Crop Selection and Recommendation using Deep Learning and Soil Analysis

Final Review

GITAM
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AY 2021-25

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Major Project
Alpha-8

Department of Electrical Electronics and Communication Engineering

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Objective and Goals

Objective

- Design a system to classify soil types and suggest crops based on pH levels.
- Develop a multi-stage system combining CNN-based soil classification and a decision system for pH-based crop recommendations.
- Optimize agricultural productivity by aligning crop choices with soil characteristics.
- Utilize machine learning models to analyze soil data and deliver actionable recommendations for farmers.
- Create a user-friendly tool for farmers to access soil-based crop recommendations easily.

Goals

Major Goals

- Soil Classification using Convolutional Neural Networks (CNN).
- Crop Recommendation Based on pH Values.

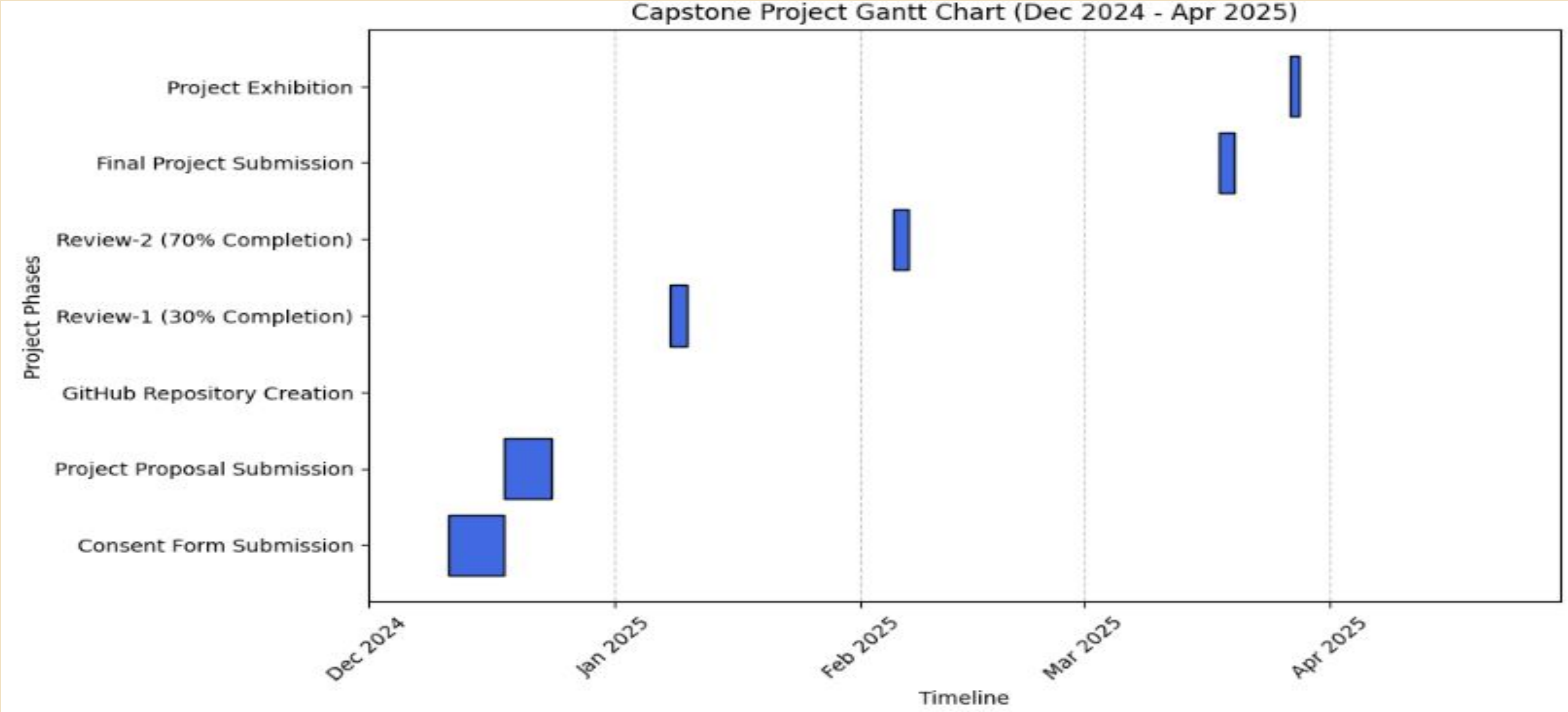
Additional Goals

- Crop Recommendation Based on Geographical Location
- Prediction of Soil Fertility Using Machine Learning Models.

