EHS MATRIX PRIVATE LTD.

Report: Developing an automatic soil fertility prediction and report printing portal. (Dt. 13/01/25 – 21/03/25)

Understanding the soil testing parameters.

1. Nitrate (NO_3):

Nitrate is a vital form of nitrogen that plants readily absorb and use for synthesizing proteins and chlorophyll, which directly affects vegetative growth and yield. It is a mobile nutrient, meaning that while it is quickly available, it is also prone to leaching from the soil, especially in sandy soils. In the laboratory, nitrate is typically measured using colorimetric methods (such as the cadmium reduction method) or ion-selective electrodes. Portable soil test kits that include chemical reagents can also be used for on-site nitrate determination.

2. Ammonium (NH_4):

Ammonium is another key form of nitrogen in the soil that is less mobile than nitrate, reducing the risk of leaching and contributing steadily to plant nutrition. It is essential for plant protein synthesis and overall metabolism. Soil ammonium is usually quantified by extracting it from the soil using a salt solution and analyzing it via colorimetric assays or with ion-selective electrodes. These techniques help determine the availability of nitrogen that plants can utilize over a longer period.

3. Phosphorus (P):

Phosphorus is critical for energy transfer in plants through its

role in ATP production, root development, and overall growth. It is a key nutrient for improving the efficiency of photosynthesis and accelerating crop maturity. Phosphorus levels in soil are commonly measured using extraction methods such as the Bray or Olsen procedures, followed by colorimetric determination or spectrophotometry. These methods help estimate the plant-available phosphorus that supports healthy root systems and metabolic processes.

4. Potassium (K):

Potassium is crucial for regulating water balance, enzyme activation, and overall metabolic functions within plants, thereby enhancing drought resistance and disease tolerance. It also aids in protein synthesis and is integral to the process of photosynthesis. Soil potassium is typically assessed by soil extraction methods and measured using flame photometry, atomic absorption spectrometry (AAS), or ion-selective electrodes, ensuring that sufficient levels are maintained for optimal plant function.

5. Sulfate (SO_4):

Sulfate provides the essential nutrient sulfur, which is important for the synthesis of certain amino acids and enzymes, as well as for chlorophyll production. Adequate sulfur is necessary for proper protein formation and overall plant metabolism. Soil sulfate is usually determined by extracting it with water or a mild acid, followed by analysis through turbidimetric methods or ion chromatography, giving an accurate measure of the available sulfur that can be utilized by plants.

6. Boron (B):

Boron is a micronutrient that, although required in very small quantities, plays an indispensable role in cell wall formation, reproductive development, and the regulation of carbohydrate metabolism. Both deficiency and toxicity of boron can lead to serious crop issues. Common laboratory methods for measuring boron include hot water or Mehlich-3 extraction, followed by colorimetric analysis or Inductively Coupled Plasma Optical Emission Spectrometry (ICP-OES) to assess its concentration accurately in the soil.

7. Organic Matter:

Organic matter is a fundamental component of soil fertility that improves soil structure, water-holding capacity, and nutrient availability. It serves as a reservoir of nutrients and supports microbial activity essential for nutrient cycling. The content of organic matter is usually estimated by methods such as loss on ignition (LOI) – where soil is combusted and the weight loss is measured – or via wet oxidation techniques, providing an overall indication of soil health and its ability to support plant growth.

8. pH:

Soil pH indicates the acidity or alkalinity of the soil, influencing nutrient availability, microbial activity, and overall plant health. Most nutrients are optimally available in soils with a pH range between 6.0 and 7.5. pH is typically measured using pH meters, ion-selective electrodes, or through colorimetric test kits that change color based on the acidity level, helping farmers and agronomists adjust soil amendments to maintain optimal pH levels.

9. Zinc (Zn):

Zinc is an essential micronutrient that supports enzyme function, protein synthesis, and growth regulation in plants. It is particularly important for reproductive development and hormonal balance. Zinc in the soil is typically measured through extraction (using DTPA or Mehlich-3 extractants) followed by analysis via atomic absorption spectrometry (AAS), Inductively Coupled Plasma Optical Emission Spectrometry (ICP-OES), or colorimetric methods, ensuring that the soil provides an adequate supply of this critical element.

