



Predictive Modeling of Lake Area Variations Using Machine Learning Techniques

KeerthanaSree S. B¹

*Department of Computer Science and Engineering, Sathyabama
Institute of Science and Technology
Chennai, India, keerthanasrikanth1@gmail.com*

Keerthana M²

*Department of Computer Science and Engineering, Sathyabama
Institute of Science and Technology
Chennai, India, keerthanamanoharan04@gmail.com*

A. Yovan Felix*³

*Department of Computer Science and Engineering, Sathyabama
Institute of Science and Technology
Chennai, India, yovaanfelix@gmail.com*

Abstract- Lake areas prediction is a prerequisite for safe and sound environmental management and planning, especially in the regions that are influenced by the changed hydrological regime. This Research displays what machine learning regression methodologies Regression (Linear Regression, Ridge Regression, and Random Forest Regression) can be carried out to predict changes of the lake area in Chennai using the real historical data from the past 35 years. The data set consists of the lake area measurements of Retteri, Kolathur, Ambattur, and Puzhal Lakes for each year along with the respective environmental variables of rainfall, land use, and water flow. The data go through an extensive process that includes the preprocessing step, which consists of cleaning the data and dealing with the missing values replacement, and feature engineering that altogether ensures the data's consistency and data reliability. The model's performance is evaluated by criteria such as Mean Absolute Error (MAE), Mean Squared Error (MSE), and the R measure. To confirm the models, cross-validation procedures are used in order to try to ascertain the model's stability. The results are that the Random Forest Regression model yields the highest accuracy of approximately 92%, outperforming Linear and Ridge Regression models. The proposed approach will predict the area of a lake using changes in environmental conditions that could vary by use for flood control, water resource management, and thus, this research shows that regional spatial integration is strong enough and proper for the purposes of sustainable urban development; it can be a powerful method to improve some accuracy, and coverage of lake area prediction systems is included that easily helps during the process of environmental planning, makes it more proactive, and makes decision-making easier.

Keywords - Machine Learning, Lake Area Prediction, Regression Models, Environmental Data, Flood Control, Urban Planning, Sustainable Development, Feature Engineering, Performance Metrics.

I. INTRODUCTION

Environmental factors affecting the lake system are many, and hence the management of water resources in a sustainable manner, flood control, and urban planning is a challenging task. The area of the lake is dynamic and can vary due to many environmental factors such as rainfall, temperature, land use, and flow of water, among others. Sudden changes in the area of the lake can cause significant impacts on the environment and society as a whole. The conventional methods of predicting the dynamic changes in the area of the lake are mostly based on statistical methods and static data, which might not be sufficient enough to handle complex dynamic relationships in hydrological systems. Hence, more efficient and advanced data-driven approaches are needed to predict the dynamic changes in the area of the lake.

Recent advancements in Machine Learning (ML) have provided powerful tools that can be used to make environmental prediction and hydrological forecasts. Machine learning is able to analyze historical data and establish complex relationships between environmental variables, which can be used to make accurate environmental predictions. Several studies have identified the application and effectiveness of using Machine Learning models in the analysis of hydrological and environmental data. For example, Deepak and Elango (2023) identified the application of meteorological datasets in the prediction of changes in the area of lakes, while Sharma and Kumar (2023) identified the application of machine learning models in the assessment of changes in hydrology in urban lakes. In addition, Varun and George (2024) identified the application of ensemble learning methods such as the Random Forest algorithm in the prediction of changes in the area of freshwater lakes.

© The Author(s) 2026

R. Vasanth Kumar Mehta et al. (eds.), *Proceedings of the International Conference on Intelligent Systems for a Sustainable Future (ISSF 2026)*, Atlantis Highlights in Intelligent Systems 16,

https://doi.org/10.2991/978-94-6239-693-7_71

Linear Regression, Ridge Regression, and Random Forest Regression are some of the machine learning regression models that have been successful in modeling linear and nonlinear relationships in environmental data sets. These models can learn from past data sets of lake area and environmental factors like rainfall, temperature, and land use, and predict the future changes in the lake area.

