Enhancing Paddy Production Forecasts with Artificial Neural Networks Models and Weather Data

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Abstract: Rice yield have a major role in ensuring no shortage of food, especially in countries like India, where a significant portion of the population relies on rice as a staple food. However, rice yield is highly sensitive to climatic variations, making accurate predictions essential to have effective- planning and making the decisions. This paper presents an Artificial-Neural-Network (ANN) based model to predict rice crop yields, using climatic data such as area, temperature (minimum, average, maximum), and Rainfall-of particular area. The study focuses on 34 districts of Maharashtra, India, covering the Kharif season (between June and November) for the years 1998 to 2019. The data was processed using the python libraries like numpy and pandas' tool, and a Multilayer Perceptron ANN model was developed with a feedforward training algorithm. The ANN model demonstrated high prediction accuracy, achieving 97.54%, with sensitivity and specificity of 96.33% and 98.12%, respectively. Additionally, performance metrics such as Mean-Absolute-Error (MAE) (0.0526) and Root-Mean-Squared (RMS) Error (0.1527) indicate the robustness of the model. Compared to traditional regression-based models, the ANN approach provided more accurate yield forecasts by effectively capturing the nonlinear relationships between climatic variables and crop yield. This research contributes to the ongoing efforts to enhance agricultural forecasting using AI techniques and offers a tool that can assist farmers and policymakers in making informed decisions under variable climatic conditions. Future work aims to expand the model by incorporating additional factors like soil quality and pest infestations, as well as real-time data for dynamic predictions.

1 INTRODUCTION

Rice is an important and major food for a large part of the global population and particularly in India, where it is a major component of the diet. The agricultural sector in India is highly dependent on rice production, and the livelihoods of millions of farmers are directly tied to the success of their crops. However, due to the unpredictable and changing nature of the climate, rice crop yields have shown significant variability in recent years. This variability poses a serious challenge to farmers, policymakers, and the overall food supply chain.

Traditional crop yield prediction models, often based on statistical methods like linear regression, are limited in their ability to capture the intricate, nonlinear relationship among climate variables (such as rainfall, temperatures, and evapotranspiration) and crop yields. These methods tend to oversimplify the complex interactions that significantly impact crop production as Ji et al., 2007 and Liu et al., 2001 have demonstrated.

Artificial-Neural-Networks (ANNs), on a new scenario, are well-suited to address this challenge. With their ability to learn from data and capture nonlinear relationships, ANNs offer a more accurate and robust approach to predicting crop yields. This paper introduces an ANN-based model developed for predicting the rice crop yields in Maharashtra (state of) India. By leveraging multiple climatic factors, the model aims to provide more reliable predictions, will be used assist farmers and stakeholders in making informed decisions and mitigating the impacts of climate change on agricultural productivity.

2 RELATED WORK

Various researches have explored the application of machine learning methods to make crop yield

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prediction, having a particular focus on Artificial Neural Networks (ANNs) as their ability includes to model complex, nonlinear relationships. Often used statistical techniques, such as linear regression, often struggle to accurately predict crop yields, as they oversimplify the interactions between climatic variables like temperature, rainfall, and evapotranspiration. These models are less effective in handling the dynamic and nonlinear nature of agricultural environments.

Recent advancements in ANN models have demonstrated their superiority in predicting crop yields over traditional regression methods. Ji et al. (2007) highlighted the effectiveness of ANNs in predicting rice yield, noting their ability to handle complex environmental interactions, which regression models often miss. Similarly, Smith et al. (2009) applied ANN models to predict crop yields, concluding that ANNs consistently outperformed statistical models in diverse and fluctuating climatic conditions. Their findings underscore the advantages of neural networks in capturing the intricate relationships between multiple climatic factors and crop yields.

This research builds on the work of these studies by applying ANNs to predict rice yields in Maharashtra, India, using historical climatic data. By focusing on variables such as temperature, precipitation, and evapotranspiration, this study focuses to further validate the accuracy of ANNs in agricultural forecasting, particularly in regions with variable climatic conditions. The proposed model is designed to enhance prediction accuracy, supporting better decision making for farmers and stakeholders.

3 PROPOSED METHODOLOGY

Using climatic and agronomic data, the work estimates rice crop yield predicting with Levenberg-Marquardt, Bayesian Regularization and Scaled Conjugate Gradient algorithms. Features are of crop year, area, rainfall, temperature, district and season codes. The purposes of data normalization with Standard-Scaler is to achieve mean and variance are centered at zero, which improves the performance and prediction results by the neural network.

3.1 Neural Network Architecture

This neural network used consists of an input layer with six neurons (representing the six features), single hidden layer with eight neurons, and a resultant layer with a single neuron, which predicts the rice production. The neurons in the network use the Sigmoid activation function. The network is trained using the LevenbergMarquardt (LM) algorithm, which is ideal for nonlinear optimization problems and converges faster than standard backpropagation methods.

3.2 Flowchart for of ANN Algorithms

This following figure 1 flow-chart illustrates an overall process for ANN algorithms for rice crop yield prediction.