10. Copper (Cu):

Copper is a micronutrient required in trace amounts for photosynthesis, respiration, and the synthesis of lignin in plants. It plays a vital role in enzyme function and redox reactions, contributing to overall plant metabolism. Soil copper is generally measured by extracting the copper with an acid solution and analyzing the extract using techniques like atomic absorption spectrometry (AAS) or ICP-OES, which help determine whether the soil has a sufficient or excessive amount of copper.

11. Iron (Fe):

Iron is a key nutrient involved in chlorophyll synthesis and energy production in plants, making it essential for photosynthesis and respiration. Despite being abundant in many soils, iron can be rendered unavailable in high pH or calcareous conditions. Soil iron is measured by chemical extraction followed by colorimetric analysis or using instruments such as atomic absorption spectrometers (AAS) or ICP-OES to assess the bioavailable fraction, ensuring that plants can obtain the iron they need.

12. Calcium (Ca):

Calcium is crucial for maintaining cell wall structure, membrane integrity, and overall soil structure. It plays an important role in nutrient uptake and root development, enhancing soil aggregation and reducing erosion. Calcium levels in soil are typically determined using extraction methods with acids followed by analysis via atomic absorption spectrometry or titration, providing vital information on soil fertility and the need for lime applications.

13. Magnesium (Mg):

Magnesium is the central component of chlorophyll, making it essential for photosynthesis and overall plant growth. It also activates various enzymes and plays a role in the synthesis of nucleic acids. Soil magnesium is typically measured after extraction using a suitable reagent (such as ammonium acetate) and is analyzed using atomic absorption spectrometry (AAS) or ICP-OES, ensuring that plants have enough magnesium for optimal photosynthetic activity.

14. Sodium (Na):

Sodium is not a required nutrient for most plants; however, its presence can influence soil structure and water availability. High sodium levels can lead to soil salinity, which affects plant growth and reduces water uptake. Soil sodium is commonly determined through extraction methods followed by measurement using flame photometry or ion-selective electrodes. Monitoring sodium levels is critical, especially in arid regions or areas with poor drainage, to prevent salinization and maintain soil health.

Understanding and preparing Data.