In this study, machine learning algorithms are used for analysis on the long-term trends in the extent of Retteri Lake, Kolathur Lake, Ambattur Lake, and Puzhal Lake in Chennai using historical environmental data collected over the past 35 years. With the increasing effects of climate change on water resources, the main objective of this research is to develop a model that can effectively capture the complex relationship between environmental variables through a predictive model. The results from Linear Regression, Ridge Regression, and Random Forest Regression algorithms are used for evaluating the models using Mean Absolute Error (MAE), Mean Squared Error (MSE), and R^2 values for predicting lake areas accurately.

By conducting the above comparative analysis, the study attempts to determine the regression method that can produce the most accurate predictions about the changes in the lake area in the future. The results obtained from the present study can be used for effective environmental monitoring and management of water resources.

II. LITERATURE SURVEY

The discipline of hydrological forecasting and environmental monitoring is evolving at an extremely rapid pace, and the application of various machine learning algorithms to predict various phenomena related to water has witnessed tremendous improvement. Many models have been used in order to predict lake flow and water quality and other environmental parameters. However, it is not possible to predict changes in the lake areas, which has not been a fully solved issue in the current systems.

Alongside the consequences of the precipitation, Babu and Srinivasan (2023) combined in their computational methods study, investigated the influence of land use changes on the lake surface area. Their research emphasized the necessity of merging both climate and anthropogenic factors to comprehend lake dynamics; however, it was confined to a mere analytical evaluation without any extension to forecasting lake area changes over a long period [1].

In a similar vein, Chakraborty (2024) introduced a data-driven framework to monitor the changes in lake morphology utilizing historical datasets. This approach, as a result, was successful in revealing the past structural changes of lakes; however, it did not shed any light on the development of predictive models to anticipate future trends in lake areas [2].

The work of Deepak and Elango (2023) was mainly concerned with forecasting changes in the areas of the lakes from weather-related factors, such as rainfall and temperature. Their research emphasized the significance of these factors in the ecosystem of lakes; however, they utilized merely a handful of regression methods and did not employ any ensemble or regularized models to cope with data intricacy [3]. Dinesh and Raj (2022) examined various hydrological regression models and suggested that using sophisticated regression methods could significantly improve the prediction accuracy; however, their work was not a direct reference to the forecasting of lake areas in urban regions [4].

Francis and Arul (2024) conducted a study on the use of machine learning methods for hydrological forecasting in water bodies of South India. They came to the conclusion that models driven by data are an efficient way to predict the environment, but their main focus was a lot broader and did not specifically concentrate on lake area estimation [5]. Harini and Joseph (2023) researched the combination of environmental data with machine learning for lake area prediction and feature selection, which they pointed out as being the most important; however, they did not do any work on model generalization through cross-validation using their research [6].

In addition, several studies attempted to pinpoint the environmental effects that led to changes in lake surfaces. In their research, Jayaprakash and Mani (2023) examined how rainfall and temperature influenced alterations in the lake surface area. Latha and Mohan (2023), on the other hand, used remote sensing data to delineate changes in lake boundaries in urban areas. These papers have helped to comprehend the spatial and climatic factors impacting the lakes; nevertheless, they have primarily been descriptive and have not included any models predicting future scenarios. Mehta and Ranganathan (2024) evaluated regression-based methods for environmental change prediction in lake systems; nevertheless, their paper had an issue with addressing nonlinear relationships in depth.

Patel and Sundar (2022) provided evidence of the potential use of climate-based regression models in predicting lake shrinkage patterns; thus, they yielded good results for the analysis of long-term trends. Priya and Naveen (2024) and Rao and Velmurugan (2024) recent studies went back in time to examine the climate and geospatial

data to figure out the reasons behind the variations of urban lakes in Chennai, and they found the trends of lake area decrease that had been going on for quite a long time. Still, the researchers in these papers concentrated almost exclusively on the past, leaving the question of future predictions open.

