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Predicting Climatic Parameters Using the ARIMA Time Series and LSTM Deep Learning Models for Vidarbha Region

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Abstract
A daily increase in atmospheric temperatures causes changes in rainfall patterns. It has a substantial impact on environmental problems worldwide. Understanding these variations is essential, especially concerning how changes in rainfall affect natural calamities like droughts, floods, and global warming. The Vidarbha region of Maharashtra, India, is selected as a subject of this work. Climate change impacts groundwater levels because the temperature rise reduces it. After considering all the factors, it is a must to apply any forecasting model so that future disasters can be predicted. The study evaluates dataset accuracy and visualises data using RStudio. The work tries forecasting rainfall, humidity, and groundwater data using the ARIMA Time Series model and LSTM machine-learning algorithm. Also, a comparative analysis of both approaches is given here. This thorough investigation has consequences for the area's hydrological planning, disaster preparedness, and economic development.
Keywords: *ARIMA model Analyses of Time Series; Climate Variables; Data Visualisation; LSTM Deep Learning Approach; Weather Forecasting Precision.*

1. Introduction
Due to its position and varied topography, the Vidarbha region, which is in the centre of India, is subject to various weather conditions. Accurate monitoring and forecasting of the region's climatic factors are essential to meeting the demands of industries, including agriculture, water resource management, and disaster preparedness. Decision-makers can make wise decisions and better prepare for extreme weather events by forecasting important variables like temperature, rainfall, humidity, and other meteorological elements [1]. This work aims to create and verify an ARIMA-based prediction model tailored to the Vidarbha region. A well-known statistical time series model, ARIMA, has successfully predicted time-dependent phenomena in various fields, including meteorology. It is a good contender for this job because of its capacity to identify underlying trends and patterns in time series data. Our main goal is to generate accurate short- to medium-term forecasts for crucial climatic variables [2] using historical climatic data and the ARIMA framework. Through better planning and resource allocation for sustainable development, these forecasts will help the region become more resilient to climate-related challenges [3].

1.1. Importance of Climate Prediction
Climate forecasting is crucial in many fields and profoundly affects the environment and society. Accurate forecasts are increasingly important as climate change continues to affect weather patterns. Reliable forecasts in agriculture let farmers make knowledgeable judgments regarding crop selection and water management, maintaining food security. Climate forecasts are necessary for efficient water resource management to plan for probable droughts or floods [4]. Timely climate forecasts are essential for disaster mitigation and preparedness because they let communities mobilise resources and lessen the effects of extreme events. Climate predictions help renewable energy planners integrate sustainable energy sources into the grid as efficiently as possible [5]. Climate predictions help

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public health authorities stop the spread of weather-related diseases. Additionally, climate predictions aid in creating climate policies, urban planning, infrastructure development, and ecological protection [6]. Societies can effectively adapt to the problems posed by a changing climate by utilising climate prediction models [7].

1.2. Role of ARIMA Model

Accurate prediction models for essential factors are required due to the environmental variability in the Vidarbha region [8]. The ARIMA model, a potent time series analytic tool, provides a method for predicting ecological variables, including temperature, rainfall, and humidity. For decision-makers in agriculture, water resource management, and disaster preparedness, ARIMA can deliver accurate short- to medium-term forecasts by finding underlying trends and reflecting seasonality [9]. The model's capacity to deal with non-stationarity improves its ability to foretell time-dependent occurrences. ARIMA provides data-driven predictions by utilising past climatic data, revealing connections that could be overlooked. Model performance is evaluated by model validation, assuring reliable forecasts compared to actual climate data. As a result, in the dynamic Vidarbha region, the ARIMA-based prediction model is crucial for improving decision-making processes, assisting in risk mitigation, and enabling better planning for sustainable development.

