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AI-BASED FERTILIZER RECOMMENDATION SYSTEM FOR SUSTAINABLE AGRICULTURE

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Abstract:
Farmers often struggle with fertilizer application due to limited access to scientific soil analysis and reliance on traditional methods. This leads to nutrient imbalance, soil degradation, higher costs, and reduced yields. Existing advisory systems provide only general recommendations, while government soil testing services are slow and lack farm-specific guidance.To address these challenges, this paper proposes an AI-based fertilizer recommendation system that analyzes soil nutrients (N, P, K), pH levels, and environmental conditions to deliver precise, crop-specific guidance. Machine learning algorithms such as Decision Trees and Random Forests are used to improve accuracy and reliability. A voice-enabled interface, supporting local languages like Telugu and Hindi, ensures accessibility for both literate and illiterate farmers.The system empowers farmers with personalized, real-time recommendations that reduce costs, improve productivity, and prevent fertilizer misuse. By promoting sustainable practices and protecting soil health, the solution bridges the gap between advanced agricultural science and everyday farming, contributing to long-term food security and rural development.

Keywords: AI-based fertilizer recommendation system, Machine Learning algorithms (Decision Tree, Random Forest), Soil nutrient analysis (N, P, K, pH), Voice-enabled farmer advisory in local languages, Precision farming technology, Sustainable agriculture practices, Crop yield optimization.

I. INTRODUCTION:

Agriculture remains one of the most essential sectors for human survival, with fertilizers playing a crucial role in boosting crop productivity. Yet, many farmers, particularly in rural areas, lack scientific guidance and often depend on guesswork or traditional practices. This leads to problems such as nutrient imbalance, soil degradation, reduced yields, and higher farming costs, while also threatening long-term soil health and sustainability.As global food demand rises with population growth, traditional farming methods alone are no longer sufficient. Farmers now require accurate, data-driven support to improve productivity and efficiency. Emerging technologies such as Artificial Intelligence (AI), Machine Learning (ML), and Data Analytics provide powerful tools to analyze soil and crop conditions and deliver actionable insights.The proposed AI-based Fertilizer Recommendation System evaluates soil nutrient values (N, P, K), pH levels, crop type, and environmental factors to generate precise recommendations. By applying ML models like Decision Tree and Random Forest, the system predicts the most suitable fertilizer and its correct quantity, ensuring optimal usage while minimizing misuse. To make the solution accessible, a multilingual voice interface in Telugu and Hindi is integrated, enabling illiterate or semi-literate farmers to interact with the system easily.This approach not only improves crop yield and reduces costs but also supports sustainable farming by preventing excessive fertilizer use and protecting soil health. By combining modern AI solutions with traditional practices, the project

empowers farmers with scientific knowledge and promotes efficient, precise, and environmentally responsible agriculture.

II. RELATED WORK:

Recent research highlights the growing use of Artificial Intelligence and Machine Learning techniques in agriculture for improving crop productivity and fertilizer management. Machine learning-based crop recommendation systems utilize soil nutrients such as Nitrogen (N), Phosphorus (P), Potassium (K), pH, rainfall, and temperature to suggest suitable crops using algorithms like Decision Tree, achieving improved prediction accuracy [1]. Fertilizer recommendation systems based on Random Forest algorithms have also been developed to suggest appropriate fertilizer types using soil test data, reducing nutrient imbalance and improving efficiency; however, these systems often lack precise dosage recommendations [2]. Traditional methods such as Soil Nutrient Index (SNI) classification provide guidance by categorizing soil fertility levels but require expert intervention and are not automated, limiting their usability for farmers [3]. In addition, voice-based agricultural advisory systems using Natural Language Processing (NLP) have enhanced accessibility by allowing farmers to interact in local languages, although such systems do not provide data-driven fertilizer recommendations [4]. AI-driven soil and crop monitoring systems integrating IoT sensors enable real-time analysis of soil conditions and crop health, supporting precision farming; however, their high cost and hardware dependency make them less suitable for small-scale and rural farmers [5]. Despite these advancements, many existing solutions either lack user-friendly interfaces, do not provide complete fertilizer guidance including quantity, or are not accessible to illiterate farmers. The proposed system addresses these limitations by integrating machine learning models such as Decision Tree and Random Forest with a multilingual voice-enabled interface, providing accurate, affordable, and user-friendly fertilizer recommendations for sustainable agriculture.