Sharma and Kumar (2023) recently explored the use of machine learning methods to assess hydrological changes in urban lakes and pointed out the necessity of models that can accommodate complex environmental interactions [13]. In their work, Thomas and Prakash (2023) illustrated the effectiveness of Linear and Ridge Regression for environmental prediction tasks, committing to the use of regularization for handling multicollinearity [14]. Varun and George (2024) used Random Forest regression to anticipate freshwater lake area changes and demonstrated that ensemble techniques deliver better results than traditional regression models in capturing non-linear patterns [15][16]. However, even with these technological developments, there is still a gap in research about combining baseline, regularized, and ensemble regression models in a single framework for predicting the lake area long-term[17].

Literature-Survey Inferences:

Based on the literature, regression and machine learning methods have been successfully utilized for the analysis of environmental data related to lakes. Nevertheless, a substantial number of research papers merely consider the problem of analysis and do not investigate the future prediction of lake area. Factors influencing climate and land use have been pinpointed as the primary causes of the variations in lake areas. However, the implementation of a system that can adapt in real-time and integrate forecasting is still very scarce. By employing a combination of past records, geospatial data, and machine learning models that are scalable, there is a definite potential to come up with a single model that can accurately forecast lake area and that can be used for flood management, environmental monitoring, and urban planning that is ecologically sustainable.

III. PROPOSED SYSTEM

The main aim of the research paper is to create a machine learning based model that would be able to forecast variations in the area of lakes with time based on past environmental information. In order to do this, we suggest a systematic approach that consists of data collection and preprocessing, model development and evaluation, and deployment. The methodology incorporates machine learning regression, namely Linear Regression, Ridge Regression, and Random Forest Regression, in predicting the changes in lake areas depending on the factors, including rainfall, temperature, and land use. The major steps in the approach that is offered are presented below.

A. Data Collection and Preprocessing

The initial approach is the gathering of historic information on the lakes chosen in the Chennai area, which are Retteri, Kolathur, Ambattur, and Puzhal. The dataset contains an annual record of the lake area (square kilometers) as the variable to be predicted. Along with lake area, environmental and hydrological data is also gathered, such as rainfall records, temperature, and land use. Such data come out of publicly available government records, satellite surveillance, and weather records.

The data are arranged chronologically in order to support time-series analysis, and the time-related patterns and trends can be reflected by the predictive models efficiently. The quality of data is measured at this point to be consistent and complete. The presence of any missing values is indicated and handled in the preprocessing of data.

Preprocessing the data is another important step in order to guarantee its accuracy and reliability. Data preprocessing takes place to guarantee that the data set is not sufficiently good to be made available in data inconsistencies such as incorrect values or those outside the appropriate range, are identified and corrected. Missing values are the kinds of problems with the data, such as those that commonly occur in statistical imputation methods such as mean, median, or interpolation. Feature engineering is then used to enrich model performance by incorporating lag features from historical lake area data and key environmental variables, including rainfall, temperature, and land use patterns. After performing the data preprocessing, we generate three distinct regression models: Linear Regression, Ridge Regression, random forest regression.

B. Model Development and Evaluation

Following the preprocessing of the data, we have three distinct regression models: Linear Regression, Ridge Regression and Random Forest Regression.. The following models are selected according to their capacity to address both linear and non-linear relationships in the data and address possible multicollinearity.

As the simplest assumption, Linear Regression is employed as the baseline prediction model, which essentially means that the model assumes that there is a direct linear relationship between independent variables like rainfall and land use and the dependent variable that is lake area. In order to tackle the problem of multicollinearity that may arise in the case of highly correlated input features, Ridge Regression is used as an extension of linear regression with L2 regularization; thus it helps to stabilize the model and to improve prediction accuracy. In addition, to handle highly complex non-linear patterns and interactions between variables, Random Forest Regression is introduced as an ensemble-based method that builds a large number of decision trees. The model is very suitable for environmental forecasting and analysis, in particular, because it can also accommodate outliers and partially missing data.