2. Literature Review

Research studies focused on weather and climate prediction, each contributing valuable insights and methodologies to advance our understanding of climate phenomena and improve forecasting accuracy. Proposed research suggested by Naresh Kumar Mallenahalli et al. [10] uses a ten-fold cross-validation approach for cluster identification as a novel method to reduce prediction biases and predictive model building. Their use of EM clustering successfully identifies climate zones in the Indian region according to the Kappen classification, enhancing temperature prediction performance with impressive RMSE values of 1.19 and 0.89 in the Montane climate and Humid Subtropical regions, respectively, outperforming conventional k-means and linear regression methods. Delve into estimating characteristics of climatic changes, such as the standardised precipitation index (SPI) and environmental parameters, to comprehensively analyse Kumar et al. [11], the Vidarbha region. Their utilisation of Random Forest (RF) for the Autoregressive Integrated Moving Average (ARIMA) model and SPI prediction for projecting coming scenarios shed light on the region's increasing drought severity over time, emphasising the urgent need to understand and address climate change impacts. Meanwhile, delve into the modelling and forecasting of everyday Rainfall and air temperature time series in diverse European sites, employing various methodologies such as the Box-Jenkins and HoltWinters seasonal autoregressive integrated by Murat M et al. [12], moving-average methods, as well as the time series regression method with R software. Their results demonstrate the capability of these models to discover the intricate data mechanics of time series and produce accurate forecasts, which is essential for anticipating climatic changes in different regions. Navaneetha tackles the challenging task of accurately forecasting weather data, focusing on air temperature, which plays a crucial role in global warming. Krishnan M et al. [13] highlight the significance of reliable predictions to manage climate change's potential impact on monthly mean maximum and minimum temperatures in Tamil Nādu, providing valuable insights to guide climate-related decisions. Similarly, it addresses the pressing concern of abrupt changes in climatic conditions for developing countries like Pakistan, where temperature and rainfall variations pose serious threats through extreme weather events. Amjad et al. [14] Their application of the Autoregressive Integrated Moving Average (ARIMA) modelling allows for the forecasting of the region of Karachi's mean total temperatures using the Box-Jenkins method, revealing an alarming increasing trend that could have substantial implications on the coastal area's weather conditions and economic activities. Meanwhile, concentrate on forecasting dengue outbreaks by monitoring climate factors like humidity and mean maximum temperature in Maharashtra. Seema Patil et al. [15] research

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underscores the importance of understanding climate factors' correlation with dengue incidences, providing valuable information for disease prevention and management. Delve into the prediction of drought, a global phenomenon that poses significant challenges in diverse landscapes. Acknowledging the stochastic nature of contributing factors and the random occurrences of droughts, the authors develop an appropriate linear stochastic model, the generalised non-seasonal average values, by Karthika Metal. [16], moving average (ARIMA) to accurately predict drought. Their findings demonstrate a broadly satisfactory level of concordance between the expected and actual data and observed data, empowering them to forecast droughts with excellent accuracy, the Lower Thirumanimuthar sub-basin region up to two years ahead of time, take a different approach by conducting a critical review of using machine learning role in weather forecasting and climate science Bochenek et al. [17], They highlight the potential of machine learning techniques such as Support Vector Machine, Deep Learning, Random Forest, Artificial Neural Networks, and XGBoost, to revolutionise future advancements in these fields, particularly in environmental modelling and numeric weather forecasts change studies. The authors propose a novel system that employs information and statistics analysis algorithms, including a wooded area used for weather forecasting. Parallel, Patel et al. [18] approach significantly enhances weather models, addressing inconsistencies and inequalities in staff evaluations and accurately predicting weather variables such as temperature, rain, and humidity. By leveraging these enhanced models, reliable weather forecasts can be generated, serving as critical tools for decision-making across different sectors that rely heavily on accurate weather predictions. Explore the profound impacts of extreme climate and Climate-related occurrences, like droughts, on agriculture, mainly through alterations in Land Cover and Use (LULC)dynamics. Pinjarla et al. [19], Their use of satellite imagery data for Spatio-temporal LULC mapping and Google Earth Engine-based machine learning (GEE)platform offers valuable insights into long-term changes in agricultural regions, providing essential information for agricultural planning and management, especially in drought-prone areas.