Abstract

The extended project builds upon the mini-project by integrating soil pH analysis with land region classification to recommend crops effectively. While the initial phase focused on soil type classification using a CNN-based deep learning model, this version incorporates additional parameters, particularly soil pH values, to enhance decision-making for crop selection. The project involves collecting and preprocessing a dataset of land region images paired with soil pH values, sourced publicly from Kaggle. A multi-stage approach is implemented, where the CNN model first classifies soil types, followed by a decision system that analyzes pH values to recommend suitable crops. Key technologies include TensorFlow for deep learning and Python for data analysis, enabling a hybrid system that combines soil classification with pH-based recommendations. This integration supports precision farming by addressing real-world challenges, such as low crop yields due to mismatched soil conditions, and leverages AI/ML to optimize agricultural productivity across diverse geographical regions. Key outcomes include a system capable of identifying land regions, analyzing soil quality, and recommending crops with high accuracy. Future work aims to include additional parameters like soil moisture and nutrient content for comprehensive agricultural decision-making, further enhancing the impact of the system.

Project Plan

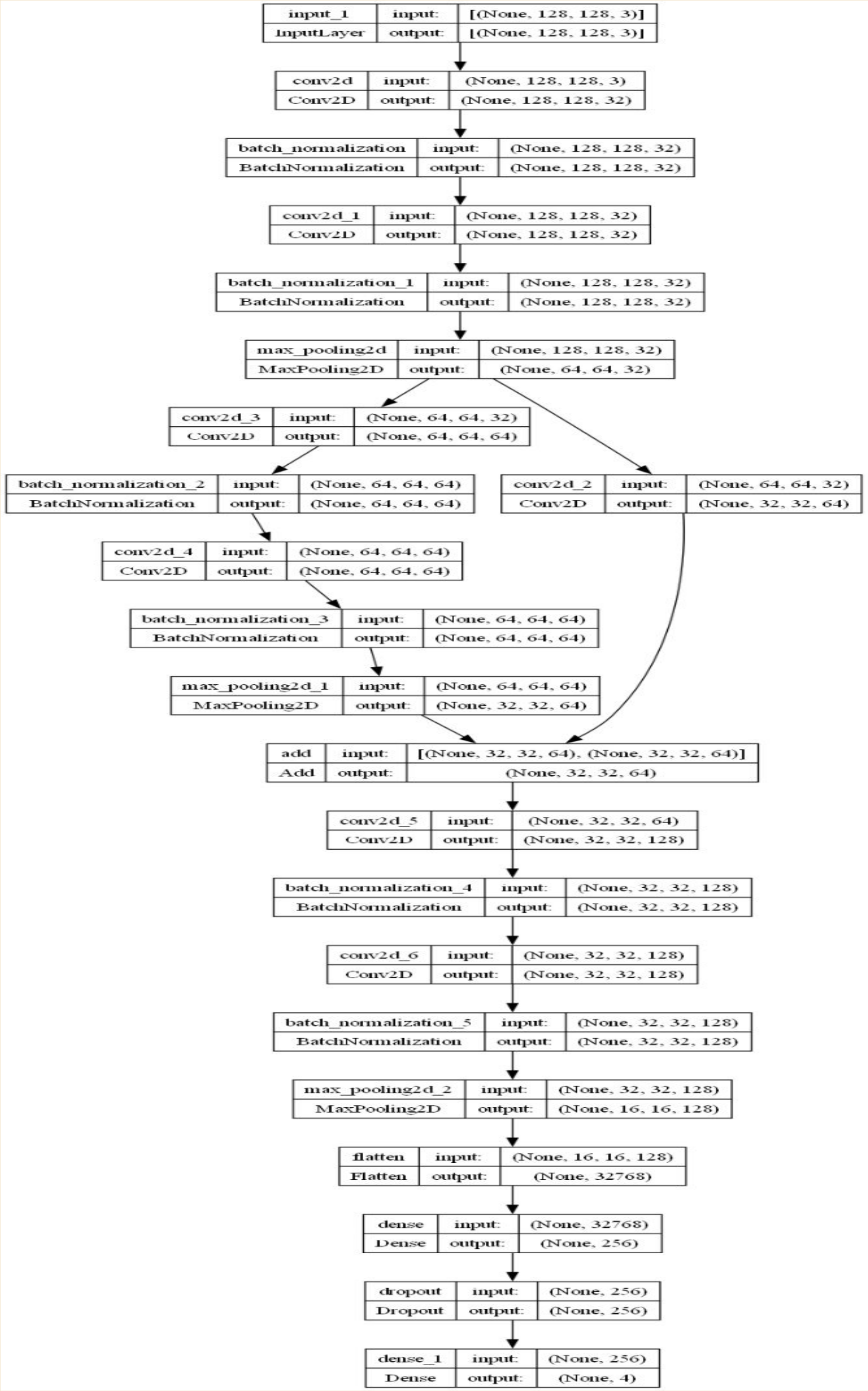


Literature Survey(Improved post minor Project)

Paper Title	Model	Methodology	Accuracy	Precision
Soil Classification and Suitable Crop Prediction	Gabor Filters and Law's Mask	Image acquisition, pre-processing, feature extraction (color and texture), classification using statistical measurements.	96%	96%
Application of Machine Vision for Classification of Tillage Quality	Artificial Neural Networks(ANN)	Uses RGB signals and image analysis for tillage quality classification.	72.01%	41.18% to 92.11%
A Novel Approach for Classification of Soils Based on Laboratory Analysis	Not Explicitly Mentioned	Laboratory analysis-based classification, possibly machine learning-based.	80%	54% to 75%
Smartphone-Based Soil Color Sensor	Linear Discriminant Analysis (LDA)	Utilizes RGB values from smartphone sensors to classify soil color.	90%	83.5%