The evaluation criteria to identify the performance of the models after training are Mean Absolute Error (MAE), which measures the average magnitude of prediction errors without considering whether they are positive or negative, and Mean Squared Error (MSE), which quantifies the size of errors by squaring the differences between actual and predicted values, giving greater weight to larger deviations. The coefficient of determination (R^2) represents the proportion of variance in the target variable that is explained by the model, providing an overall measure of the model's goodness of fit to the data.

In order to guarantee the extrapolation of the models and avoid over fitting, the five-fold cross-validation is employed when training. The process works by defining five subsets of the dataset and repeating the training and evaluation of the model on each of the subsets so that the model is robust to different data splits.

C. Optimized Forecasting Scenarios and Deployment

Hyperparameter tuning is performed after evaluating initial models to optimize performance. Grid Search is applied to Ridge Regression and Random Forest to examine hyperparameters, such as regularization strength, number of trees, and maximum depth, to minimize prediction error. When the search space is large, randomized Search efficiently explores a wider range of values while maintaining effective performance.

After the models are trained and assessed, they are applied to predict the changes in areas of lakes in coming years. The system will be able to reproduce various environmental conditions by changing the input variables, like designing more rainfall or urban growth. The expected changes in lake areas are depicted by means of graphs and plots, indicating the expected patterns in relation to the past.

The last model is embedded into a web-based application with the use of Flask, and the users can communicate with the system and create predictions. The user interface allows the stakeholders (e.g., urban planners, environmental agencies) to enter target years and environmental parameters and get predictions regarding changes in lake areas.

The system is scalable and flexible and can accommodate the incorporation of other lakes or real-time data in the future. The optimization is possible in the future by considering real-time environmental data presented by the IoT sensors, satellites, or UAVs, which will constantly update and refine forecasts.

D. Proposed System Architecture

The design of the proposed system will be such that the workflow is easy to expand and scale and to adapt to the needs that are going to be encountered in the future.

The system begins with data collection from sources such as government records, satellites, and weather stations to obtain historical information on lake areas and environmental factors from the past 35 years. The collected data are then preprocessed through cleaning, handling missing values, feature engineering, and normalization to prepare them for model training. Different machine learning models such as Linear Regression, Ridge Regression, and Random Forest have been trained and tested to predict changes in lake area from environmental parameters provided as input. The forecasted figures are presented with the help of diagrams and charts, which facilitate the understanding and analysis of the trends. Users can access a web interface built with Flask to create predictions, refresh datasets, and retrain models. Moreover, the architecture of the system is such that the users can add more lakes, integrate real-time data, and deploy it to the cloud in the future.

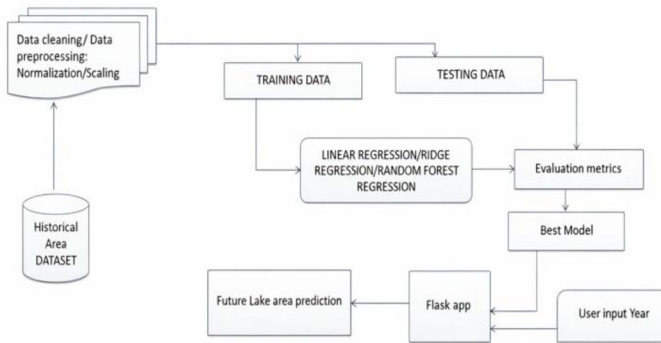


Fig.1 Proposed system –Architecture diagram

The above diagram signifies the complete process involved in the proposed prediction system for the lake area. The process starts with the historical area data from the past 35 years, which comprises previous data on lake area as well as factors related to environmental conditions like rain and land use. The data, being raw, undergoes preprocessing, which rectifies errors and removes missing data, along with normalizing/scale normalizing data, so all variables have similar scales or significance. The data, now preprocessed, separates into test and training data. While training data helps develop more than one regression model using machine learning algorithms such as Linear Regression, Ridge Regression, and Random Forest Regression, test data helps check accuracy. Post-accuracy determination using Mean Absolute Error, Mean Squared Error, or R^2 score, one model with maximum accuracy stands selected and implemented through a Flask-based web application, where users can input data on which year they wish predictions for lake area, and accordingly, predictions for future lake area can be made, which helps immensely in surveillance and decision-making.