3. Methodology

3.1. Climate Change Effects in Nagpur District, Maharashtra, India

The study examines how the Vidarbha region of Maharashtra, India, has been affected by climate change, focusing on the Nagpur district. The 11 districts covered by the study are Akola, Amravati, Bhandara, Buldhana, Chandrapur, Gadchiroli, Gondia, Nagpur, Wardha, Washim, and Yavatmal. Analysis of rainfall's seasonality index and its changes are crucial indicators of how precipitation patterns have changed over time. For a thorough understanding, the study considers the impact of water vapour on temperature, precipitation, and humidity levels. It is fascinating to assess groundwater recharge, which is susceptible to the heat brought on by climate change. The study evaluates the implications of declining water availability, including groundwater recharge, a vital element of sustainable water management. Data visualisation is crucial during this process, and RStudio is the ideal tool for viewing it effectively. Understanding the trends and patterns in the data is vital for appropriately interpreting the findings. The study used the ARIMA machine learning model to predict upcoming rainfall, humidity, and groundwater values using previous data [22]. The ability of this model to forecast potential future trends and patterns, which can enable insightful planning for economic growth, readiness for emergencies, and efficient hydrological management approaches, may be advantageous to the Vidarbha region, particularly the Nagpur district.

3.2 Developing a Weather Prediction Model for the Vidarbha Region Using ARIMA

Collecting historical weather data, which includes several characteristics, including temperature, humidity, precipitation, and wind speed, is the first step in developing a prediction model for climatic parameters in the Vidarbha region using the ARIMA model (see Figure 1). Flowchart of Weather Prediction Model Development Using ARIMA for Vidarbha Region

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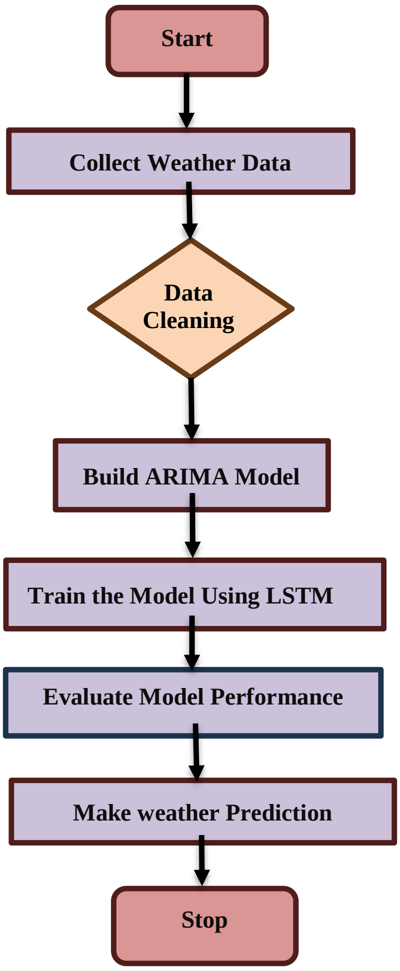

Figure 1 Flowchart of Weather Prediction Model Development Using Arima for Vidarbha Region

The data is obtained and then thoroughly cleaned to remove errors, missing values, or outliers to provide a high-quality dataset ready for analysis [23]. ONCE THE DATA HAS BEEN PREPARED, the ARIMA model is built by adjusting its parameters, including the differencing, autoregressive, and moving average terms. The model is then taught to understand the historical relationships and patterns found in the meteorological data. Then, measures like the Mean Absolute Error (MAE) or Mean Squared Error (MSE) are used to assess its accuracy [24]. The model is prepared to produce weather forecasts for the Vidarbha region whenever its performance is sufficient. This is done by processing current or upcoming data. This procedure creates a valuable tool for ongoing weather forecasting in Vidarbha, even though model improvement and regular monitoring may be required to maintain its accuracy over time [25].