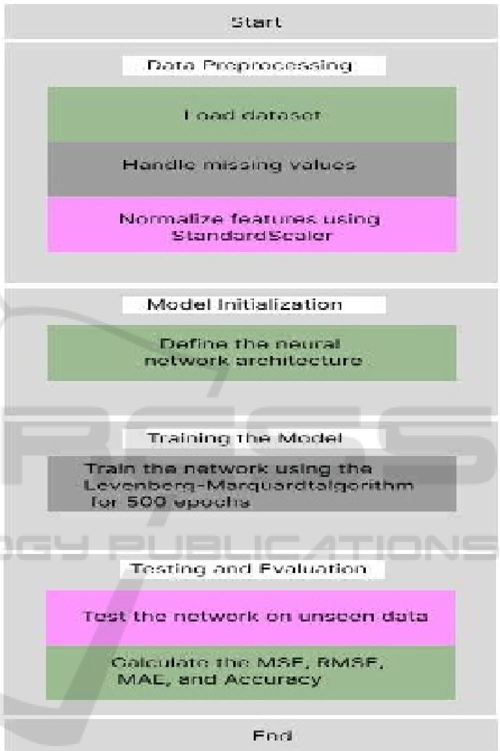

Figure 1: Flowchart of Overall for ANN Algorithm.

The training process for the network involves minimizing the error among values of the predicted and actual rice production using the ANN algorithms. The LM algorithm is a combination of the Gauss-Newton method and Gradient Descent, offering a balance between speed and stability when converging towards an optimal solution. The models were trained with 500 epochs, ensuring that the network learns the complex nonlinear relationships among the input features, middle layers and rice production.

During testing phase, trained networks are used for make predictions on the test data. Various metrics, such as Mean-Squared-Error (MSE), Root-Mean-Squared-Error (RMSE), Mean -Absolute-Error

(MAE), and Accuracy, are calculated for testing the accuracy of the model. These metrics provide insights into how well the model generalizes to new information and its ability to predict rice yields accurately.

This methodology provides a robust and efficient way to predict rice crop yield, leveraging the LM algorithm to capture the nonlinear relationships among the input features middle layers and the target variable. The neural networks architecture and optimization ensure high accuracy and low error rates, making this approach suitable for large-scale crop yield prediction.

4 PRELIMINARY DATA

The dataset used to develop the Artificial- Neural-Network (ANN) models consisted of climate and agricultural data from Maharashtra, India, during the Kharif season between 1998 and 2002. The features included critical factors such as rainfall, minimum-temperatures, average- temperatures, maximum-temperatures, reference crop, area, and yield. The data was pre-processed using the WEKA tool, where missing values were handled, and features were normalized to ensure a balanced input to the ANN model. A multilayer perceptron architecture was employed, with six input neurons corresponding to the input variables, a hidden layer of three neurons, and a single output neuron for predicting rice yield. Dataset was divided for training and testing data, and 10-fold-cross validation was used for ensuring the models generalizability and reliability among different datasets of the data. Table 1 gives the confusion matrix.

Table 1: A Confusion Matrix.

Predicted / Observed	True	False
True	True Positive (TP)	False Positive (FP)
False	False Negative (FN)	True Negative (TN)

5 EXPERIMENTAL RESULTS

The ANN model achieved remarkable prediction performance with an overall accuracy of 97.54% This research aligns with previous studies, such as those conducted by Ye et al.2011, signifying its ability to accurately forecast rice yields. The model's sensitivity was 96.33%, meaning it correctly predicted most positive cases, and its specificity was 98.12%, indicating that it effectively identified negative cases. Performance metrics such as the Mean -Absolute-Error (MAE), which stood at 0.0526, and the Root-Mean-Squared-Error (RMSE) of 0.1527 further reinforced the model’s precision and effectiveness. These findings show that the ANN models highly reduced prediction errors when comparing with traditional regression models, making it a robust tool for rice yield forecasting in Maharashtra. Figure 2 gives the neural network diagram and Figure 3 gives the knowledge flow layout.

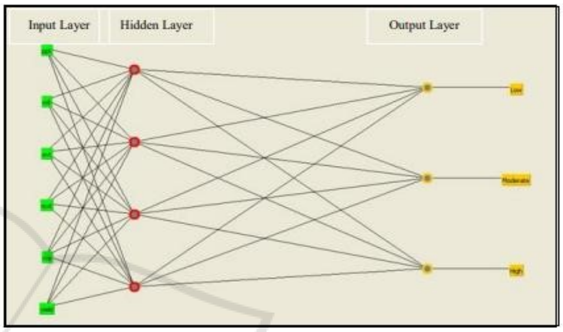

Figure 2: Neural Network Diagram.

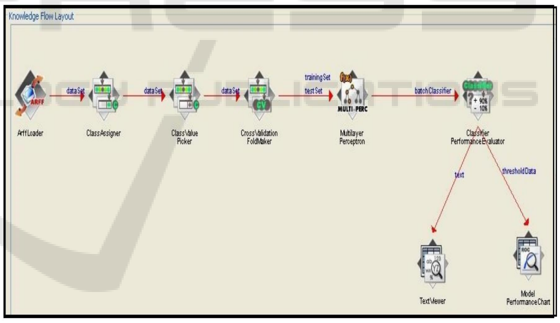

Figure 3: Knowledge Flow Layout.

6 DISCUSSION

Our model's high accuracy demonstrates the ANN's ability to model nonlinear relationships between climatic factors and rice yields. The results suggest that climatic variables such as precipitation and temperature are critical in determining crop yields, and ANNs are well-suited to capture these relationships. The model's success indicates the potential for expanding its use to other regions and crops. However, the model's dependence on historical data highlights the need for updated, real-time climatic data for more dynamic predictions.

7 CONCLUSIONS

This research helps finding the importance of ANN models in predicting rice crop yields. By effectively capturing the nonlinear interactions between climatic variables, our model offers a robust alternative to traditional prediction methods. The findings can assist policymakers and farmers in making informed decisions to mitigate the impacts of climatic variability on rice production. Further work should explore the integration of additional variables and real-time data for more dynamic and precise predictions.

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