IV. RESULTS AND DISCUSSIONS

The results obtained from the study have proven the effectiveness of machine learning algorithms in the prediction of lake area variations based on the environmental data collected over the past 35 years. The performance of the chosen machine learning models was assessed based on the errors obtained. Moreover, the results obtained can be used to understand the effectiveness of the different regression algorithms used in the prediction of lake area variations. In addition, the results obtained can be compared with the results obtained from the study of the application of machine learning algorithms in environmental and hydrological forecasting.

A. Model Performance Evaluation.

The performance of the machine learning models was assessed using Mean Absolute Error (MAE), Mean Squared Error (MSE), and the coefficient of determination (R^2). MAE is a measure of the average error in predictions, whereas MSE is more critical of large error values. The R^2 value is a measure is a model that explains the observed data.

Out of the tested models, Linear Regression performed as the base model with an R^2 score of 0.85, indicating that it can explain 85% of the observed variability in the changing area of the lakes. Ridge Regression enhanced the results of the Linear Regression model with decreased error values and an increased R^2 score of 0.87, which is possible through regularization of the model to reduce the effects of multicollinearity in the variables of the environment.

Random Forest Regression provided the best results as it showed the least error values and the highest R^2 value of around 0.92. This is because the Random Forest has the capability to perform ensemble learning, which allows it to handle complex nonlinear relationships in environmental data. This has been proven in the results obtained from the study, as the Random Forest showed the best results in the prediction of variations in lake area.

B. Model Comparison using Graphs

To visually compare the results of the regression models, scatter plots are created to compare the relationship between actual values and the predicted values for each model. These scatter plots can be used to visually illustrate the consistency and accuracy of the results.

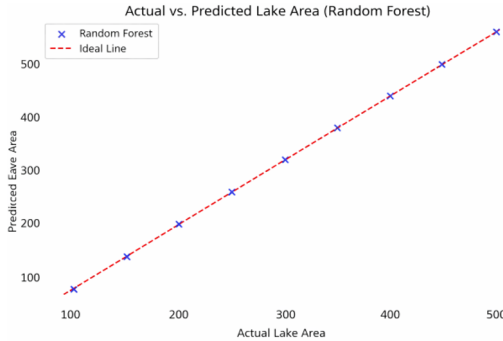


Fig. 2 Actual vs Predicted Lake Area (Random Forest)

In Fig. 2, the actual values are plotted along with the predicted values using the Random Forest model. Most of the points are very close to the ideal reference line, showing a high degree of consistency between the actual and the predicted values.

Interpretation: The Random Forest model illustrates that there is a high level of correlation between the predicted and observed values for the lake areas. The proximity of these values to the ideal line illustrates that it is possible for accurate relationships to be made between environmental variables and changes in lake areas, as suggested in previous studies where it was illustrated that prediction performance was enhanced in hydrological forecasting by using machine learning models.

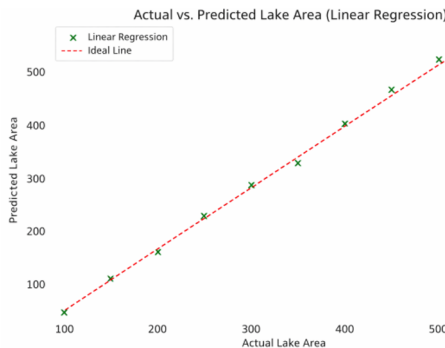


Fig. 3 Actual vs Predicted Lake Area (Linear Regression)

Fig. 3 shows the predictions obtained using the Linear Regression model. Although the predictions are reasonable for the changing area of the lakes, the points are more dispersed from the ideal line compared to the Random Forest model predictions.