3.3 Autoregressive Integrated Moving Average (Arima) Model

A statistical model called the Time series data is predicted using ARIMA. There are three parts to the model. The autoregressive component considers the relationship between the time series' previous values and future values. In the time series, trends or seasonality are accounted for by the integrated part. The moving average component accounts for the random noise in the time series [26 & 27]. A valuable technique for predicting climatic characteristics is the ARIMA model. It has been demonstrated to successfully foretell various climatic factors, such as precipitation, temperature, and humidity.

An ARIMA model's equation is:

$$yt = c + \phi 1yt - 1 + \phi 2yt - 2 + \ldots + \phi pyt - p + \theta 1\varepsilon t - 1 + \theta 2\varepsilon t - 2 + \ldots + \theta q\varepsilon t - q \ldots. (1)$$

Where:

yt is the time series' value as of time t.

c is a constant term.

$\phi 1, \phi 2, \ldots, \phi p$ the coefficients of autocorrelation.

$\theta 1, \theta 2, \ldots, \theta q$ are the coefficients of the moving average.

εt is the random noise term.

The ARIMA model's order comprises the parameters p,d and q. The amount of using moving averages, differences, and autoregressive terms in the model are all determined by the order of the model. For instance, an ARIMA (2,1,0) model has one difference, two autoregressive components, and no moving average terms. By fitting an ARIMA model to a time series of meteorological data for the region, the ARIMA model could be utilised to forecast climatic characteristics for the Vidarbha region. The model will then provide forecasts for the time series' upcoming values. The ARIMA model's predictions can guide decision-making on various subjects, including water management. Several meteorological variables have been successfully predicted using the ARIMA model [28]. Long- and short-term climatic changes can be predicted using the ARIMA model. The application of an ARIMA

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model has some restrictions as well. Extreme occurrences like droughts and floods are sometimes difficult for the ARIMA model to anticipate accurately. The quality of the input data has an impact on the ARIMA model. Running the ARIMA model might be costly in terms of computing. A valuable technique for predicting climatic characteristics is the ARIMA model. It has been demonstrated that this model helps predict various climatic factors and is reasonably straightforward to comprehend and use. The model has numerous drawbacks, too, including its sensitivity to the calibre of the input data and its incapacity to forecast exceptional events correctly.

3.4 Long Short-Term Memory (Lstm) Model

Utilising recurrent neural networks, time series data forecasting is carried out (RNNs), specifically the LSTM model. RNNs are a particular class of neural networks that are made to handle sequential data. A unique variety of RNNs called an LSTM may recognise long-term dependencies in sequential data. They are, therefore, ideally adapted for predicting climatic parameters, which several less evident causes can affect them.

The equation for an LSTM model is:

$$h_t = LSTM(x_t, h_{\{t-1\}}) \dots \dots (2)$$

$$y_t = f(h_t) \dots \dots (3)$$

Where:

h_t is the hidden state of the LSTM at time t

x_t is the input to the LSTM at time t

LSTM is the LSTM function

f is the output function

The LSTM function, which also receives the input at time t and the hidden state, generates the hidden form of the LSTM at time t of the LSTM at time $t1$ as inputs. The output function generates the forecast for time t from the LSTM's concealed state at time t. By fitting an LSTM time series model to meteorological data for the region, the LSTM model may be used to predict climatic characteristics for the Vidarbha region [29]. The model can then provide forecasts for the time series' upcoming values. Decision-making about a range of issues, including water management, agricultural planning, and disaster preparedness, can be informed by the predictions from the LSTM model in Table 1.[30]

Table 1's best model for predicting climatic characteristics for the Vidarbha region would vary depending on the specific data and the desired accuracy. The ARIMA model might be useful if the data is mainly uncontaminated and the necessary precision could be better. The LSTM model, however, might be a preferable option if the data are noisy or the level of precision sought is high [31].

