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Future Rainfall Forecasting for Water Supply Management in Agriculture

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Abstract: Precipitation forecasting and water supply management enable farmers to make informed decisions, optimize crop yields, reduce risks, conserve resources, and contribute to food security and economic stability. Important for agriculture. Actual rainfall is often not sufficient to support plant growth. Therefore, the aforementioned knowledge will help farmers estimate the amount of water provided through different farming techniques. Accurate forecasting helps farmers manage water according to crop needs. This information is critical to maximizing agricultural productivity. This article examines the rainfall forecasting method by analysing key parameters such as maximum temperature, minimum temperature, maximum humidity, minimum humidity, evaporation, average wind speed, and wind direction for Pune district, Maharashtra. Furthermore, it takes into account the water requirements of commonly cultivated crops. This holistic analysis informs the decision-making process regarding crop irrigation, determining both the necessity and the appropriate volume of water allocation to the crops.
Keywords: XGBoost, Linear regression, Random forest, Rainfall prediction, Water management, Irrigation, agriculture and IoT.

I. INTRODUCTION

The role of precipitation forecasting and water supply management is essential. As the effects of climate change continue to disrupt traditional weather patterns, the need for accurate precipitation prediction and efficient water resource allocation becomes increasingly important. The purpose of this article is to examine the complex interactions between precipitation forecasting and water supply management in agriculture, and to address these challenges and promote innovative strategies in optimizing crop yields. is to recognize their joint importance. The challenge of managing water supply to crops requires a delicate balance as both excess and deficiency can have deleterious consequences. Oversupply can cause problems such as salinity, while undersupply can lead to lower crop yields.

Thus, estimating the right amount of water is paramount for enhancing agricultural productivity. Extensive research has identified specific meteorological features—temperature, humidity, evaporation, average wind speed, and total rainfall—as critical for precise rainfall forecasting in a given region. The data for these features is collected by sensors and serves as the foundational input for our system. Our system leverages machine learning techniques to harness this data. It preprocesses the information and employs sophisticated algorithms to predict rainfall. Based on this predicted rainfall, our system effectively determines the amount of water that needs to be provided to the crop and provides the right amount to optimize crop yield and alleviate water-related challenges. water supply. This article explores innovative solutions that positively impact the sustainability and productivity of agricultural landscapes by considering the subtle dynamics of precipitation forecasting, water supply management, and their critical role in agriculture. It is intended to provide insight. In this study, only a few common crops were considered (see Table 2). Relevant meteorological data such as temperature, humidity, evaporation, average wind speed, and total precipitation are collected from sensors in Pune district, Maharashtra.

This data is stored in a dataset for further analysis. The system preprocesses the collected data, corrects missing values and outliers, and ensures that all features are at a consistent scale. The necessary encoding of categorical data is performed. Machine learning algorithms such as random forests, linear regression, and XGBoost are used for precipitation prediction. These models are trained using historical weather data. The system evaluates the accuracy of each machine learning model using appropriate metrics, such as mean absolute error (MAE), mean squared error (MSE), and classification accuracy, depending on the type of precipitation prediction task. The system selects the most accurate model and generalizes well to previously unknown data to ensure reliable precipitation forecasts. Using the selected model, the system predicts precipitation for on per day basis. Based on this rainfall forecast, the amount of water required for the selected crop type is calculated. The system provides users with recommendations on the amount of water needed for proper irrigation and crop management, tailored to the specific crop type and local climate conditions.