II. PROPOSED SYSTEM:

A. Overview of Proposed System:

The proposed AI-Based Fertilizer Recommendation System helps farmers make accurate fertilizer decisions by analyzing soil parameters such as N, P, K, pH, crop type, and environmental conditions. It uses Machine Learning algorithms like Decision Tree and Random Forest to predict the suitable fertilizer and its required quantity. A multilingual voice-enabled interface in Telugu and Hindi ensures easy access for rural and illiterate farmers. The system is cost-effective, user-friendly, and promotes efficient fertilizer usage, improving crop yield while supporting sustainable agriculture.

B. System Architecture:

The system architecture consists of the following modules:

- Voice Input Module
- Speech-to-Text (STT) Module
- Data Collection Module
- Data Preprocessing Module
- Machine Learning Module
- Model Evaluation Module
- Prediction Module
- Text-to-Speech (TTS) Module
- Voice Output Module

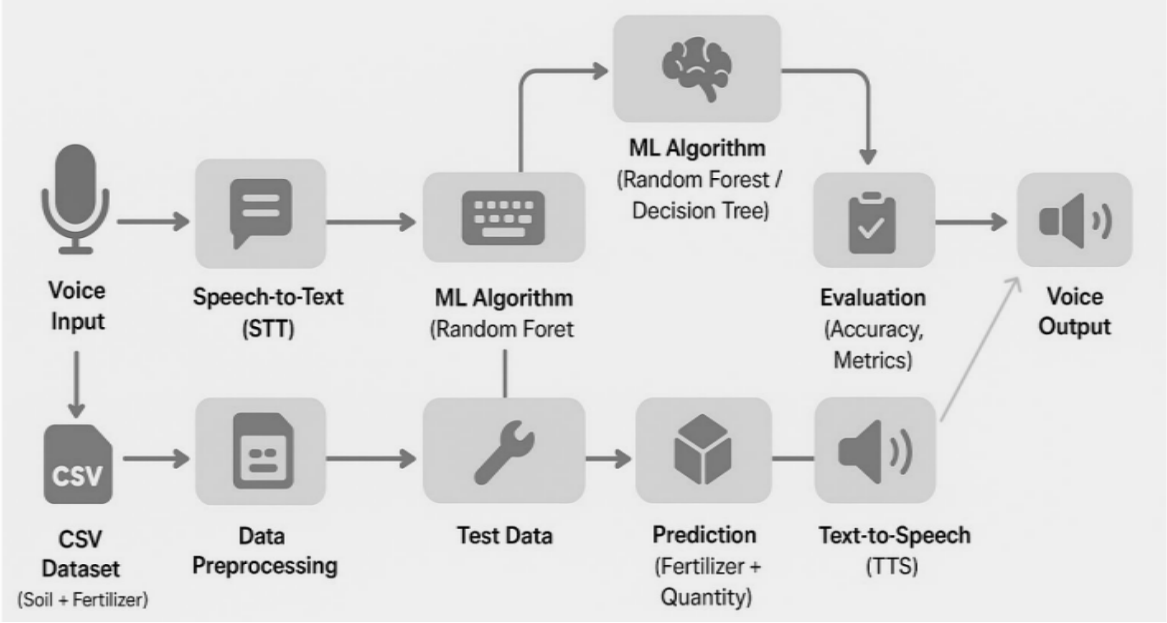

Figure 1: System Architecture of AI-Based Fertilizer Recommendation System

• **Voice Input Module:**
This module allows users to give input through voice in Telugu and Hindi, making the system easy to use for rural and illiterate farmers.

• **Speech-to-Text (STT) Module:**
The voice input given by the user is converted into text format so that it can be processed by the system.

• **Data Collection Module:**
This module collects soil nutrient values such as Nitrogen (N), Phosphorus (P), Potassium (K), pH level, crop type, and environmental factors.

• **Data Preprocessing Module:**
The collected data is cleaned and formatted to remove errors and make it suitable for further processing.

