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A Novel Approach to Classification of Soil Type for Crop Agronomy Using Decision Tree with Multiplayer Neural Network

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Abstract: The present research work focuses on developing a novel framework for the building of a decision tree model that employ multilayer neural network(MLNN) to classify the soil of a given geographical area. The biggest challenge that farmers in India face is selecting suitable crops to planting as they're unaware of the soil types of their region and its properties. This research work proposes a navel approach using decision tree to classify the soil type, utilizing a multilayer neural network. Once the soil types are identified, the proposed model helps to select the most suitable crops to cultivate. The proposed model also proposes to apply the most suitable fertilizers to the identified crops to provide essential nutrients, promoting plant growth and increasing crop yield, and also suggest appropriate irrigation system (drip, sprinkler, wells, tube wells etc) for the selected crops of that specific region. To get started with the soil type classification procedure, the necessary dataset is downloaded. The present research uses a proposed algorithm MLNN for classifying the different types of soil for crop agronomy. The superiority of Multilayer Neural Network in accuracy over the existing algorithms, namely SVM, KNN, Decision Tree (DT), Bayesian Models, Ensemble learning algorithms etc highlights the effectiveness of proposed model in capturing pattern within the data. Finally our proposed model helps in providing more reliable guidance to the agronomists to maximize the production.

Keywords: *Multilayer neural networks (MLNN), Soil Classification, Crop suggestion, decision tree, irrigation systems.*

I. Introduction:

In the realm of agriculture, understanding and classifying soil type is crucial for optimizing crop cultivation and ensuring sustainable practices. This research work employs cutting-edge artificial intelligence and machine learning techniques, specially the multilayer neural network, to build a decision tree model for the soil type classification.

Primary objective is to simplify the complex task of classification of soil type by utilizing advanced computational models. The multilayer neural network inspired by human brain's neural structure, proves to be an effective tool in discerning intricate pattern within soil data, contributing to accurate soil classification.

Beyond soil classification, this research work extends its focus to practical applications, providing recommendation for suitable crop cultivation based on the classified soil types. The research delves into the domain of fertilizers, offering guidance on the most appropriate fertilizers for the identified crops. The research process also suggesting the most suitable irrigation system for the crops of the selected region.

The integrated approach aims to empower farmers with accessible and practical insights, utilizing AI and ML to demystify soil classification, crop prediction, application of fertilizers and suitable irrigation systems.

ML algorithms have the ability to learn from large amount of data, allowing them to identify pattern, construct logical models, and make predictions without explicit programming. This approach is particularly powerful in handling complex tasks and adapting to changing data pattern.

In India, there exist eight primary types of soil: black soil, red soil, Laterite soil, sandy soil, forest soil , mountain soil and alluvial soil. For our research work, we considered only 6 different classes of soil types out of the 8 types of soil, since there can be maximum of 6 soil type present in a chosen region.

II. Literature Survey:

Hanzah et.al[1] proposed a novel approach which employed a deep learning algorithm for classification of soil of an specific geographical area, to design an effective model wherein they a innovation machine learning techniques to identify the suitable crop predication to maximize the earnings to the farmers. Using their proposed system they achieved 92.5% of prediction accuracy.

Ayele Tesema Chala et.al [1], they suggested Robertson's Machine Learning algorithms, namely,

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SVM algorithm, Artificial Neural Networks, and Random Forest algorithm for the purpose of effective soil classification to assists the farmers to plant the most appropriate crops, which will maximize the production and yield more profit the farmers.

Vrushal Milan Dolas et al., [3] devised an enhanced decision tree algorithm to fix the flaws of the current algorithms, namely CART and C4.5. When the domain of the attribute is relatively large, the misclassification error is produced by the CART algorithm .Moreover C4.5 is favors qualities with higher values. Their proposed model improves in the effective classification of soil of given huge soil dataset.

Rushika Gadge et al [4] they proposed a new methodology to whcih took soil quality into consideration to determine which crop would be most productive for the anticipated soil, Their proposed system enhances the soil type classification process, and farmers can select best crop and maximize the production of crops by applying suitable fertilizers.