Dataset: 410 entries of each parameter

Vegetation Cover,NO3,NH4,P,K,SO4,B,Organic Matter,pH,Zn,Cu,Fe,Ca,Mg,Na

100.0,23.0,2.25,101.0,32.0,12.0,0.71,0.96,7.8,1.7,0.3,4.0,6.6,0.8,0.12

95.0,6.0,0.75,58.0,10.0,7.0,0.27,0.3,8.2,0.8,0.1,1.0,5.0,0.5,0.07

98.0,7.25,1.0,115.0,8.0,10.0,0.56,0.62,7.9,1.4,0.2,2.0,5.2,0.4,0.04

100.0,21.0,1.25,130.0,30.0,13.0,0.78,1.04,7.9,1.8,0.3,2.0,6.1,0.7,0.1

15.0,1.75,0.5,17.0,4.0,6.0,0.25,0.1,8.8,0.3,0.1,1.0,4.7,0.5,0.1

45.0,2.0,0.75,40.0,8.0,6.0,0.24,0.22,8.3,0.9,0.1,1.0,4.9,0.5,0.09

45.0,1.5,0.25,21.0,12.0,5.0,0.2,0.08,8.7,0.3,0.1,1.0,5.7,0.4,0.08

70.0,14.75,0.75,53.0,12.0,8.0,0.18,0.41,8.3,0.8,0.1,1.0,5.6,0.4,0.07

100.0,12.75,2.0,72.0,15.0,10.0,0.64,0.45,8.0,1.2,0.2,2.0,5.6,0.5,0.08

100.0,18.5,1.75,47.0,21.0,7.0,0.29,0.28,8.3,0.6,0.1,1.0,5.9,0.5,0.11

80.0,6.25,1.25,46.0,17.0,10.0,0.26,0.13,8.5,0.5,0.1,1.0,6.6,0.4,0.09

99.0,7.5,1.0,58.0,13.0,6.0,0.27,0.36,8.1,0.7,0.1,1.0,5.2,0.4,0.04

90.0,2.0,0.75,31.0,12.0,6.0,0.22,0.55,8.7,0.3,0.1,1.0,5.7,0.4,0.05

90.0,3.25,1.25,41.0,10.0,6.0,0.22,0.54,8.6,0.4,0.1,1.0,5.3,0.4,0.07

80.0,2.25,1.5,56.0,7.0,5.0,0.26,0.9,8.6,0.4,0.1,1.0,6.0,0.4,0.05

85.0,4.0,0.75,41.0,4.0,6.0,0.23,0.1,8.7,0.4,0.1,1.0,5.5,0.4,0.04

55.0,9.25,2.25,11.0,10.0,10.0,0.55,0.77,7.9,1.6,0.4,2.0,5.2,0.5,0.08

98.0,22.5,2.0,95.0,13.0,11.0,0.54,0.83,7.7,1.3,0.2,1.0,5.9,0.6,0.1

45.0,8.0,2.0,64.0,7.0,8.0,0.2,0.35,8.1,0.5,0.1,1.0,4.5,0.4,0.04

98.0,16.0,2.0,114.0,17.0,12.0,0.81,1.78,7.8,1.7,0.3,2.0,6.6,0.6,0.11

75.0,11.75,2.0,109.0,12.0,12.0,0.43,0.46,8.0,1.2,0.1,2.0,5.8,0.6,0.06

30.0,0.25,0.75,21.0,6.0,4.0,0.15,0.19,8.7,0.1,0.1,1.0,4.2,0.4,0.06

70.0,6.75,1.5,81.0,14.0,7.0,0.22,0.57,8.1,0.7,0.1,1.0,5.1,0.4,0.04

75.0,14.25,2.25,49.0,15.0,10.0,0.25,0.88,7.7,0.5,0.1,1.0,5.4,0.5,0.05

70.0,63.5,2.25,160.0,35.0,24.0,1.5,2.25,8.0,2.9,0.9,3.0,6.8,0.6,0.21

98.0,23.75,1.75,76.0,19.0,11.0,0.5,0.65,7.9,0.9,0.1,1.0,5.8,0.5,0.11

95.0,14.25,1.5,61.0,22.0,8.0,0.4,0.58,7.9,0.8,0.1,1.0,5.5,0.6,0.09

98.0,5.0,0.75,49.0,13.0,6.0,0.2,0.11,8.4,0.5,0.1,1.0,5.7,0.4,0.1

75.0,2.25,0.75,36.0,9.0,6.0,0.19,0.21,8.6,0.3,0.1,1.0,6.0,0.4,0.07

90.0,6.5,1.5,57.0,13.0,7.0,0.34,0.33,8.3,0.6,0.2,1.0,5.0,0.5,0.1

85.0,14.5,1.5,59.0,15.0,11.0,0.53,0.39,8.4,0.7,0.1,1.0,5.3,0.6,0.12

15.0,0.25,1.75,21.0,14.0,6.0,0.3,0.12,8.8,0.2,0.1,1.0,5.8,0.5,0.11

50.0,3.75,1.5,67.0,13.0,6.0,0.18,0.84,8.0,0.5,0.1,1.0,4.8,0.3,0.08

50.0,9.5,1.5,70.0,14.0,8.0,0.22,0.28,8.0,0.6,0.1,1.0,5.5,0.4,0.06

45.0,4.25,2.75,125.0,15.0,11.0,0.65,0.76,7.9,1.5,0.3,2.0,5.8,0.5,0.09

45.0,24.5,2.75,129.0,19.0,16.0,0.72,0.92,7.8,1.7,0.3,3.0,5.9,0.5,0.11

