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# Soil Quality Classification Using CNN

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**Abstract:** — Assessing soil quality is vital for sustainable farming, efficient crop planning, and resource management. Traditionally, soil fertility analysis relies on lab-based chemical testing, which is costly, slow, and often inaccessible for many small and rural farmers. Recent advances in technology, including high-resolution satellite images from platforms like Sentinel-2 and ISRO BHUVAN, along with drone imaging, have revolutionized soil monitoring. The full potential of these rich image datasets is realized through AI, particularly CNN, which automatically detect complex patterns related to soil fertility without requiring manual feature extraction. This project integrates CNNs into an easy-to-use web application that classifies soil fertility levels—high, medium, and low— using satellite and drone images. Users such as farmers and agricultural advisors can quickly upload or capture field images to obtain fast, accurate soil fertility assessments along with practical recommendations. Advanced preprocessing standardizes images from diverse sources to maintain model accuracy across varying conditions, while extensive training on annotated datasets ensures reliable and rapid performance, surpassing many traditional methods.

**Index Terms:** Soil Fertility, Deep Learning, Convolutional Neural Networks, Remote Sensing, Precision Agriculture, Web Application

## 1. Introduction: -

Soil classification is essential in modern agriculture as it helps identify and categorize soils based on their physical, chemical, and biological properties, which directly affect crop yields and land management. Traditional methods rely on laborious and time-consuming chemical tests and manual inspections, posing accessibility and cost challenges for small and remote farmers. The advent of advanced technologies, such high-resolution satellite images from platforms like Sentinel-2 and BHUVAN, alongside drone imaging, has transformed soil assessment at scale. These technologies capture detailed information on soil texture, color, moisture, and other surface traits critical for evaluating soil health .By combining these rich datasets with artificial intelligence methods, especially CNNs, automated and efficient soil classification becomes possible. CNNs excel at recognizing complex visual patterns in images without needing manual feature extraction, making them choice for interpreting subtle cues related to soil types and fertility. This project employs CNNs to categorize soils into fertility levels—high, medium, and low—based on spectral and visual patterns from satellite and drone imagery. The method replaces costly and invasive traditional soil sampling with a fast, scalable, and non-invasive assessment technique .Model training involves labelled datasets covering diverse soil types and fertility classes, incorporating preprocessing steps like image normalization, augmentation, and sometimes vegetation indices (e.g., NDVI) to boost performance and robustness. The architecture typically features convolutional and pooling layers to extract features, followed by dense layers for classification. Training strategies such as dropout and batch normalization help avoid over fitting and improve generalization on new data. This integration of remote sensing and deep learning offers a promising path to advance precision agriculture by providing timely and accurate soil health information.

## 2. Literature Survey: -

### Decision Trees, KNN, and Random Forest in Agriculture

Kushal B. J. et al. proposed an IoT and cloud-enabled system integrating machine learning for real-time crop prediction. Sensors captured parameters such as soil pH, temperature, and moisture, with data processed on ThingSpeak cloud. Among classifiers, Random Forest achieved the highest accuracy (93.11%), outperforming Decision Tree (90.96%) and KNN (87.63%). This work highlights the potential of combining traditional ML algorithms with IoT for real-time advisory in precision farming.

S. Abelen et al. applied Interactive Decision Trees using Transformed Divergence (TD) and user-adaptable thresholds for Landsat ETM+ image classification. Their segmentation-based and multi-resolution approach achieved over 80% accuracy, up to 33% higher than fixed threshold trees. Importantly, this method enables non-experts to classify urban scenes in heterogeneous environments, demonstrating interpretability advantages of decision tree methods in remote sensing.

### CNN-based Soil and Crop Classification

Rakesh Kr. Dwivedi et al. provided a review of **image processing and feature extraction techniques** for soil classification, focusing on CNNs relative to traditional SVM methods. While CNNs generally provided superior performance, the study underlined challenges such as dataset noise, inadequate automation, and dependency on quality data acquisition.

S. M. Jasvanth and E. J. Thomson Fredrik applied CNN with image preprocessing for classifying soil types (sandy, clay, loamy, etc.) and recommending suitable crops. Their approach demonstrates how soil texture classification can directly contribute to automated agricultural decision-making. Kajal Chatterjee et al. explored transfer learning with pre-trained CNNs such as ResNet50, VGG19, and InceptionV3 for soil image classification into categories like clay, red, black, and alluvial.

## 3. Proposed System: -

The proposed system utilizes Convolutional Neural Networks (CNNs) to accurately classify soil fertility levels directly from satellite and drone imagery, enabling automated and scalable soil quality assessment. By integrating the trained CNN model into a user-friendly web or mobile application built with frameworks such as Flask, the system improves accessibility for farmers, agronomists, and agricultural specialists. Unlike traditional soil testing, this system offers real-time, non-invasive predictions of soil fertility categories such as high, medium, and low, with potential for soil type classification as well. It supports informed decision making on crop selection and fertilizer use. The system efficiently processes large multispectral datasets and manages variability caused by differences in lighting, soil texture, and environmental factors through advanced preprocessing and data augmentation.