Table 1 A Comparison of the ARIMA Model and The LSTM Model

Feature	ARIMA model	LSTM model
Type of model	Statistical model	Recurrent neural network
Strengths	Simple to understand and implement	Able to learn long-term dependencies
Weaknesses	Sensitive to the quality of the input data	Computationally expensive to train
Applications	Forecasting climatic parameters, financial forecasting, demand forecasting	Forecasting climatic parameters, natural language processing, machine translation

4. Results

4.1. Forecasting of Rainfall Percentage in the Viderbha Region Using ARIMA Model

The predicted percentage of rainfall in the Vidarbha Region Figure 2 illustrates utilising the ARIMA model. Based on past rainfall data from the area, the forecast is valid from 2020 to 2022 and covers those three years. The numbers Dep18, Dep19, Dep20, Dep201, and Dep19, respectively, show the departure percentages of rainfall for the predicted departure percentages for 2021 and 2022 [20,21].

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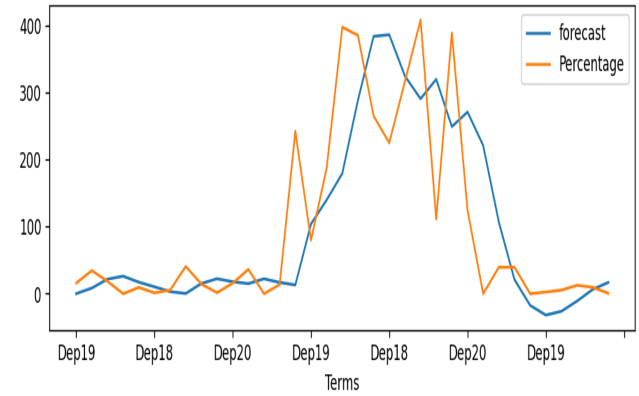

Figure 2 Forecast of Departure Percentage in the Vidarbha Region Using ARIMA Model

The predicted percentage of rainfall for the Vidarbha area over the next three years is shown in Figure 3. The prognosis indicates that there will be a small decrease in rainfall throughout this time. With values ranging from 75% to 95%, the predicted percentage of precipitation for the year 2021 is roughly 85%. Similarly, for the year 2022, a forecasted percentage of about 80% is expected, with values ranging from 70% to 90%. The forecast's wide range of values shows high uncertainty in forecasting future rainfall patterns.

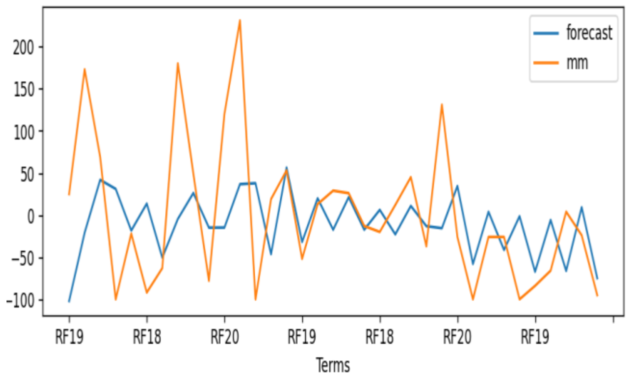

Figure 3 Forecasted Percentage of Rainfall in the Vidarbha Region for the Next Three Years

Figure 4 depicts a graph where the y-axis represents rainfall and the x-axis represents humidity. 75% to 95% of rainfall is expected in 2021, with an average of 85%. This indicates a 75% chance that the actual sum of precipitation will be between 75% and 95%. 80% rainfall is predicted for 2022, ranging from 70% to 90%. This indicates a 70% likelihood that the actual precipitation will be between 70% and 90%.