Paper Title	Model	Methodology	Accuracy	Precision
Soil texture classification using multi class support	Multi-class SVM	SVM with linear kernel applied to HSV histogram Gabor wavelets, Discrete Wavelet Transform, etc.	91.37%	83%
Soil classification using machine learning methods	Gaussian SVM, kNN, Bagged Trees	SVM (Gaussian kernel). Weighted kNN, Bagged Tree ensemble	94.95%	56% to 80%
Classification of agricultural soil parameters in India	Random Forest, SVM	SVM with Gaussian kernel, Random Forest classifier implemented with Cohen's kappa measure	95.8%	86%
Improving the Prediction Accuracy of Soil Nutrient Classification	Extreme Learning Machine (ELM)	ELM with activation functions (Gaussian radial basis, hyperbolic tangent, triangular basis, hard limit, sine-squared)	90% for P-F	90% for K-F

Block Diagram



Soil Properties

ID	Sand %	Clay %	pH	EC mS/cm	O.M.%	CA C03 %	N_N 03 ppm	P ppm	K ppm	Mg ppm	Fe ppm	Zn ppm	Mn ppm	Cu ppm	B ppm
1	42	38	5.16	0.274	3.78	0	14.46	18.61	147	1115	91.32	0.89	27.06	1.77	0.40
2	54	26	6.07	0.355	1.45	0	14.59	32.74	180	1055	60.04	3.66	17.58	1.68	0.41
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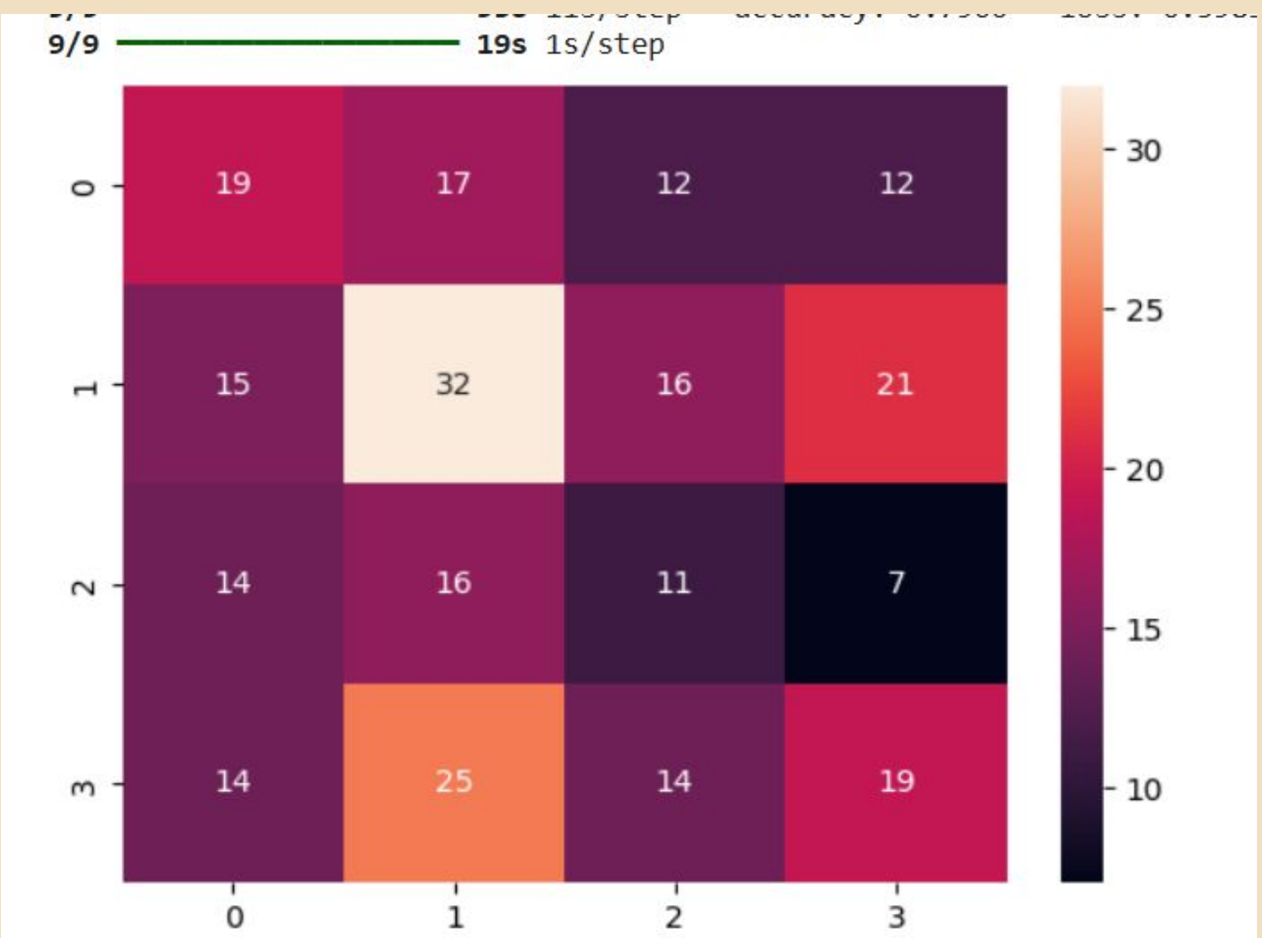
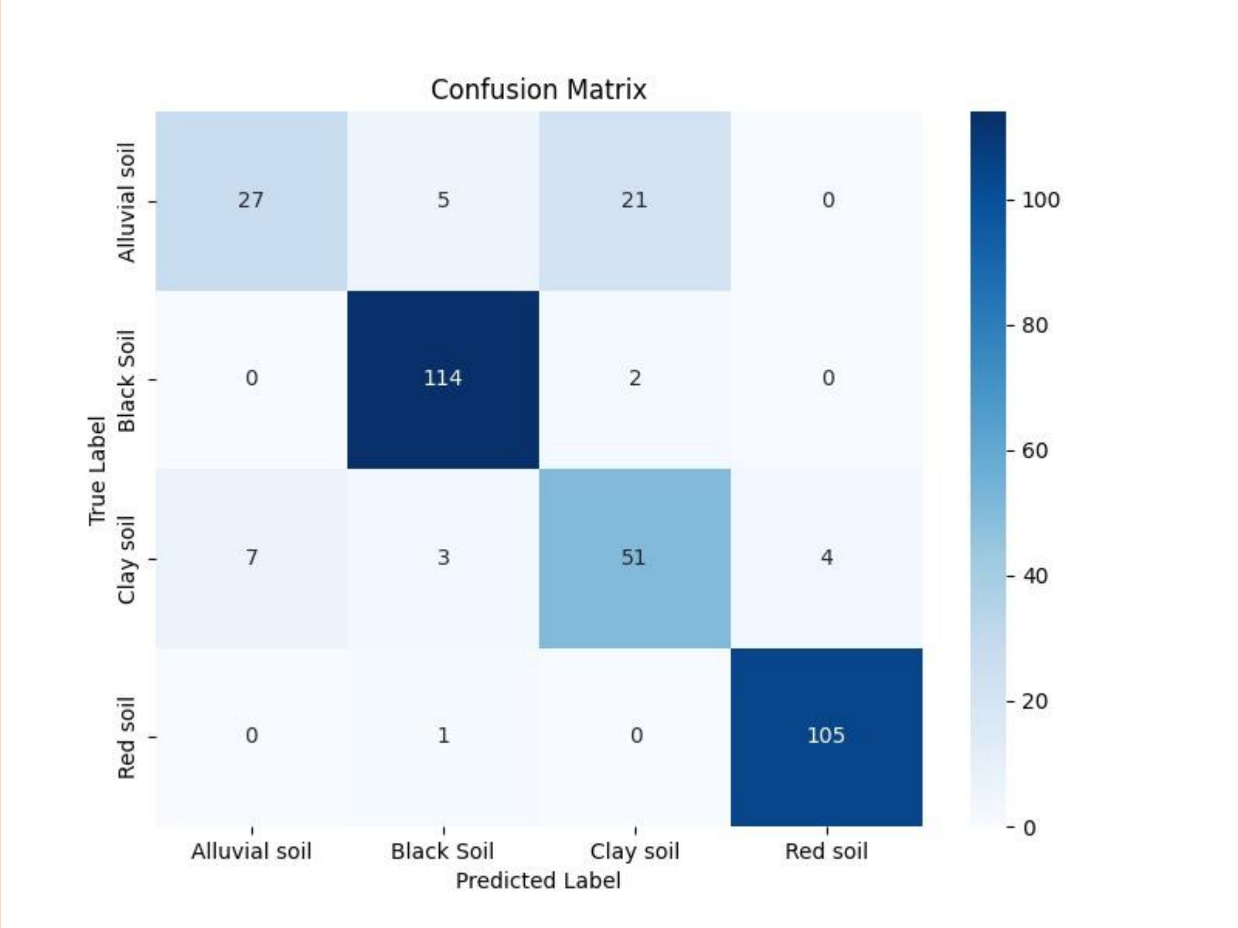
Crop Details