Tanuja K. Fegade et.al [5] they utilized the ANN and SVM algorithms in their proposed work. The proposed method predicts most suitable crops by choosing parameters such as soil type, rainfall, humidity etc. Their proposed method classifies the soil types with the accuracy of 86.89%. They designed an interface that assists in accessing the required information for selecting the suitable crop to cultivate to maximize the production of crops and also increase their earnings.

Rub. G et.al [6] , they used the SVM and K-means algorithms in their research work to increases the practice to enhance the crop production and yield more earnings by adopting the machine learning techniques in the agricultural field.

Kushwaha et.al [7] they made an innovative concept to forecast crop adaptability based on a particular type of soil and raise the overall quality of present-day agricultural methods.

III. Proposed System:

In the proposed method, we propose an innovative model for the classification of soil type of an specific region , employing the Multilayer Neural Network as powerful machine learning tool. This methodology centers on utilizing a diverse dataset encompassing key soil attributes to train the multilayer neural network, we aims to provide a sophisticated model for automating the soil classification process.

Once the soil types are classified, the proposed system seamlessly transition into suggesting suitable crop cultivation based on the identified soil types. The proposed work also extends its functionality to suggest most suitable fertilizer for identified crops; and also suggesting most appropriate irrigation system based on the identified crop to cultivate in the selected region.

Powerful Python libraries have been employed to implement the proposed work, and work's outcomes are compared with the existing algorithms which include KNN, SVM, Decision Tree, Bayesian Models and Ensemble learning model.

Multilayer Neural Network (MLNN):

The multilayer neural network also known as a Feed forward neural network is a fundamental architecture in a artificial neural network design to model a complex relationship and patterns within the data. MLP consists of an input layer, one or more hidden layers and an output layer. Each node in the input layer represents features. Nodes in hidden layer and output layer perform computations on the input layer.

A MLNN is a computational model with interconnected layer of artificial neurons, designed to process complex information. Comprising an input layer, hidden layers and an output layers, it employs activation function like ReLU for non-linearity. Training involves adjusting connection weights through backpropagation and optimization algorithms namely gradient decent. Hyper parameters like learning rate influence performance. Techniques like dropout prevent overfitting, and proper weight initialization is crucial. What happens in each layers of MLP is given below:

Input Layer: No mathematical operations involved in the input layer of MLP.

Hidden Layer: Weighted sum for each neuron $Zi = \sum_j w_{ij} + b_i$

Activation function applied to element-wise to the weighted sum: $a_i = f(z_i)$

For each neuron in Hidden layer, repeat the process.

Output layer: Similar to hidden layer, compute the weighted sum for each neuron.

$$Z_k = \sum_i wk_i\, a_i + b_k$$

The simple architecture of MLP with multiple layers is shown in the below figure-1.

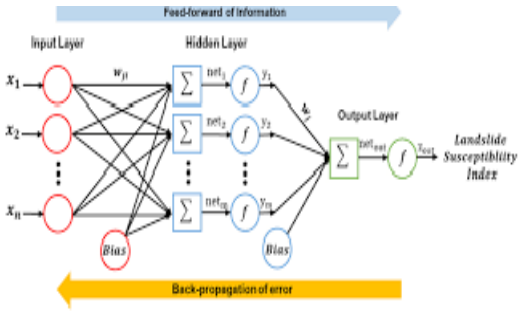


Fig-1 Architecture of Multilayer Neural Network

In our current work, MLP is employed to design the decision tree which is used in the task of soil classification from the dataset of chosen region.

Algorithm of Proposed System:

The necessary soil dataset with the name "*soil.csv*" is employed in both existing and proposed systems. This dataset consists of 5200 records and 13 attributes. Start with, 80%, i.e., 4160 records of the training samples are given and trained to construct the classifier model for the prediction and 20%, i.e., 1040 records (unknown class label) of the testing sample are employed for the task of soil type prediction.