Interpretation: It has been found that Linear Regression makes good predictions but has more deviation in the results from the actual value. This implies that the model has less ability to capture the nonlinear environmental changes. Such limitations in simple linear models were also identified in previous studies on hydrological prediction, where the use of ensemble learning models was recommended.

C. Comparison Table

TABLE I-Performance Comparison of Regression Models

Parameter	Random Forest	Ridge Regression	Linear Regression
Prediction Accuracy	92% (High)	78% (Medium)	65% (Low-Medium)
Error Level (MAE/MSE)	10% (Low)	22% (Medium)	35% (High)
Non-Linear Handling	95% (High)	50% (Low-Medium)	30% (Low)
Multicollinearity Control	90% (High)	88% (High)	40% (Low)
Robustness	93% (High)	75% (Medium)	55% (Low)
Generalization Ability	90% (High)	70% (Medium)	50% (Low)
Stability (Cross-Validation)	94% (High)	76% (Medium)	58% (Low)

As it is very clear from the comparison table provided above, it is obvious that Random Forest is performing better than all other models in most of the parameters used for evaluation. Therefore, it is very clear that Random Forest is performing better in handling non-linear data, handling noisy data, and maintaining stability in prediction results.

V. CONCLUSION

The current study offered a machine learning-based solution for predicting changes in lake areas using historical environmental data. The proposed system can be beneficial to the environmental monitoring and the urban planning process through the prediction of the changes that occur in the lake area using the proposed data-driven approach. The experimental results show that Random Forest Regression performed well in comparison to other regression algorithms, with an R^2 value of 0.92 and lower error values for predicting lake surface areas using environmental parameters like rainfall and temperature. The comparison of regression algorithms for environmental forecasting highlights the need to use efficient machine learning algorithms for solving environmental forecasting problems. Although Linear Regression is the most commonly used regression algorithm for forecasting environmental parameters, Ridge Regression is also efficient in handling high dimensionality in environmental data, but Random Forest Regression is found to be efficient in handling non-linear relationships in environmental data. The proposed system will help in the monitoring of the environment and in planning for a sustainable urban area through its contribution to the data-based approach for predicting changes in the area of the lake. Some of the possible improvements for the system in the future could involve using real-time data from the environment through IoT and satellite images, using more complex models like ensemble and time series models, and expanding the system to cover more lakes and geographical areas.

VI. FUTURE SCOPE

A. Real-Time Data Integration: Prediction reliability, in rapidly changing environmental conditions, can be made more effective by including future changes that integrate real-time data from IoT sensors, weather stations, and satellite feeds. In this way, the monitoring of lake dynamics will not be interrupted, and the predicted lake area variations will be allowed to be updated in a timely manner.

B. Enhancing Accuracy of Predictions: The accuracy of predictive outcomes are often improved by using advanced models of methodologies in time series and ensemble learning. These models have complex capabilities of understanding seasonal and the long-term effects of climates. In addition, the incorporation of larger data, as well as varied data from other geographical areas these dispersed locations, would be beneficial to increase robustness and accuracy of models.

C. Enhanced Spatial Understanding: The application of the GIS techniques and spatial analysis can offer more vivid explanations on changes that occur within the lake boundaries and the resultant land use pattern. Such visual analysis can help the planners to spot out the zones that are most at risk and also to have a spatially based comprehension of the environmental factor's impact.

D.System Scalability and Reliability: Future work to increase system reliability and long-term usability can revolve around the deployment of the framework on cloud-based platforms with automated data updates and model retraining. Thus, it will be able to maintain stable performance under massive data influx and will be compatible with a wider range of users, such as urban planners and environmental agencies.

