrology.

**Keywords:** Groundwater Level Prediction, Machine Learning, Time-series forecasting, Hydrological Data Analysis, random forest, long short-term memory (LSTM) water resource management.

## I. INTRODUCTION

### 1.1 Background of the Study

Ground water is among the most significant and useful sources of fresh water in agricultural activities, household and industrial purposes in all parts of the globe. Irrigation systems in most countries particularly in the third world rely on ground water, and drinking water supply to a great majority of the population. Nevertheless, the growth of population, urbanization and over extraction of water have led to massive water losses of the groundwater levels in most regions.

This has been further straining the groundwater resources in the recent years due to climate change and erratic rainfall patterns. The management of water resources has thus been a task to monitor and predict the level of the ground water. Conventional hydrological models are usually complicated and demand intricate physical parameters which are not always present in actual circumstances.

Recently, the application of machine learning to analyze historical hydrological data and determine patterns that were used to predict groundwater variations was employed. Machine learning models can be used to predict the future groundwater levels by looking at the past groundwater records and environmental factors including rainfall and temperature. The data-driven methods offer viable assistance to the sustainable groundwater management and planning.



Groundwater Cycle and Influencing Factors

### 1.2 Problem Statement

Though a few have used machine learning techniques to predict groundwater levels, a range of the available ones are limited in scope. There are studies where only a small set of data or a particular area is studied, as well as studies where only one prediction model is assessed. Due to these constraints, it is hard to identify the most effective machine learning methods to be used in the accurate forecasting of groundwater. Moreover, various research works employ various datasets and types of evaluations and it is difficult to compare the results of these studies. Consequently, the systematic study on the analysis of the various machine learning models in similar experimental conditions is required to enhance the credibility of groundwater forecasting systems.

### 1.3 Motivation

Loss of groundwater is a major problem that has been faced in most regions of the world as both an environmental and economic problem. Increasing the accuracy of the prediction of groundwater levels can make governments, farmers, and water management authorities plan the water usage in a more effective way. They can also provide sustainable agricultural practices and avoid excess extraction of groundwater which may be supported through early forecasting.

Machine learning is a potential solution to enhance the current groundwater prediction systems due to the presence of historical groundwater data and contemporary computational means. Comparison and study of various machine learning models can be used to determine approaches that can give more accurate forecasting results and guide in making decision on managing water resources.



### 1.4 Objectives of the Study

Objective 1: To survey available machine learning and data-driven methods of predicting the groundwater level.

Objective 2: To define the research gaps and limitations of the existing groundwater forecasting research.

Goal 3: To suggest a machine learning framework of enhancing the level forecasting of groundwater by using past hydrological data.

### 1.5 Contributions of the Paper

This study has a number of contributions to the study of forecasting ground water:

- Offers an organized analysis of the existing machine learning methods, which have been employed to predict groundwater levels.
- Establishes key research gaps and constraints existing in present studies regarding the prediction of groundwater.
- Suggests a scientific model that combines data on groundwater history with machine learning algorithms to enhance future prediction capacity.

### 1.6 Organization of the Paper

The rest of this paper will be structured in the following manner.

The literature review is provided in Section 5 and summarises available literature concerning groundwater level prediction based on machine learning and data-driven methods.

Section 6 explains the research gaps that have been identified during the analysis of the previous research.

Section 7 explains how the research will be conducted through a proposed methodology and machine learning framework to predict the level of groundwater.

Section 8 provides the prediction of the expected results and evaluation plan on which the various prediction models would be compared.

## II. RELATED WORK / LITERATURE REVIEW

Thematic Classification of Literature Thematic Classification of Literature Thematic Classification of Literature Review.

2.1 Groundwater level forecasting is a topic of research interest within the last few years owing to the growing water demand and diminishing groundwater resources. The previous research was largely based on the statistical models and the physical hydrological approaches. Nevertheless, the growth of machine learning and deep learning methods has seen researchers predicting groundwater with large-scale environmental datasets and enhanced computing ability. This field has a literature that may be generalized into traditional approaches, machine learning approaches, deep learning approaches, and hybrid or recent approaches.