N	P	K	Label
90	42	43	rice
90	42	43	rice
90	42	43	rice

Previous Results Vs Improved & Final Results





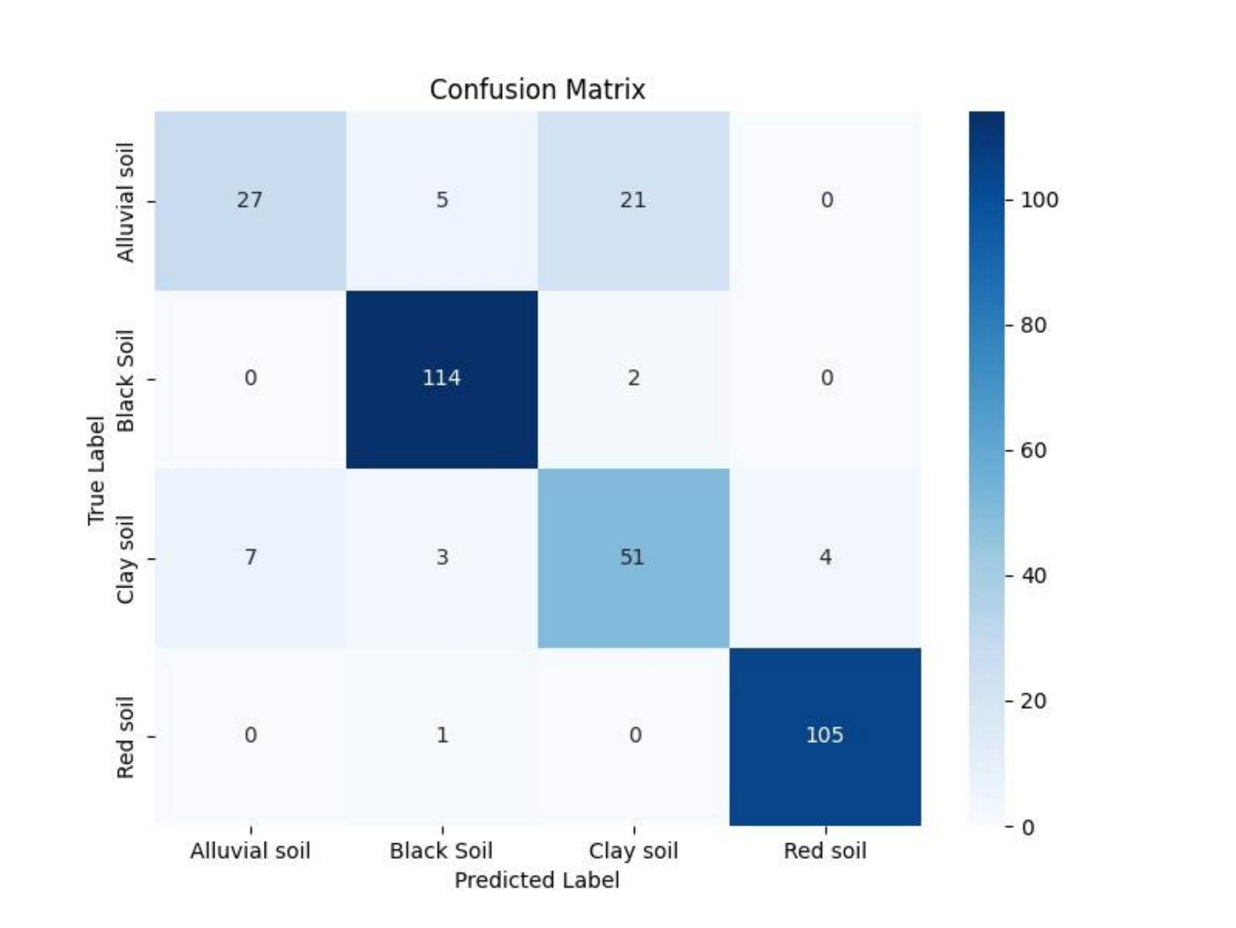
Results

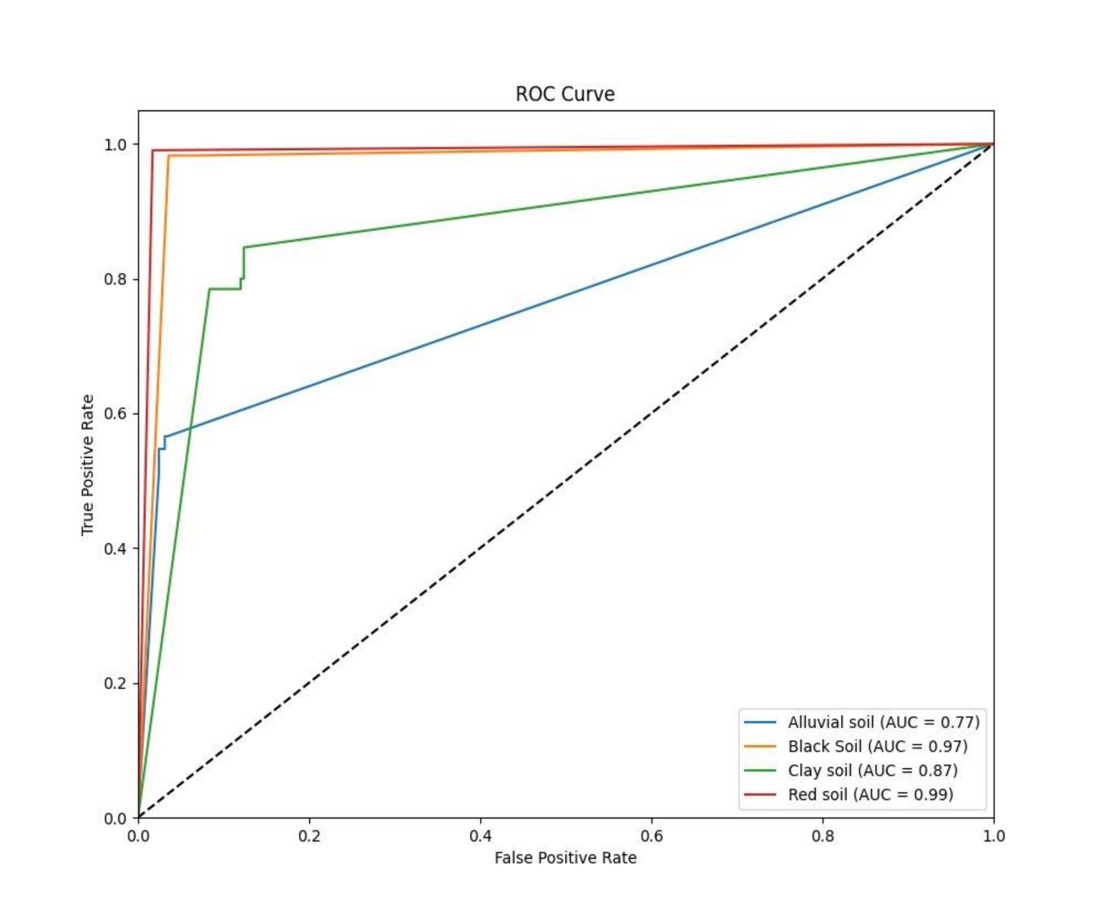
```python
def full_pipeline(image_path, N, P, K):
    soil_type = predict_soil_type(image_path)
    predicted_pH = predict_ph(N, P, K)
    recommended_crop = recommend_crop(N, P, K, predicted_pH)
    return soil_type, predicted_pH, recommended_crop