## 4. Methodology: -

The proposed solution integrates multispectral images, preprocessing pipelines, and CNN-based classification. High-resolution imagery from Sentinel-2, ISRO BHUVAN, and drone captures undergoes normalization, cropping, and augmentation. A fine-tuned MobileNetV2 backbone extracts soil features including texture, moisture, and color. The CNN is trained on a labeled dataset representing multiple agro-climatic zones, achieving high classification accuracy. The trained model is deployed in a Flask-based web application where users can upload geo-tagged soil images for real-time fertility assessment. Results are displayed along with recommendations for fertilizer and crop selection.

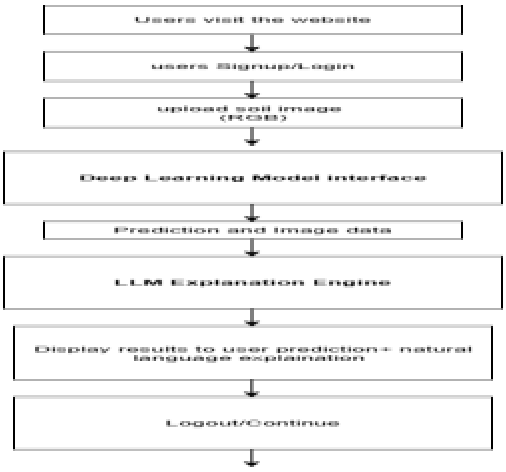
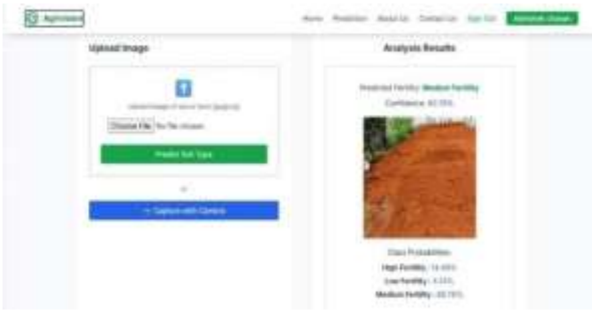



**Figure 1: Use Case Diagram**

## 5. Result: -


```
Validation accuracy: 0.8726114649681529
Weighted F1: 0.8703744613538428
              precision    recall  f1-score   support

        high       0.89      0.76      0.82       157
         low       0.85      0.97      0.91       157
      medium       0.88      0.89      0.88       157

    accuracy                           0.87       471
   macro avg       0.87      0.87      0.87       471
weighted avg       0.87      0.87      0.87       471

Confusion matrix:
 [[119  19  19]
 [  4 153   0]
 [ 11   7 139]]
```

## 6. Conclusion: -

The project introduces an innovative approach for evaluating soil quality and fertility using CNN with Mobile V Net applied to satellite and drone imagery. This method offers accurate and efficient soil fertility classification, significantly reducing dependence on traditional, labour-intensive, and costly physical soil tests. By embedding the CNN model within an accessible web or mobile platform, the system provides farmers and agricultural experts with valuable insights to optimize crop planning and resource management. Beyond classification, the system has the potential to offer recommendations on crop selection and promote sustainable land-use practices. By automating soil analysis and delivering prompt, precise information, the project supports enhanced agricultural productivity while encouraging environmentally responsible farming. Overall, it represents a notable leap forward in utilizing machine learning and geospatial data for modernizing agricultural diagnostics, aligning with the goals of digital and precision agriculture to foster food security and strengthen rural livelihoods through technological innovation.

## Future Scope

1. Multiclass Soil Type Detection:

The model can be expanded to identify and classify various soil types such as clay, sandy, loamy, and others, providing more granular soil information.

2. Real-time Drone Integration:

The system could connect with drones equipped with edge computing devices like TensorFlow Lite or NVIDIA Jetson to enable live, on-site soil fertility analysis, facilitating immediate decision-making.

**3.** Crop Recommendation Engine:

Using soil classification results, the system could suggest optimal crops, fertilizers, and irrigation strategies, supporting precise and efficient farming operations.

**4.** Smart Farming Platform Integration:

Embedding the soil classification system into IoT-enabled agricultural dashboards that amalgamate weather, soil, and water data would provide comprehensive insights and recommendations.

**5.** Government Policy and Subsidy Mapping:

The platform could assist local authorities in identifying areas needing soil improvement or subsidy allocation, aiding targeted policymaking and resource distribution.

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