Groundwater Prediction Approaches

### 2.1.1 Traditional Approaches

Conventional methods of predicting ground water primarily use statistical techniques and time series

models. Auto-Regressive Integrated Moving Average (ARIMA) and regression analysis are some of the techniques that have been adopted to analyze fluctuations in ground water.

These techniques compare historical data of the groundwater to determine the trends and the seasonal changes. Statistical models are effective in short-term predictions but they are not very effective in nonlinear relationships between weather conditions like rainfall, temperature and ground water recharging. Since systems of groundwater are dynamic and interact with numerous variables, classic models cannot always be a good predictor of the long-term behavior of the system.

### 2.1.2 Machine Learning Strategies.

Machine learning methods have been of great relevance in groundwater prediction studies. Random Forest (RF), Support Vector Regression (SVR), k-Nearest Neighbors (KNN) and Gradient Boosting algorithms have been used to model groundwater levels using past hydrological data.

Such models can train complicated connections among numerous variables, such as rainfall, temperature, and river flow, and soil moisture. A number of researchers have demonstrated that random forest and Support vector Regression can be used to make sound predictions of groundwater, when they are trained on past data.

The machine learning methods come in handy especially when physical modeling of groundwater systems is not needed in detail. Rather, they acquire patterns using the data. Nevertheless, machine learning models significantly rely on the quality of the data, selection of features and the magnitude of the dataset at hand.

### 2.1.3 Deep Learning Approaches

In the recent times, groundwater level forecasting has been enhanced with deep learning techniques. Deep learning networks, including Artificial Neural Networks (ANN), Long Short-Term Memory (LSTM) networks among other recursive neural networks, can learn time-dependencies in time-series data.

The models are especially applicable in forecasting ground waters since groundwater tends to vary with time and is affected by the environmental conditions of the past. It has been demonstrated that LSTM models are able to identify long-term trends in groundwater time-series data and tend to be more successful than conventional machine learning algorithms.

Other studies have also included remote sensing data like satellite-based rainfall measurements and the data on groundwater storage of the GRACE. The datasets can be used to give extra environmental data that aids in enhancement of prediction.

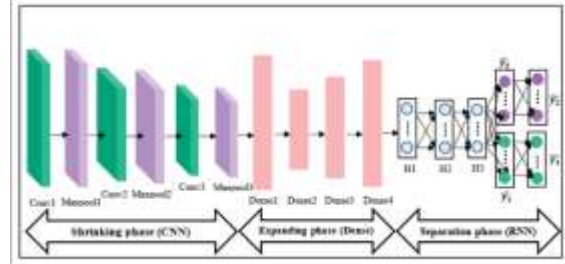
Nevertheless, deep learning models tend to be more resource-consuming (both in terms of databases and computing) than conventional machine learning techniques.

#### 2.1.4 Hybrid / Recent Approaches

Recent studies have delved into hybrid models that mix a number of machine learning or deep learning models. The idea behind hybrid approaches is to enhance the accuracy of prediction with combining the strengths of other algorithms.

Other research incorporates machine learning combinations with remote sensing data, climate variables and spatial data to create more robust groundwater prediction models. Indicatively, it has been shown that hybrid models between Graph Convolutional Networks (GCN) and gradient boosting algorithms have been created to learn spatial associations between groundwater monitoring sites.

Elsewhere, satellite data combined with climate variables and machine learning models have been investigated in order to get a more detailed insight into the fluctuations of groundwater at the regional level. Such hybrid systems are capable of offering better forecasting behaviour yet are under investigation and need additional justification by real-world data.