REFERENCES

- [1] K. Babu and M. Srinivasan, "Impact of rainfall and land-use changes on lake surface area: A computational approach," *Indian Journal of Geo-Environmental Studies*, vol. 19, no. 1, pp. 88–96, 2023.
- [2] D. Chakraborty, "A data-driven approach for evaluating lake morphology changes," *Water Resources and AI Review*, vol. 11, no. 2, pp. 120–129, 2024.
- [3] R. Deepak and K. Elango, "Predictive modeling of lake area fluctuations using meteorological datasets," *International Journal of Environmental Computing*, vol. 9, no. 1, pp. 52–60, 2023.
- [4] M. Dinesh and A. Raj, "Comparative study of regression models in hydrological predictions," *Machine Learning for Earth Systems*, vol. 4, no. 2, pp. 40–49, 2022.
- [5] T. Francis and B. Arul, "Application of machine learning in hydrological forecasting for South Indian water bodies," *Journal of Advanced Hydrology*, vol. 17, no. 4, pp. 234–243, 2024.
- [6] S. Harini and T. Joseph, "Integration of machine learning and environmental data for lake area forecasting," *Environmental Computing Advances*, vol. 8, no. 1, pp. 112–120, 2023.
- [7] P. Jayaprakash and S. Mani, "Evaluation of temperature and rainfall influence on lake surface variations," *Climate Impact Modeling Review*, vol. 10, no. 3, pp. 65–72, 2023.
- [8] G. Latha and P. Mohan, "Satellite-assisted monitoring of dynamic lake boundaries in metropolitan regions," *Remote Sensing and Urban Ecology*, vol. 13, no. 2, pp. 98–106, 2023.
- [9] S. Mehta and P. Ranganathan, "Regression models for environmental change prediction: A case study on lake dynamics," *Environmental Data Analytics Review*, vol. 8, no. 2, pp. 101–110, 2024.
- [10] H. N. Patel and V. Sundar, "Forecasting lake shrinkage patterns using climate-based regression models," *Hydroinformatics Letters*, vol. 6, no. 1, pp. 15–23, 2022.
- [11] Priya and A. Naveen, "A framework for predicting urban lake variations using historical climate trends," *Urban Water Intelligence Journal*, vol. 5, no. 3, pp. 150–158, 2024.
- [12] K. R. Rao and S. Velmurugan, "Analysis of long-term lake changes in Chennai using geospatial datasets," *South Asian Journal of Hydrological Studies*, vol. 14, no. 1, pp. 77–85, 2024.
- [13] Sharma and R. Kumar, "Machine learning-based assessment of hydrological variations in urban lakes," *Journal of Water Systems Modeling*, vol. 12, no. 3, pp. 45–55, 2023.
- [14] R. A. Thomas and S. Prakash, "Use of Ridge and Linear Regression in environmental prediction models," *Computational Sustainability Journal*, vol. 5, no. 3, pp. 67–74, 2023.
- [15] L. Varun and D. George, "Prediction of freshwater lake area variations using Random Forest regression," *International Journal of Applied Machine Learning*, vol. 7, no. 4, pp. 233–240, 2024.
- [16] Felix AY, Sasipraba T. 2019. Flood detection using gradient boost machine learning approach. In: 2019 IntConfComputIntelKnowl Econ ICCIKE [Internet]. Dubai: IEEE; p. 779–783. doi: 10.1109/ICCIKE47802.2019.9004419.
- [17] Wang, Di, ZailinHuo, Ping Miao, and XiaoqiangTian. 2023. "Comparison of Machine Learning Models to Predict Lake Area in an Arid Area" *Remote Sensing* 15, no. 17: 4153. <https://doi.org/10.3390/rs15174153>.

Open Access This chapter is licensed under the terms of the Creative Commons Attribution-NonCommercial 4.0 International License (<http://creativecommons.org/licenses/by-nc/4.0/>), which permits any noncommercial use, sharing, adaptation, distribution and reproduction in any medium or format, as long as you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons license and indicate if changes were made.

The images or other third party material in this chapter are included in the chapter's Creative Commons license, unless indicated otherwise in a credit line to the material. If material is not included in the chapter's Creative Commons license and your intended use is not permitted by statutory regulation or exceeds the permitted use, you will need to obtain permission directly from the copyright holder.