• **Machine Learning Module:**
This module uses Decision Tree and Random Forest algorithms to analyze the data and predict the suitable fertilizer and its quantity.

• **Model Evaluation Module:**
The model is evaluated to ensure accuracy and reliability of the predictions.

• **Prediction Module:**
Based on the processed input, the system predicts the most suitable fertilizer along with the required quantity.

• **Text-to-Speech (TTS) Module:**
The predicted output is converted into voice format for easy understanding.

• **Voice Output Module:**
The final result is provided to the user in audio form in their selected language.

IV. IMPLEMENTATION:

A. Data Collection:
The system collects soil nutrient values such as Nitrogen (N), Phosphorus (P), Potassium (K), pH level, crop type, and environmental factors. This data can be obtained from agricultural datasets and user inputs. Accurate data collection is important to ensure correct fertilizer recommendations.

B. Data Preprocessing:
The collected data is cleaned and formatted to remove errors, inconsistencies, and missing values. This step ensures that the dataset is reliable and suitable for further processing. Proper preprocessing improves the performance and accuracy of the model.

C. Model Training:
Machine Learning algorithms such as Decision Tree and Random Forest are used to train the model using the processed data. These algorithms learn patterns between soil parameters and fertilizer requirements, enabling the system to make intelligent decisions.

D. Prediction:
Based on the input data provided by the user, the trained model predicts the most suitable fertilizer along with the required quantity. This ensures that the soil receives the right amount of nutrients, avoiding both overuse and under-use of fertilizers.

E. Voice Interface:
The system uses Speech-to-Text (STT) technology to convert user voice input into text and Text-to-Speech (TTS) technology to convert the output into voice. This allows farmers to interact with the system easily in regional languages such as Telugu and Hindi without the need for typing.

F. Result Output:
The final fertilizer recommendation is provided to the user in both text and audio formats. This makes the system more user-friendly and accessible, helping farmers understand the results clearly and take appropriate actions for improving crop yield.

V. ALGORITHM:
INPUT: N, P, K, pH, Crop_Type, Temperature, Rainfall, Humidity, input_type
OUTPUT: fertilizer_type, fertilizer_quantity, audio_output
BEGIN

Initialize system modules: Voice_Input, STT, Data_Processor, ML_Model, TTS

Read input_type

IF (input_type == "voice") THEN
Read voice_input
text_input = STT(voice_input)
ELSE
Read text_input
ENDIF

```
Extract N, P, K from text_input
Extract pH from text_input
Extract Crop_Type from text_input
Extract Temperature, Rainfall, Humidity from text_input

IF (missing_values_exist(text_input)) THEN
   text_input = replace_missing_values(text_input)
ENDIF

text_input = remove_duplicates(text_input)
text_input = validate_ranges(text_input)
text_input = normalize_values(text_input)
text_input = encode_crop_type(text_input)

Load ML_Model

processed_data = text_input

prediction = ML_Model(processed_data)

fertilizer_type = prediction.type
fertilizer_quantity = prediction.quantity

Display(fertilizer_type, fertilizer_quantity)

audio_output = TTS(fertilizer_type, fertilizer_quantity)
```

VI. RESULTS:

It presents the results of the AI-based fertilizer recommendation system using inputs like N, P, K, pH, crop type, and environmental factors. The system predicts the suitable fertilizer and its quantity, providing output in both text and voice format.