Algorithm of our proposed model is implemented using the powerful libraries of Python and the algorithm is given below:

Step 1: Load the Soil dataset of chosen region ("Soilmain.csv") and data preprocessing techniques are applied to remove the noisy, missing values and inconsistency in the data. Also import necessary python libraries to carry out the classification task as per our proposed system.

```
import pandas as pd1
from sklearn.Model_Selection import train_test_split
from sklearn.Neural_Network import MLPClassifier1
from sklearn.Tree import Decision_TreeClasssifier
data1=pd1.read_csv('Soilmain.csv')
```

Step 2: Split the Soil dataset into two part, namely Training data (80%) and Testing data (20%)

Step 3: Build the Multilayer Neural Network model by supplying input layer with feature, hidden layer with activation function and output layer for soil type classification; and then train the model using the training dataset.

```
classifier =MLPClassifier1 (hidden_layer=(100,),,max_iteration =100,random_state=42)
classifier.fit (x-train,y-train)
```

Step 4: Construct the decision tree model using the outputs from the Multilayer Neural Network and then evaluate the decision tree model using the test datasets.

```
tree_model = Decision_TreeClassifier()
tree.model.fit(feature, train_data['soil_type']
```

Step 5 : Once the Soil types are identified, suggest the agronomists with the suitable crop to cultivate and also recommend the proper fertilizers and suitable irrigation system (such as drip, sprinkle, wellbore etc).

Step 6: Finally evaluate the performance of the decision tree, use the testing set and measure the accuracy, the precision, the recall and the F1-Score.

```
test_features=nn.model.transform ((test_data.drop ('soil_type'axiz=1))
tree.model.fit(feature, train_data['soil_type']
```

Step 7 : Suggest suitable crop against the type of soil predicated. Also suggest fertilizers and irrigation method to adopted for best crop cultivation.

IV. Results & Analysis:

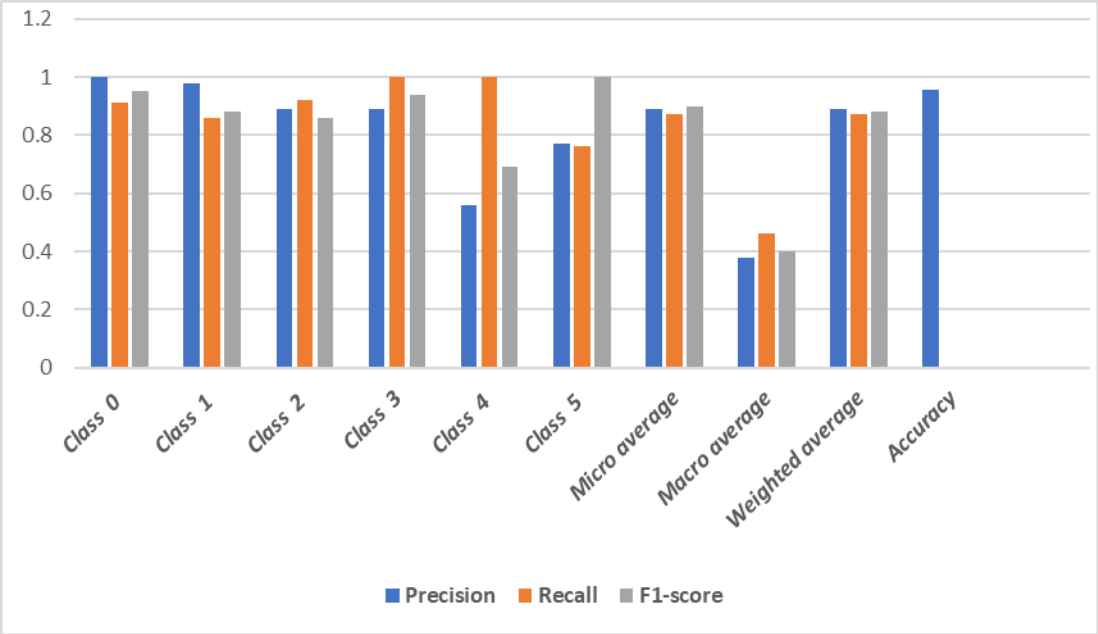
The results of the proposed algorithm signify a promising avenue for the agronomists to make informed decisions, fostering sustainable agricultural practices and potentially improving overall crop productivity. The combination of advanced machine learning techniques with practical agricultural insights holds significant promise for future development in agriculture. The final results of soil classification is provided in the below table (Table-1). The evaluation of classification task is done using the metrics shown in the table, namely Precision, Recall, F1-Score and Accuracy.