II. LITRATURE REVIEW

1) *Utilization of IoT Sensors for monitoring atmospheric parameters [1]:* focuses on using IoT sensors extensively to monitor atmospheric conditions and improve real-time weather assessment and forecast accuracy through wireless networking. Combining IoT data with satellite observations and models will improve weather forecasting and make atmospheric cyclone predictions more accurate. This research covers a variety of sensors and provides a valuable resource for meteorological departments, environmental protection agencies, corrosion assessment agencies.
2) *Measure the hazardous gases using IoT Sensors [2]:* frequently goals to apprehend climate influencers, along with temperature, pressure, humidity, and environmental pollutants. It makes use of a Raspberry Pi-primarily based totally climate tracking gadget with sensors like DHT22, BMP180, MQ3, MQ7, and MCP 3208. Historical climate facts spanning 4 decades, blended with superior neural community models, complements correct destiny climate predictions, promising improvements in climate tracking, forecasting, and environmental assessment.
3) *Rainfall Forecasting in Bijapur District Karnataka[3]:* This article describes a system that uses historical rainfall data to predict rainfall patterns. It helps farmers in Bijapur district of Karnataka to select suitable crops. Although this study covers his 20 years of rainfall data, data mining techniques can be further improved to benefit farmers.
4) *Future Rainfall Estimation by Humidity,Temprature and Rainfall received [4]*: Estimating effective precipitation mainly depends on three important factors: humidity, temperature, and precipitation. Water is an important natural resource and rainfall data is critical to the region. Mathematical climate models can significantly improve precipitation predictions by linking large-scale weather and local observations to create region-specific precipitation models.
5) *Rainfall Prediction Techniques for flood specific area [5]* : Floods endanger lives, cause economic disruption, and disrupt daily life. Predicting river flooding mathematically is essential, but its complexity comes from a variety of factors, including climate, river flow, precipitation, soil, and location. Despite advances in hydrology, traditional methods still have some degree of error.
6) *Extreme Rainfall Prediction Model [7]:* The authors proposed a version that is based on high quality correlation coefficients among unbiased meteorological indices, including floor and air temperatures. They applied statistics on severe rainfall. events, floods, and coastal herbal failures in Saudi Arabia to set up the standards for his or her version.
7) *Future Rice Production Forecasting [8]:* The work discussed in played an important role in the advancement of forecasting methods to predict future rice production. In the experimental study, the researchers used a region-specific dataset of Bangladesh. This region was chosen because climatic factors such as wind speed, temperature, and precipitation significantly influence the study area.
8) *Comparative Based Study on Rainfall prediction using SVM, RF, & DT [10]*: In a comparative study to evaluate the accuracy of statistical modeling and regression methods (SVM, RF, DT) for precipitation prediction based on environmental characteristics, regression methods were found to be superior. Experimental results showed that the RF model provides more accurate predictions than SVM and DT. The results showed that the machine learning model performed better than the traditional model, highlighting the effectiveness of machine learning models in accurately predicting precipitation. Instead of relying on statistical methods, this study used various machine learning techniques to predict daily rainfall..
9) *Rainfall Prediction In Agriculture [11] :*Precipitation prediction takes into account important factors such as evaporation, transpiration, humidity, groundwater, and temperature. These findings can be used to predict water requirements for crops in Bijapur district of Karnataka.
10) *Improving Accuracy of Prediction Algorithms using Fuzzy Logic [12]:* Real-time weather data is collected from multiple sensors strategically placed throughout the city. Four classification techniques are used to achieve high accuracy, including decision trees, Naive Bayes, k-nearest neighbors, and support vector machines. Additionally, fuzzy logic is integrated into the framework to improve the modeling process.
11) *Rainfall Prediction Using LSTM and Neural Network[13]* : An artificial intelligence-based rainfall prediction model using LSTM technology is presented. The model uses six parameters (temperature, dew point, humidity, wind pressure, wind speed, and wind direction) to predict precipitation and achieves 76% accuracy.
12) *Rainfall Prediction Using Artificial Neural Network, Random Forest, and Multiple Linear Regression [14]:* To predict precipitation, the authors focused on atmospheric characteristics such as temperature, humidity, pressure, and wind speed. They used machine learning algorithms such as artificial neural networks, random forests, and multiple linear regression.