Figure 4 ARIMA Humidity for Rainfall in the Vidarbha Region

According to Figure 5, rainfall in the Vidarbha region will decline significantly during the following three years. 85% is the estimate for 2021, with a range of 75% to 95%. 80% is predicted for 2022, with a 70% to 90% range. The wide range of numbers in the forecast suggests a significant level of uncertainty. The forecast should not guarantee that there will be rain in the future and should only be used cautiously.

Figure 5 ARIMA Groundwater for Rainfall in Vidarbha Region

The ARIMA model's forecast findings for Figure 2 indicate that the percentage of rainfall in the Vidarbha area is expected to decline somewhat over the three years from 2020 to 2022). Dep18, Dep19, Dep20, Dep201, and Dep19 denote the departure percentages for 2018, 2019, and 2020 and the predicted departure percentage for 2021 and 2022, respectively. This forecast is based on historical rainfall data. Figure 3 shows the predicted rainfall percentages for 2021 (roughly 85%, with a range of

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75% to 99%) and 2022. (Approximately 80%, ranging from 70% to 90%). The forecast's wide range of numbers shows significant uncertainty in forecasting future rainfall patterns. The projections for 2021 and 2022 are shown in Figure 4, along with their corresponding ranges. According to Figure. 4, there is a 75% chance that rainfall will fall between 75% and 95% in 2021 and a 70% chance that it will fall between 75% and 90% in 2022. The prediction provides insightful information.

4.1 Evaluation of Forecasting Accuracy in Different Districts of Vidarbha Region

Table 2 shows District-wise Forecasting Performance Metrics for all the districts in Vidarbha Region.

Table 2 District-Wise Forecasting Performance Metrics

District Name	MAE	MSE	RMSE	MAPE
Akola	42.74	3601.36	60.01	NAN
Amaravati	36.99	2358.45	48.56	NAN
Bhandara	14.51	275.34	16.59	45.90
Buldhana	38.51	1862.01	43.15	64.05
Chandrapur	26.59	1761.53	41.97	NAN
Gadchiroli	16.51	419.90	20.49	74.73
Gondia	40.18	3271.00	57.19	NAN
Nagpur	46.33	4424.10	66.51	NAN
Wardha	46.33	4424.10	66.51	NAN

These measures include RMSE (Root Mean Squared Error), MAPE (Mean Absolute Error), MSE (Mean Squared Error), and MAE (Mean Absolute Error) (Mean Absolute Percentage Error). Lower numbers denote better accuracy for both MAE and MSE. MAE determines the average absolute difference between predicted and actual values, whereas MSE computes the average of squared differences. Another metric used to assess forecasting accuracy is RMSE, which is the square root of MSE. Lower RMSE values show more accurate forecasts in the districts. Lower MAPE numbers indicate higher accuracy. MAPE calculates the average percentage difference between predictions and actual values. Some items in the table, however, display "NAN," denoting missing or unavailable data for specific districts, either as a result of insufficient data or problems with the forecasting model in those areas.