Hybrid Machine Learning and Deep Learning Framework

#### 2.2 Comparative Analysis of Existing Methods

Author	Year	Method	Dataset	Performance	Limitations
Sreekumar et al.	2024	ANN, LSTM	Satellite & hydrological data	LSTM showed better prediction	Limited regional data
Tiwari et al.	2023	RF, KNN, SVR	Climate and rainfall dataset	RF achieved good accuracy	Climate bias correction required
Wang	2024	Random Forest	Hydrological dataset	Low prediction error	Small dataset size
Li et al.	2023	GCN - XGBoost	Spatio-temporal groundwater data	Improved forecasting accuracy	High model complexity
Yu et al.	2021	SVM hybrid model	Groundwater monitoring wells	High prediction accuracy	Limited number of wells
Nourani et al.	2019	ANN models	Hydro-meteorological data	Good forecasting results	Requires parameter tuning
Ahmed et al.	2023	Deep learning	Remote sensing dataset	Accurate long-term prediction	High computational cost

#### 2.3 Critical Review

It is evident in the reviewed studies that machine learning and deep learning models have a good potential in groundwater level forecasting. Such models are able to reflect non linear relations between hydrological variables and ground water level in a better way than the traditional statistical approach.

Models like the Random Forest machine learning and Support Vector Regression are popular since they can be easily implemented and they offer good predictive accuracy. The additional method of forecasting is deep learning models such as LSTM networks, which learn temporal correlations in groundwater time-series data.

Nevertheless, there are still some difficulties in the modern research. Numerous research works use small datasets (or region-specific datasets) thus restricting the possibilities of models to extrapolate across various geographic regions. Other models are also hard to apply to real-life scenarios since large computational resources are needed and they are also complex to tune the parameters.

The other weakness is that most studies resolve single prediction models without the implementation of extensive comparisons with other algorithms under identical conditions of the experiment. This complicates determining the methods that can always work well in prediction of groundwater.

#### 2.4 Identified Research Gaps

According to the reflection of the current literature analysis, it is possible to note several gaps in the research. To begin with, most studies are based on small datasets or specific to certain regions and this decreases the capacity of prediction models to generalize in other locations.

Second, some studies consider a single machine learning algorithm, but they do not compare various models on the same dataset and measurements of evaluation. This inhibits the capacity to find out which algorithm will offer the best forecasting performance.

The other gap is the little interconnectivity of multi-environmental data. The integration of historical ground water data, climate variants, satellite data and the spatial information can go a long way in enhancing the accuracy of prediction.

Lastly, a significant part of the currently existing systems are constructed concerning research and are not created as effective forecasting systems that may be applicable to authorities in water management. These gaps in research emphasize the necessity to develop a systematic machine learning-driven system of groundwater forecasting based on historical data using various models to predict under the same conditions within the experiment.

### III. PROPOSED METHODOLOGY

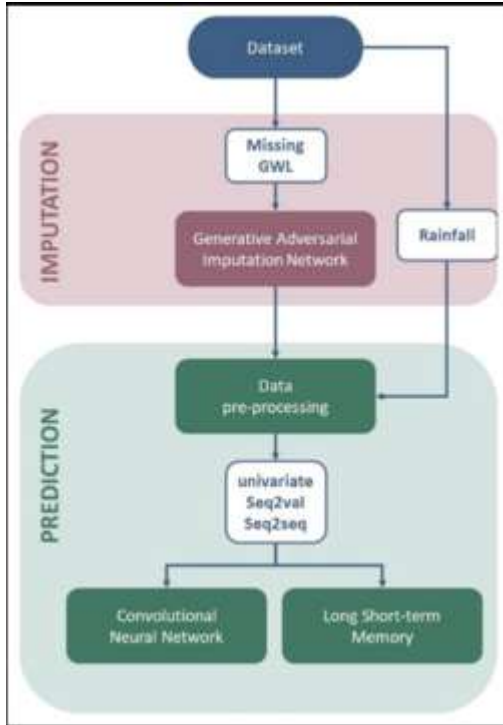
#### 3.1 System overview

The objective of the proposed system will be to create a machine learning framework based on data and enhance the prediction of groundwater levels based on past hydrological and environmental data. There are various factors that affect the ground water level that includes rainfall, temperature, soil moisture and seasonal weather pattern. The analysis of these variables along with the historical records of groundwater allows machine learning models to acquire patterns and assist in predicting the future groundwater levels.