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III.METHODOLOGY

1) *Selecting the Crop:* In this first step the user is allowed to select the crop. For these study we have only considered grapes, maize, tomato , sugarcane ,onion as crops for which the water amount is determined.
2) *Data preprocessing*: For data Preprocessing and converting the data into appropriate format the following techniques are used
a) *Data Cleaning:* In data cleaning the main focus is given on Handling Missing Value, converting the categorical variable in numerical using label encoder. This ensure that model accuracy should not be decreased
b) *Discretisation:* Using this technique data is categorised into equal-sized bins, this allows us to deal with each bin as an independent entity. This method allows us to improve the accuracy of our predictive methods, smoothen noisy data and also easily identify outliers.
c) *Data Transformation:* Data transformation allows us to make data better organised thus improving quality overall. Also it transform data to make it compatible with the algorithm for training and testing purpose.
d) *Feature Selection:* Specific set of features are selected as input variable and rainfall will be considered as output variable and this selection eliminate the need to train the model on unnecessary features. Apart from it also improves the overall accuracy.

3) *Splitting of Dataset:* After that the dataset is divided into training and testing . The training split constitute of 75% of total dataset and remaining 25% considered for testing.
4) *Training of the ML Model:* The Machine Learning model is trained on the training dataset.

After the Training the ML model is ready for rainfall Prediction the. The water supply to the crops on per day basis is determined by the amount of water required for standard grass(see table 3)

Suppose in a certain area the standard grass crop needs 5.5 mm of water per day.

Then, in that same area, maize will need 10% more water. Ten percent of 5.5 mm = 10/100 × 5.5 = 0.55 mm. Thus maize would need 5.5 + 0.55 = 6.05 or rounded 6.1 mm of water per day.

5) *Calculation of Water Amount:* The amount of water to be supplied is determined by predicted rainfall for that day and water requirement of that crop Computed by the method discussed above.

A. *Machine Learning Algorithms*

1) *XGBoost:* XGBoost is a powerful machine learning algorithm known for its effectiveness in both classification and regression tasks. It features the use of ensemble learning and combines the predictions of multiple decision tree models into a boosting framework. XGBoost stands out for its ability to process large amounts of data, maintain predictive accuracy, and efficiently manage missing data. This includes regularization techniques such as L1 regularization and L2 regularization to prevent overfitting and improve model robustness. XGBoost's speed and versatility have made it a popular choice in data science and machine learning, making it an essential tool for predictive modelling and competitive machine learning challenges.
2) *Random Forest:* Random Forest is a flexible ensemble studying method extensively carried out in gadget studying for duties which include type and regression. It includes more than one selection trees, every created on bootstrapped subsets of the education information with randomly decided on functions for splitting. This range mitigates overfitting. During prediction, the Random Forest combines the effects from those trees, yielding strong and correct predictions, especially while coping with complicated or noisy datasets. It excels in dealing with lacking information, offers insights into characteristic importance, and reveals sensible use in domain names requiring each accuracy and interpretability.
3) *Linear Regression:* Linear regression is a essential statistical and gadget getting to know method used for modelling the connection among a based variable and one or greater impartial variables. It assumes a linear, proportional relationship, in which modifications withinside the impartial variables bring about a linear extrade withinside the based variable. The purpose of linear regression is to discover the best-becoming line (or hyperplane in more than one dimensions) that minimizes the sum of squared variations among the determined facts factors and the anticipated values. This linear version is characterised via way of means of coefficients representing the slope and intercept of the line, bearing in mind prediction and inference. Linear regression is broadly hired for duties like prediction, fashion evaluation, and information the effect of 1 variable on another, making it a foundational device in facts evaluation and modelling.