Table- 1: Result of Proposed System

Type of Soil	precision	recall	f1-score	support
class - 0	1.00	0.91	0.95	**395**
class -1	0.78	0.76	0.78	**129**
class -2	0.00	0.00	0.00	**0**
class -3	0.89	1.00	0.94	**338**
class -4	0.50	1.00	0.67	**91**
class -5	0.67	0.76	1.00	**87**
micro- average	0.89	0.87	0.90	**1040**
Macro- average	0.48	0.46	0.40	**1040**
weighted - average	0.89	0.87	0.88	**1040**
Accuracy	**0.957368**			

From the above table, we can realize that the proposed algorithm classified the 5 soil types, Red Soil

Fig--2: Visual Display of proposed Method



(class-0), Black Soil (class-1)), Laterite (class-3) , Rad Sandy soil (class-4) and alluvial Soil (class-5).

Table- 2: Suggested suitable crops

Type of Soil	Season	Suitable crops
Class -0 (Red Soil)	Kharif	Maize, Rice, Cotton, Black gram, Groundnut
	Rabi	Wheat, Rice, Bajra, Oil seeds (Grounnut, sunflower)
	Zaid	Tomato, Watermelon, Musk melon, cucumber
Class -1 (Black Soil)	Kharif	Cotton, Soybean, Red Grams, Groundnut, sorghum(jowar), chickpeas(channa) and Millet
	Rabi	Wheat, Sunflower, Mustard, barley, chick peas, soybean, Red gram and Vegetables.
	Zaid	Oil seeds (ground nut, sun flower), Pulses (green gram, black gram), Pearl millet, Finger millet.
Class - 3 (Literate Soil)	Kharif	Rice, Pulses (dry peas, Faba Bean, dry beans), Tea, Coffee and Cotton
	Rabi	Tea, Coffee, Pepper and wheat
	Zaid	Coconut, vegetables and pulses
Class -4 (Red Sandy Soil)	Kharif	Paddy, Maize , sorghum, Peal millet, groundnut
	Rabi	Wheat, Barley, mustard, lentils, Fenugreek, safflower
	Zaid	Maize (Corn), Sorghum, Fenugreek (Methi), sunflower
Class -5 (Alluvial Soil)	Kharif	Rice, Maize, Sorghum, Groundnut, sunflower, soybean.
	Rabi	Wheat, Barley, mustard, chickpeas, oil seeds, sunflower
	Zaid	Cucumber, Bitter gourd, Ridge gourd, Bottle gourd, Okra (Lady's finger)

The performance results of the proposed algorithm are furnished in the above Table-1. And the results of Table-1 are visually depicted in the Figure 1 using the bar chart. There are six classes which are classified in the

proposed algorithm namely Red Soil(class 0), Black soil(class 1), sandy soil (class 2), Laterite soil (class 3), red sandy soil (class 4) and alluvial soil(class 5). The overall accuracy is 95% which is predicted from the proposed algorithm.

The agronomists are suggested to cultivate the crops based on the identified soil type of their land and climatic condition (Cultivation Seasons) shown in the below Table-2

The recommendation extends by guiding the agronomists with suitable fertilizers and irrigation systems to the identified crops of chosen region. Few of them is shown in below table (Table-3).

Table-3 Suitable fertilizers and irrigation system against identified crops.