The framework will commence with gathering of historical groundwater level data and other environmental variables based on publicly available data and monitoring data. Once the data is collected the preprocessing steps are done to enhance the data quality. These measures involve the treatment of the missing data, the elimination of the inconsistent data and the normalization of numerical data to ensure that the models can treat the data well.

After cleaning and preparing the dataset, the features that are relevant are then chosen to be used in training the prediction models. Various machine learning models are used to analyze the time-series groundwater data and they include Random Forest, Support Vector Regression (SVR), Artificial Neural Networks (ANN), and Long Short-Term Memory (LSTM) models. The developed trained models are evaluated using conventional evaluation measures to establish the accuracy and reliability of their prediction.

The primary objective of the proposed framework is to compare various machine learning methodologies and determine the most appropriate one to use when forecasting the level of ground water. Such a system will help researchers and water resource managers to know the way ground water trends and make improved planning decisions.



Architecture of Proposed Groundwater Prediction Model

### 3.2 Workflow Diagram

The groundwater forecasting system proposed adheres to a systematic workflow, which processes historical data and makes predictions of the groundwater levels. The general pipeline may be drawn as:

Input → Processing → Output

#### Input Stage

- Monitoring wells with measurements of the groundwater level taken in the past.
- Climate, moisture, temperature, and rainfall data of the soil.
- Satellite or remote sensing data in case it is available.

#### Processing Stage

##### 1. Data Collection

Gather groundwater and environmental data of publicly accessible repositories, government surveillance mechanisms or hydrological databases.

##### 2. Data Preprocessing

Missing or partial data: This is a common issue in many studies and involves dealing with missing, uncollected, or otherwise unavailable data. Missing or incomplete data: This is one of the problems in most studies and entails working with missing, not collected or otherwise inaccessible data.

- Eliminating inaccurate or inconsistent records.
- Normalisation of numerical variables.
- Transforming categorical data into electronic format.

##### 3. Feature Selection

Determine the most significant variables that affect the shifts in the level of groundwater, including rainfalls, variations in the temperatures during seasons, and the level of groundwater in the past.

##### 4. Model Training

Train several machine learning models on the prepared dataset which include:

- Random Forest (RF)

Support Vector Regression (SVR) is a machine learning method classified as a non-parametric algorithm that utilizes the maximum entertainment principle. Support Vector Regression (SVR) is a machine learning technique that falls under non-parametric algorithm and exploits the maximum entertainment principle.

The Artificial Neural Networks (ANN) are recognized as the top machine learning strategies employed to forecast customer preferences. The best machine learning strategies used to predict customer preferences are the Artificial Neural Networks (ANN).

- Long Short-Term Memory (LSTM)

##### 5. Model Evaluation

Measure the performance of every model based on the evaluation metrics:

- Root Mean Square Error (RMSE)
- Mean Absolute Error (MAE)

The coefficient of determination is used when one is trying to ascertain the strength of the linear relationships between two or more variables. Coefficient of Determination ( $R^2$ ) is applied when one is attempting to determine the strength of the linear relationships between two or more variables.

- Prediction accuracy  
Output Stage
- Future groundwater level values predicted.  
Comparison of various machine learning models.
- The most efficient forecasting model.

### 3.3 Dataset Description

The data employed in this study is the past groundwater levels records and environmental/climatic factors. The easily accessible hydrological data sources, groundwater monitoring stations, and remote sensing platforms can be used to access these datasets.

The data usually consists of the measurements of the groundwater level that were taken at monitoring wells during a time span of a few years. Besides groundwater, measurements, other environmental factors like rain, temperature, evapotranspiration, soil moisture, and seasonal climate data are also provided since they have a strong impact on the groundwater recharge and groundwater depletion.