soil_type, pH, crop = full_pipeline('/content/drive/MyDrive/sem-4AIML/soil_detection/organized_dataset/test/Clay/2a5m859_jpg.rf.fc96ef2b20f3d22a7d05f48330394a53.jpg', 50, 40, 60)
print(f"Soil: {soil_type}, pH: {pH}, Crop: {crop}")
```

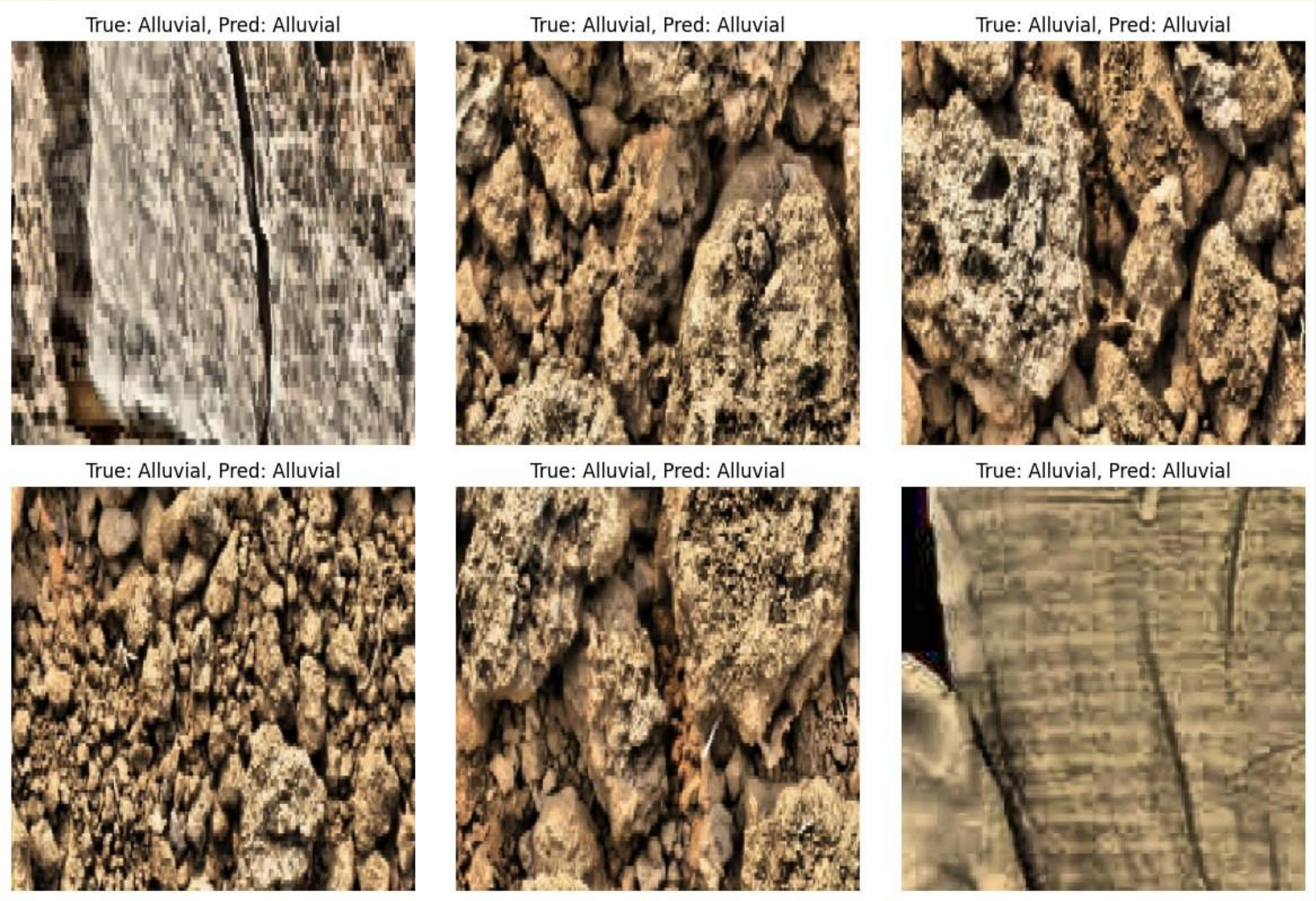
```
1/1 ━━━━━━━━━━━━━━━━━━━━ 4s 4s/step
Soil: Clay, pH: 5.441720000000004, Crop: papaya
/usr/local/lib/python3.11/dist-packages/sklearn/utils/validation.py:2739: UserWarning: X does not have valid feature names, but RandomForestRegressor was fitted with feature names
  warnings.warn(
```