B. IoT Sensors

1) *Anemometer:* An anemometer is a tool for measuring wind pace. Cup anemometers use rotating cups, and their pace correlates with wind pace. Vane anemometers appoint a rotating vane that aligns with the wind`s direction. Hot-twine anemometers degree wind pace primarily based totally at the cooling or heating of a twine. Sonic anemometers calculate wind pace with the aid of using measuring the time sound waves take to journey among transducers.
2) *DHT 111:* The DHT11 is a low-cost digital temperature and humidity sensor. It consists of a capacitive humidity sensor and a thermistor to measure temperature. The sensor provides accurate readings in a digital format, making it easy to interface with microcontrollers. It operates on a single-wire communication protocol, making it convenient for various electronics projects. The DHT11 is commonly used in weather stations, climate control systems, and IoT devices for monitoring temperature and humidity conditions. Although accuracy and response time are limited, they provide an affordable solution for basic environmental sensing.
3) *Rain Sensor:* The presence of rain or moisture. Typically, the conductivity of the sensor surface is measured, and when wet, the conductivity changes. When raindrops or moisture come into contact with the sensor, the electrical resistance decreases, signaling the presence of rain. Rain sensors are commonly used in cars to activate windshield wipers, in weather stations to measure precipitation, and in irrigation systems to prevent unnecessary watering when it rains. It is used in the system. Improve the safety and efficiency of a variety of applications by automating responses based on weather conditions.

Crop	Water requirement (mm)	Crop	Water requirement (mm)
Rice	1200	Tomato	600 – 800
Wheat	450 – 650	Potato	500 – 700
Sorghum	450 - 650	Pea	350 – 500
Maize	500 – 800	Onion	350 – 550
Sugarcane	1500 – 2500	Chillies	400 – 600
Sugarbeet	550 - 750	Cabbage	380 – 500
Groundnut	500 – 700	Banana	1200 – 2200
Cotton	700 – 1300	Citrus	900 – 1200
Soybean	450 – 700	Grapes	700 – 1200
Tobacco	400 - 600	Mango	1000 – 1200
Beans	300 - 500	Turmeric	1200 – 1400

Table 1. General Crop Water Requirements Over The Season

Feature	Type	Scale
Temperature	Numerical	Degree Celsius
Maximum Humidity	Numerical	Percentage
Minimum Humidity	Numerical	Percentage
Evaporation	Numerical	Millimeter/day
Average Wind Speed	Numerical	Kilometer per Hour
Wind Direction	Numerical	Cardinal Direction
Rainfall	Numerical	Millimeters

Table 2. Features Used for Rainfall Prediction

Crop Name	Percentage Water Requirement as Compared to Standard Grass
Grapes	Less than 30%
Maize	More than 10%
Tomato	More than 10%
Sugarcane	More than 20%
Onion	Same as standard grass

Table 3. Average Daily Crop Water Needs As Compared To Standard Grass

Climatic Zone	Low(less than 15°C) In millimetres	Medium(15-25°C) In millimetres	High (more than 25°C) In millimetres
Desert/arid	4-6	7-8	9-10
Semi-arid	4-5	6-7	8-9
Sub humid	3-4	5-6	7-8
Humid	1-2	3-4	5-6

Table 4. Average Daily Water Need Of Standard Grass

IV. CONCLUSION

This proposal addresses major challenges in modern agriculture. First, it provides a means to accurately measure and determine how much water is truly useful to crops. This knowledge allows farmers to manage water Use resources more efficiently, use water effectively and avoid water surpluses or shortages. Second, the technology enables customized irrigation practices by understanding the precise water needs of different types of crops. By providing plants with the right amount of water at the right time, farmers can promote healthier growth and maximize yields while conserving water resources. Third, incorporating this system into agriculture is expected to revolutionize the management of water supplies to crops in specific regions. By collecting data on local weather patterns, you can predict water availability and plan irrigation strategies accordingly. This advancement will expand the area that can be effectively monitored, reduce water wastage, and contribute to sustainable and productive agriculture. Overall, this innovation promises to bring significant positive changes to the field of irrigation.