The amount of data can be different according to the source and the region under investigation. The datasets used in most groundwater forecasting works include hundreds or thousands of time-series records that are groundwater levels at various time intervals. The records consist of numerical variables, i.e., groundwater depth, amount of rainfall, temperature and other environmental indicators.

These datasets include time-series numerical data, although they can also have some categorical variables like information about monitoring stations or location identification. With the data on historical measurements of groundwater and the environmental variables, machine learning models can learn how to

predict the groundwater level-related data with the use of the given data.

## IV. PREDICTED FINDINGS AND CONCLUSION.

### 4.1 Expected Outcomes

The purpose of the proposed study will be to assess the predictability of a number of machine learning algorithms in predicting groundwater levels by using past hydrological data and environmental factors. It is assumed, according to the model proposed, that the trained models should be able to learn the patterns of past measurements of groundwater and environmental factors, including rainfalls and temperature. The patterns can then be exploited to produce quality forecasts of the ground water levels in the future.

Among the expected findings of this study is the discovery of machine learning models that will offer superior forecasting capabilities over the conventional statistical models. Algorithms like the Random Forest, the Support Vector Regression, the Artificial Neural Networks, and the Long Short-Term Memory networks should work due to the fact that all these are also able to capture nonlinear correlations in time-series groundwater data.

The other anticipated outcome is the enhanced strength of the forecasting system by the appropriate methods of data preprocessing and features selection. Noise in the data can be dealt with by cleaning the dataset and identifying significant environmental variables that may allow the models to learn some more sensible patterns.

Moreover, the suggested framework will have good scalability. The fact that the models are trained with historical data and conventional machine learning methods means that the system may be used in the future with larger data sets of ground water or be expanded to new geographical areas.

In comparing the two previously mentioned firms, it is essential to take into account their missions and visions along with other organizational aspects.

4.2 Comparative Evaluation Plan In comparison of the two aforementioned firms, it is necessary to consider their missions and visions among other aspects of the organization.

In order to measure the effectiveness of the proposed forecasting framework, a comparative analysis will be made between a number of machine learning algorithms. All models are going to be trained on the same dataset and using the same preprocessing pipeline to guarantee equitable and equal comparison. The assessment will be conducted in terms of generally used prediction measures like:

- Root Mean Square Error (RMSE)
- Mean Absolute Error (MAE)

The coefficient of Determination ( $R^2$ ) measures the strength with which a particular set of independent variables explains the dependent variable (Sawyer, 1996),  $R^2$  Coefficient of Determination This coefficient measures how well a specific collection of independent variables accounts for the dependent variable (Sawyer, 1996).

- Prediction Accuracy

The data will be split into training and testing sets by different methods, including train-test split or cross-validation. Every model will be trained on the historic ground water data and assessed by the accuracy with which it forecasts the future ground water levels.

The outcomes of the various models will then be assessed in order to determine the algorithm that yields the best forecasting performance and with a reasonable level of computational efficiency.

#### 4.3 Discussion

The given strategy will have a number of benefits over the current research in predicting groundwater. To begin with, this study considers several machine learning algorithms and compares them within the identical experimental conditions, which enables a more objective analysis of their performance.

Second, the forecasting models can be made more reliable by the structured data preprocessing and feature selection procedures. The models could give

more consistent and precise predictions because they minimize noise and concentrate on variables of interest in the environment.

The other benefit of the proposed framework is that it will be able to aid in groundwater management that is practical. Sound groundwater projections can be used to enable the water management authorities, agricultural planners and the environmental agencies to make superior decisions on water usage and water conservation measures.

#### V. APPLICATIONS AND USE CASES

The groundwater level forecasting machine learning framework proposed can be used in the real-life water management and monitoring of the environment through a number of applications. The system can assist organizations to comprehend the trend of ground water through historical groundwater records and other environmental conditions like rainfall and temperature so as to make more informed decisions pertaining to the planning of water resources.