Improved and Final Results:-

- After 50 epochs, the final custom CNN model accurately detects soil with high precision.
- With an accuracy exceeding 87.35%, the model proves to be a reliable tool for soil analysis.






True: Alluvial, Pred: Alluvial
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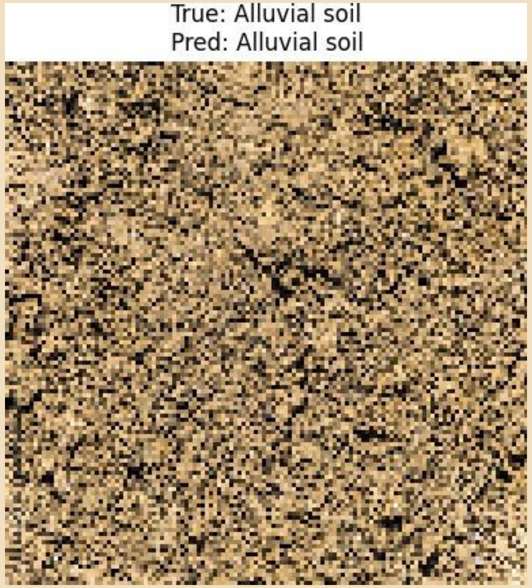
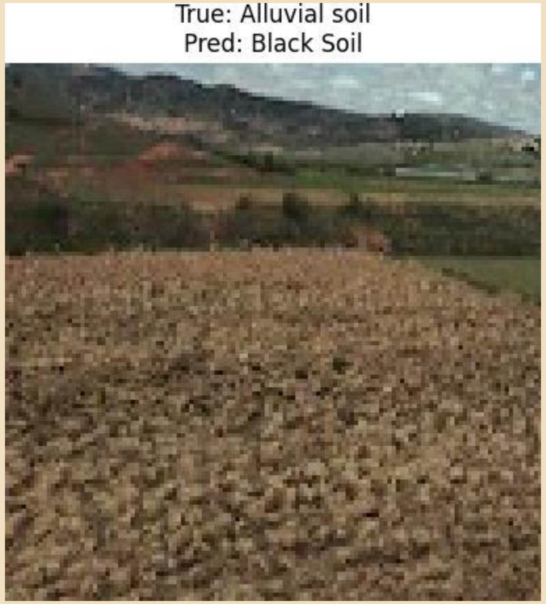
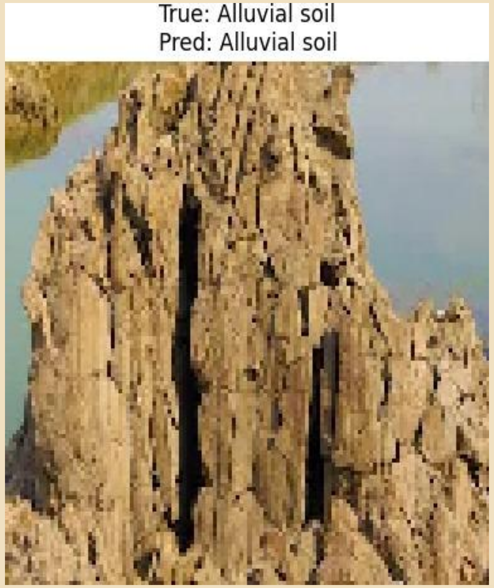
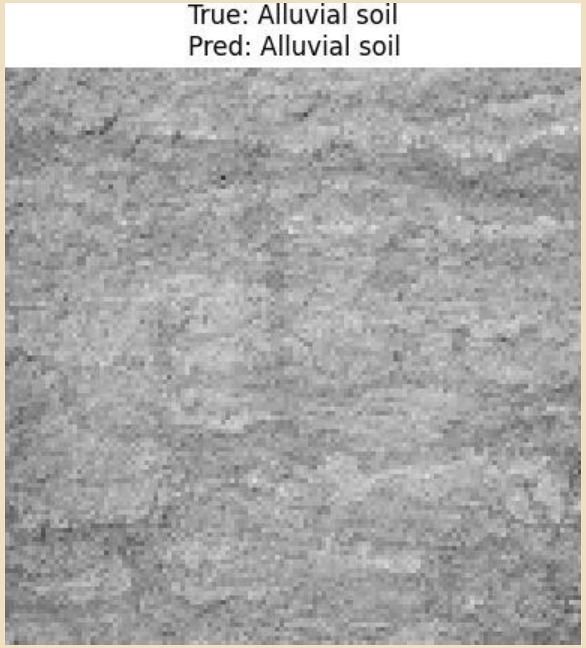