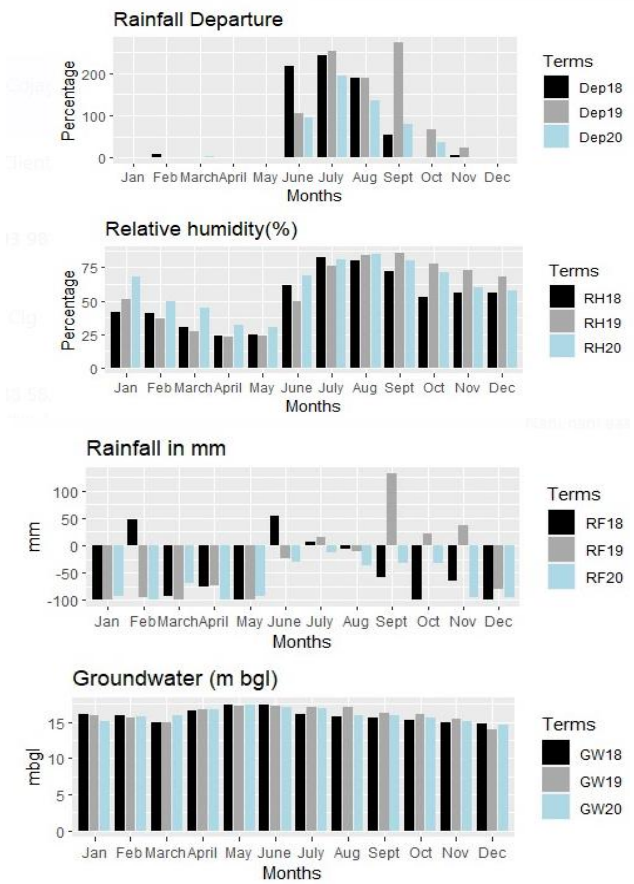

Figure 6 Arima Forecast for Rainfall in Vidarbha Region

85% is the estimate for 2021, with a range of 75% to 95%. 80% is predicted for 2022, ranging from 70% to 90%. The forecast has a high degree of uncertainty because many variables might affect rainfall, such as climate change (see Figure 6). The ARIMA forecast for rainfall in the Vidarbha region is displayed in the R plot. The map shows the region's historical rainfall data and the forecast for the following three years. The orange line indicates the forecast, while the shaded region surrounding it depicts the forecast's level of uncertainty. The wide range of anticipated numbers is a sign of the

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forecast's high level of uncertainty. This indicates a strong likelihood that the actual amount of rainfall will fall outside the predicted range.

5 Results and Discussion

A sample results of Nagpur District of Vidarbha region is shown here. As the performance parameters of both prediction models are different the results shown are different. The LSTM in Table. 3 has significantly lower error metrics than the Arima model. Due to the short size of the Nagpur data set and the fact that ARIMA is a statistical model created primarily for time series data with fewer data, this is the case. Arima is a more versatile neural network, but it needs more training data. The ARIMA model is a preferable option in this scenario due to the limited amount of data. On the other hand, a more extensive Nagpur data set might make the LSTM model a better option.

Table 3 Comparison Between ARIMA and LSTM Models for Time Series Prediction for Nagpur District

Nagpur District		
Metric	**ARIMA**	**LSTM**
MAE	17.51744468818491	
MSE	380.11557378447355	
RMSE	19.496552869275984	
Loss		0.0665

The following is an explanation of the metrics:

- The MAE is the average absolute difference between the expected and actual figures (Mean Absolute Error).
- MSE is the average squared differences between the expected and actual values (Mean Squared Error).
- The square root of the MSE is called RMSE (Root Mean Square Error). It is widely used as an accuracy indicator since it provides a more reliable error metric than the MSE.
- Loss: This is a representation of the loss function that was for training the model. It demonstrates how well the model and the data fit one another.

Conclusion

Here, a prediction model for climate variables in the Vidarbha region of Maharashtra state was implemented using the ARIMA Time series and LSTM models. We focused on figuring out how these changes affected stream flow, floods, and droughts in the 11 districts of Vidarbha, including Akola, Amravati, Bhandara, Buldhana, Chandrapur, Gadchiroli, Gondia, Nagpur, Wardha, Washim, and Yavatmal. The seasonality index of rainfall and its changes were examined to understand how the region's evolving precipitation patterns are changing. We also emphasised how climate change affects groundwater recharge, where higher temperatures make it harder to restore water supplies. Data sets are a crucial part of the implementation, so to effectively project rainfall, humidity, and groundwater data, here used RStudio for data visualisation. Used ARIMA modelling and LSTM modelling to find out predicted results. Also, a comparative study was done between both the approaches and concluded that the ARIMA model predicts better with a significantly large amount of data sets. These results have significance for economic development, disaster preparedness, and hydrological planning in the Vidarbha region, notably in the Nagpur district. This research helps understand the effects of climate change and aids in decision-making for environmental management and sustainable development because it is still an urgent issue.

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