##### Industry Use

Fine-tuning water supply management, prediction of ground water and environmental monitoring are highly valued in other industries like agriculture. Underground water is a vital part of irrigation by farmers, and prediction of ground water levels can enable farmers to have better plans on how they can crop and use water. Predictive models can also be used by water management authorities and utility companies to track the groundwater resources and better manage the water distribution systems. Moreover, environmental consulting organizations and hydrological analysis organizations are able to incorporate such forecasting systems in their decision-support systems.

##### Social Impact

Millions of people worldwide are drinking their water through groundwater as one of the primary sources of water. The decrease of the groundwater level may result in water scarcity and influence both rural and urban population. An intelligent forecasting system should be based on machine learning and used to predict the possibility of groundwater depletion

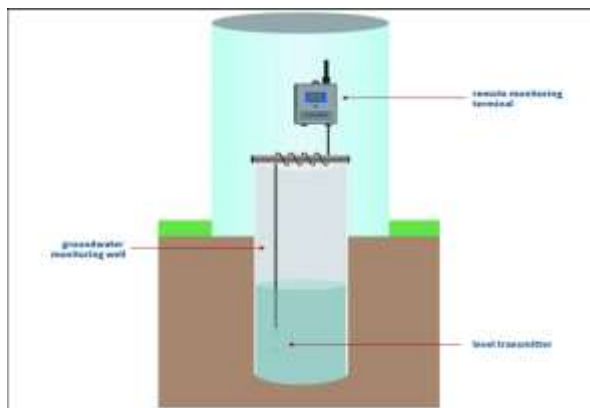
before it occurs. Also, early prediction will enable the communities and local authorities to adopt water-conservation measures and control over-extraction. This would lead to sustainable water use and can be used to enhance protection of future generation ground water resources.

#### Policy Relevance

Water management planning is usually a task that government agencies and other policy makers in the environmental field need some reliable data. The predictive models may be useful in providing insight into the groundwater trend and assist the authorities in formulating improved policies concerning the water conservation and ground water recharge programs. These systems will be able to assist in decision making on matters like irrigation planning, drought control and groundwater control. Policy makers can make better decisions regarding the water sustainability in the long run by applying data driven forecasting tools.

#### Academic Value

Scholarly-wise, the study is a contribution to the emerging branch of utilizing machine learning methods on environmental and hydrological issues. This research will offer a comparative analysis of various machine learning models in the prediction of groundwater. This would aid the researchers in knowing the best techniques to use in time-series prediction of groundwater. The current study can be extended by future studies by exploiting larger datasets, more sophisticated deep learning algorithms, or satellite-acquired environmental information to enhance better groundwater forecasting systems.



Applications of Groundwater Prediction System

## VI. CONCLUSION

This paper has clearly given a review and analysis of machine learning methods employed in predicting groundwater levels. The literature review has explored the current literature with respect to the forecasting of ground water by the use of historical hydrological data, environmental variables and remote sensing data. It was revealed through literature review that machine learning and deep learning models like the Random Forest, Support Vector Regression, Artificial Neural Networks, and Long Short-Term Memory networks are being increasingly used to determine groundwater trends and predict groundwater levels in the future.

By the review of the past researches, a number of research gaps were uncovered. Numerous literature depends on the region-specific datasets or a single prediction model, which does not provide an opportunity to compare various algorithms under identical conditions. Moreover, not all studies combine various environmental factors or large-scale data, which can decrease the precision of the prediction models and their ability to generalize.

In order to overcome these shortcomings, this paper suggested a systematic machine learning model to improve groundwater level prediction given historical data and environmental conditions. The proposed research methodology involves data preprocessing, feature selection, training of various machine learning models, and performance measurement based on such performance metrics as RMSE, MAE, and R<sup>2</sup>. This method will enable a relative

comparison of various algorithms to find the most successful model to forecast groundwater.