Figure 2: User Interface of AI-Based Fertilizer Recommendation System

Figure 3: User Input Interface

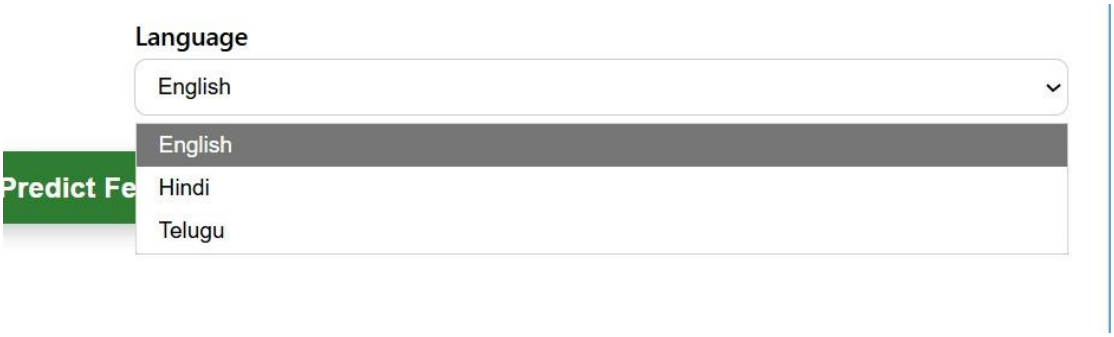

Figure 4: Language Selection Module

Figure 5. Fertilizer Recommendation Result

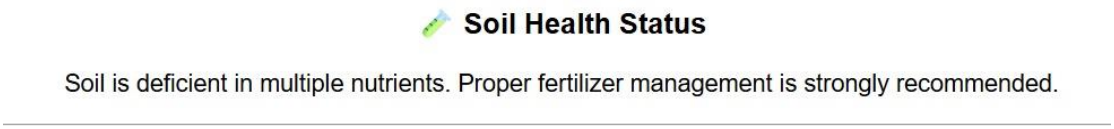

Figure 6. Soil health status interface

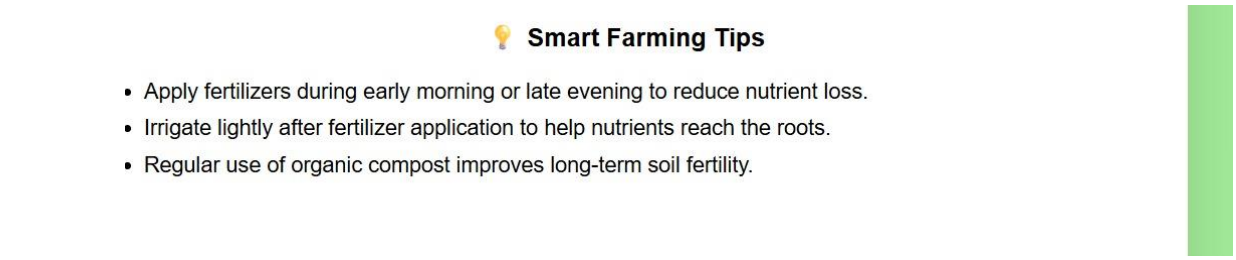

Figure 7: Advisory Tips Interface

VII. CONCLUSION:

The AI-based fertilizer recommendation system successfully predicts suitable fertilizer types and quantities using soil nutrients, crop type, and environmental conditions. The system provides accurate results along with user-friendly features such as voice input, multilingual support, and smart farming tips. This approach helps in improving crop productivity, reducing fertilizer misuse, and supporting better decision-making in agriculture. Overall, the system demonstrates the effective use of machine learning for sustainable and efficient farming.

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[4] R. K. Gupta and S. Verma, in their paper "Fertilizer Recommendation System using Machine Learning Techniques," published in the *International Journal of Computer Applications* (2023), proposed a system based on soil nutrients such as N, P, and K. However, it was limited to prediction, whereas the proposed system includes voice input, multilingual support, and environmental factors.

[5] A. Kumar and R. Patel, in "Crop and Fertilizer Recommendation System using Data Mining Techniques," published in the *International Journal of Engineering Research & Technology* (2023), developed a system without considering environmental conditions, whereas the proposed system includes temperature, rainfall, and humidity.

[6] P. Singh and M. Yadav, in "Machine Learning Based Fertilizer Recommendation System for Indian Agriculture," published in the *International Journal of Scientific Research in Computer Science* (2024), focused on decision-making models, while the proposed system improves accessibility through voice-based and multilingual features.

[7] M.Reddy and K. Rao, in "Soil Nutrient Analysis and Fertilizer Recommendation using AI," published in the *International Journal of Advanced Research in Computer Science* (2023), emphasized soil analysis, whereas the proposed system combines soil and environmental data with user interaction.

[8] N. Mishra and A. Tripathi, in "Machine Learning Approach for Soil Fertility and Fertilizer Recommendation," published in the *International Journal of Computer Science and Information Technologies* (2023), focused only on prediction, whereas the proposed system provides both text and audio outputs.