Crops Identified	Appropriate fertilizers	Suitable Irrigation system
Vegetables	NPK fertilizers	Drip / Sprinkler / well
Cotton	Organic manure, Phosphatic fertilizers	Drip / Furrow
Sugarcane	Phosphorus, Nitrogen	Flood irrigation
Pulses	Phosphatic fertilizers	Drip / Sprinkler
Ginger	Phophhatic fertilizers, Organic manures	Drip /mulching
Millets	Nitrogen-rich fertilizers	Rain fed and Drip irrigation
Wheat	Phosphorus, Nitrogen	Flood / Drip irrigation system
Coconuts	Balanced NPK and organic manure	Drip / Sprinkler irrigation
Tea	Nitrogen-rich and organic manures	Drip/ Furrow irrigation
Coffee	Nitrogen-rich and organic manures	Drip /, Sprinkler

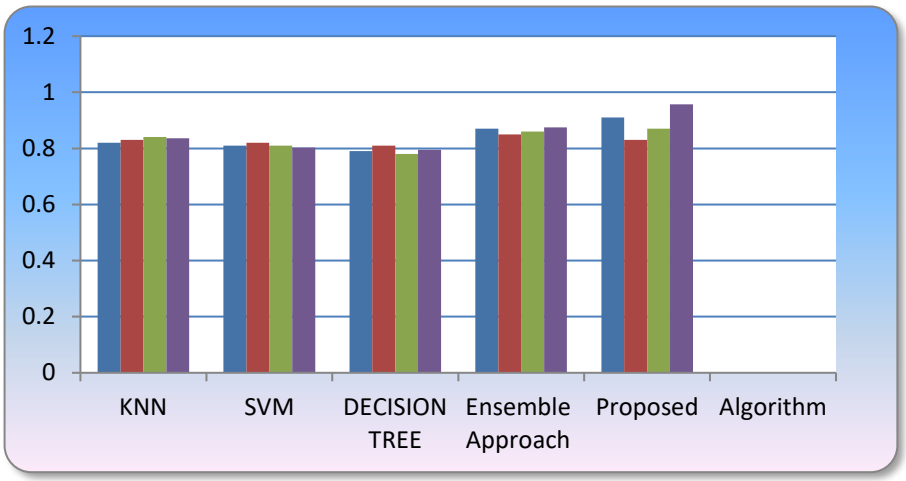
Comparing the Proposed Model with the existing models:

The comparative analysis of the proposed Multilayer neural network model with existing algorithms SVM, KNN, Decision tree, Bayesian Models, Stacking Ensemble learning techniques etc., Finally the results obtained from the proposed models are compared with the results of already existing models taken into the account of this current research work and the same are shown in the below table (Table- 4) and also shown in the following figure (Figure-3) using bar chart.

Table- 4: Comparison of the proposed model with existing techniques.

Algorithms	Precision	Recall	F1-Score	Accuracy
K-Nearest Neighbor Algorithm	0.82	0.83	0.84	**0.8356872**
Support Vector Machine Algorithm	0.81	0.82	0.81	**0.802529**
Decision Tree Algorithm	0.79	0.81	0.7805	**0.794765**
Ensemble Learning Approach	0.87	0.85	0.86	**0.874867**
Proposed Algorithm	0.91	0.83	0.87	**0.957368**

Figure-3: visual representation of Table-4



The above Table-4 and visual representation of the same is depicted in the above Figure-3, where it is we can easily understand the performance of the both existing and proposed systems.

V. **Discussion & Conclusions:**

This proposed model in this research work has successfully employed a sophisticated approach, utilizing a decision tree constructed using multilayer neural network, for the purpose of soil type classification. The accurate prediction of soil type facilitates targeted recommendation for agronomists, guiding them towards the most suitable crops for cultivation. Moreover, the algorithm extends its impact by suggesting optimal fertilizers and irrigation systems, thereby fostering sustainable and efficient agricultural practices. Significantly our finding demonstrates that the proposed system surpasses the existing algorithms, namely KNN,, SVM, Bayesian models, Ensemble learning techniques etc affirming its superiority in delivering precise and reliable results. The innovative approach holds great promise in revolutionizing agricultural decision-making processes and contributing to continued enhancement of crop yield and resources utilization of chosen area.

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