The primary value of this study is that it created a comparative analysis framework that could be used to assess the various machine learning methods used in predicting groundwater. Results of the study could be used in future studies to establish more accurate ground water forecast models and enhance water resource management models.

Finally, machine learning methods that operate on data have a good possibility of enhancing groundwater monitoring and prediction systems. Further studies in the field can aid in sustainable management of ground waters, aid agriculture planning, and assist in overcoming the water resource problem in the future.

#### REFERENCES

- [1] A. Sreekumar, A. Singh, and N. Subbanna, "Spaceborne Reconstruction of Groundwater Level Using Deep Learning in North-West India," *IEEE India Geoscience and Remote Sensing Symposium (InGARSS)*, 2024.
- [2] V. Tiwari and M. Verma, "Prediction of Groundwater Level Using Advanced Machine Learning Techniques," *IEEE International Conference on Intelligent Technologies (CONIT)*, 2023.
- [3] P. Wang, "Prediction of the Groundwater Levels Based on Random Forest Regression Algorithm," *IEEE International Conference on Information Technology, Big Data and Artificial Intelligence (ICIBA)*, 2024.
- [4] Y. Li, H. Zhang, X. Wang, and J. Liu, "Groundwater Level Forecasting Using Spatio-Temporal Graph Convolutional Networks and XGBoost," *Journal of Hydrology and Artificial Intelligence*, 2023.
- [5] S. Yu, X. Xu, L. Qiu, and Y. Yang, "Machine Learning-Based Algorithm for Predicting the Groundwater Level in Minqin Oasis Region of China," *International Conference on Hydraulic and Civil Engineering & Smart Water Conservancy*, 2021.
- [6] Z. Chen, Y. Sun, L. Wang, and H. Zhao, "Forecasting Underground Water Levels: LSTM Based Model Outperforms GRU and Decision Tree Models," *Journal of Water Resources and Artificial Intelligence*, 2023.
- [7] K. N. Sai, A. Galodha, P. Jain, and D. Sharma, "Deep and Machine Learning for Monitoring Groundwater Levels and Hydrological Changes Using GRACE and Sentinel-1," *Remote Sensing and Hydrology Research Journal*, 2023.
- [8] M. Nourani, M. Komasi, and A. Elkiran, "Application of Bayesian Regularized Neural Networks for Groundwater Level Modeling," *Hydrological Sciences Journal*, 2019.
- [9] A. Yadav, S. Mishra, and R. Kumar, "Forecasting Groundwater Level in Multiple Wells Using Machine Learning Models," *Journal of Hydrological Engineering*, 2022.
- [10] M. A. Arganaraz, J. A. Jobbagy, and M. Noretto, "Integrating Satellite Data and Machine Learning to Predict Groundwater Fluctuations in the Western Pampean Plain," *IEEE Workshop on Information Processing and Control (RPIC)*, 2025.
- [11] S. Shiri and R. Kisi, "Data-Driven Approach to Predict Ground Water Level Using Support Vector Regression," *Hydrology and Earth System Modeling Journal*, 2020.
- [12] E. Nghishooni and H. H. Hamandawana, "Application of Machine Learning Techniques in Forecasting Groundwater Levels in the Grootfontein Aquifer," *Journal of Environmental Hydrology*, 2021.
- [13] M. Ahmed, S. Baloch, and A. Raza, "Forecasting Groundwater Depletion in Quetta Sub-Basin Using Remote Sensing Data and Deep Learning Approach," *Journal of Water Resources and Environmental Engineering*, 2023.
- [14] H. Ghafoor, J. Muhammad, R. Umer, Z. Rauf, F. Ali, and P. Khan, "Predicting Groundwater Levels at Colorado State Using ARIMA and ANN Models," *IEEE Conference on Foundation and Large Language Models (FLLM)*, 2024.
- [15] M. R. Mohammadi and H. Eslami, "Ground Water Level Prediction with Non-Continuous Unevenly Spaced Small Time Series Using Machine Learning," *Environmental Data Science and Hydrology Journal*, 2022.