True: Alluvial soil
Pred: Alluvial soil


True: Alluvial soil
Pred: Black Soil


True: Alluvial soil
Pred: Alluvial soil


True: Alluvial soil
Pred: Alluvial soil


True: Alluvial soil
Pred: Alluvial soil

Final Results:-

- **Highly Accurate Soil Classification** – The custom CNN model achieved 87.35% accuracy after 50 training epochs, demonstrating its reliability in soil analysis.
- **Strong Classification Performance** – The confusion matrix confirms accurate predictions, particularly for Black Soil (114 correct) and Red Soil (105 correct), with minor misclassifications in Alluvial and Clay soil categories.
- **Precision-Driven Crop Recommendation** – The system integrates soil pH analysis and land classification to enhance data-driven crop recommendations.
- **Multi-Stage Classification Approach** – The custom model employs a two-step process, first classifying soil types using CNN, followed by a decision system analyzing pH values for optimal crop selection.
- **Robust Model Performance** – The ROC Curve shows high classification capability, with Black Soil (AUC = 0.97) and Red Soil (AUC = 0.99) achieving near-perfect accuracy, while Clay Soil (AUC = 0.87) and Alluvial Soil (AUC = 0.77) maintain solid predictive performance.

Contribution

Individual Contribution

Key contributions: Faiz Ali
- Model Development & Implementation
- Crop Recommendation System
- Software & Tools Integration

Key contributions: Yaswanth Reddy
- Data Collection & Preprocessing
- Literature Survey
- Research Paper for IEEE Conference

Key contributions: Rameshwar Reddy
- Data Collection & Preprocessing
- Capstone Project Report

Conclusion

In project, we successfully combined an image processing model with predictive analytics to determine soil type, pH level, and the most suitable crop for a given soil sample. The system was able to analyze soil images, predict key soil properties (such as pH), and recommend an optimal crop based on predefined nutrient values. The results indicate that the model can effectively support agricultural decision-making by providing data-driven crop suggestions. However, some limitations exist, particularly in handling pH values across different soil types.

Future Work

To enhance the model's usability and accuracy, the following improvements are proposed:

1. **User Input for Nutrient Values**: Currently, the system operates with predefined nutrient values (N, P, K). In future iterations, users should be able to manually enter their own values, allowing for greater flexibility in crop predictions.

2. **pH Range Constraints Based on Soil Type**: Each soil type has a specific pH range within which it remains stable. For example, black soil has a pH range of X-Y. Future versions should implement constraints to ensure that pH predictions align with known soil characteristics, improving model accuracy.

3. **Default pH Values**: The system should automatically assign a default pH based on the detected soil type to accommodate scenarios where users do not provide a pH value. This will make the tool more user-friendly while maintaining reasonable accuracy in predictions.

4. **Improved Model Generalization**: The current model is trained on a limited dataset. Expanding the dataset to include diverse soil samples from different regions would improve its predictive capabilities and make it more robust.

Summary and Conclusion

Summary:

The custom CNN model was trained to classify soil types and recommend crops based on pH values. Initially, the model underwent 50 epochs of training, achieving an accuracy of 87.35%. The system was designed to analyze soil images, predict key soil properties (such as pH levels), and recommend optimal crops based on predefined nutrient values. Performance evaluation using the confusion matrix and ROC curve confirmed strong classification accuracy The model integrates image processing and predictive analytics, making it a valuable tool for precision farming.

Conclusion:

The custom deep learning model effectively classifies soil types and recommends crops using soil pH analysis. It provides data-driven insights to support agricultural decision-making. While the system demonstrates high accuracy, handling pH variability across different soil types remains a challenge. Future improvements will incorporate additional soil parameters such as moisture content and nutrient composition, further enhancing precision farming and optimizing crop yields. The system’s adaptability makes it a promising solution for modern, AI-powered agricultural management.

THANK YOU

Have a Great Day !