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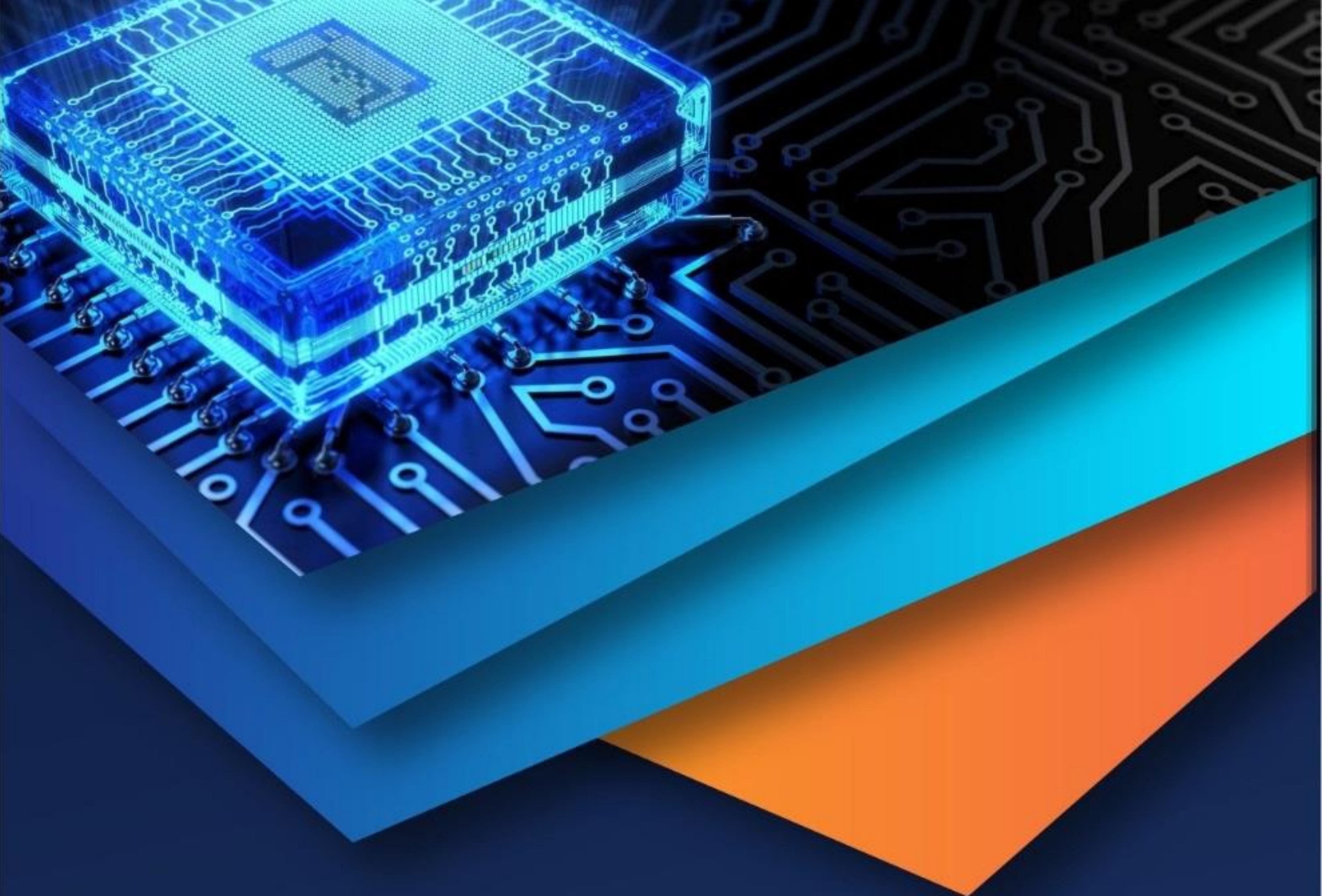

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