40.0,2.75,2.25,44.0,11.0,8.0,0.14,0.26,8.4,0.4,0.1,1.0,6.1,0.4,0.08

40.0,14.25,1.75,50.0,9.0,6.0,0.15,0.13,8.4,0.4,0.1,1.0,5.6,0.3,0.06

55.0,34.0,2.75,123.0,23.0,17.0,0.51,2.08,7.7,1.3,0.2,2.0,7.2,0.5,0.11

55.0,23.25,3.0,128.0,15.0,14.0,0.48,0.65,7.8,1.2,0.2,2.0,7.0,0.4,0.09

60.0,9.5,2.75,84.0,18.0,10.0,0.63,0.82,7.9,1.3,0.1,1.0,6.3,0.8,0.13

60.0,11.25,2.25,89.0,14.0,12.0,0.46,0.63,8.0,1.0,0.1,1.0,5.4,0.5,0.15

35.0,14.25,3.0,81.0,18.0,10.0,0.42,0.87,7.9,1.0,0.1,1.0,5.4,0.5,0.14

35.0,28.5,6.75,95.0,16.0,14.0,0.49,0.51,7.8,1.3,0.1,2.0,5.7,0.5,0.12

50.0,24.75,4.75,129.0,20.0,13.0,0.47,0.8,7.8,1.3,0.1,2.0,6.0,0.5,0.11

50.0,23.75,1.75,69.0,16.0,17.0,0.76,1.38,7.7,1.9,0.4,3.0,5.9,0.5,0.1

60.0,7.75,1.0,111.0,17.0,11.0,0.62,0.43,8.1,2.8,0.2,1.0,5.0,0.6,0.21

60.0,16.0,1.0,129.0,16.0,10.0,0.56,0.73,7.9,2.7,0.4,2.0,5.7,0.8,0.08

40.0,7.75,0.75,66.0,13.0,12.0,0.25,0.68,8.0,0.7,0.1,2.0,5.6,0.4,0.04

40.0,8.5,0.75,55.0,11.0,9.0,0.26,0.55,8.0,0.7,0.1,2.0,5.5,0.4,0.04

35.0,16.5,1.25,61.0,21.0,9.0,0.37,0.64,7.8,0.9,0.2,1.0,4.9,0.4,0.12

35.0,8.0,2.25,61.0,7.0,6.0,0.28,0.82,8.0,0.8,0.2,1.0,5.1,0.3,0.1

35.0,3.75,1.25,51.0,5.0,5.0,0.14,0.54,8.2,0.4,0.1,1.0,5.0,0.3,0.09

35.0,14.25,1.0,48.0,6.0,4.0,0.14,0.36,8.2,0.4,0.1,1.0,5.2,0.3,0.07

20.0,14.25,0.25,59.0,5.0,7.0,0.16,0.26,8.1,0.5,0.1,1.0,5.4,0.3,0.04

20.0,7.5,0.75,58.0,7.0,6.0,0.15,0.37,8.3,0.5,0.1,1.0,5.6,0.3,0.03

50.0,6.25,1.0,50.0,5.0,7.0,0.2,0.54,8.1,0.4,0.2,1.0,5.6,0.4,0.04

50.0,12.5,0.75,69.0,7.0,9.0,0.19,0.42,8.0,0.5,0.1,1.0,5.4,0.4,0.03

45.0,12.75,2.0,90.0,9.0,8.0,0.37,0.68,7.9,1.0,0.2,1.0,5.7,0.4,0.05

45.0,6.0,0.75,84.0,14.0,6.0,0.3,1.0,7.9,0.8,0.1,1.0,5.7,0.4,0.06

45.0,2.0,0.75,48.0,8.0,5.0,0.16,0.28,8.3,0.3,0.1,1.0,4.9,0.3,0.09

45.0,5.25,0.75,41.0,8.0,4.0,0.1,0.08,8.4,0.3,0.1,1.0,5.2,0.3,0.08

40.0,8.75,1.5,104.0,10.0,9.0,0.43,0.66,7.8,1.0,0.2,1.0,6.1,0.5,0.11

40.0,20.75,2.5,120.0,16.0,10.0,0.65,0.625,7.6,1.5,0.3,1.0,7.0,0.8,0.1

15.0,5.25,0.75,41.0,5.0,6.0,0.22,0.39,8.2,0.5,0.1,1.0,5.4,0.3,0.08

15.0,34.0,1.0,69.0,13.0,13.0,0.2,0.58,7.9,0.6,0.1,1.0,5.5,0.4,0.03

35.0,14.25,1.0,81.0,14.0,14.0,0.36,0.95,7.7,0.8,0.1,1.0,5.6,0.5,0.07

35.0,23.0,1.0,83.0,12.0,16.0,0.46,0.65,7.8,1.0,0.1,1.0,5.8,0.5,0.06

10.0,37.0,0.75,49.0,11.0,19.0,0.35,0.43,8.2,0.5,0.1,1.0,5.6,0.6,0.26

Choosing the ML Algorithm.

Why Random Forest Was Chosen for Soil Fertility Prediction

Introduction

Soil fertility prediction is a crucial task in modern agriculture, enabling farmers and agronomists to optimize fertilizer use, improve crop yields, and enhance soil health. The goal of this project is to predict soil fertility (vegetation cover) based on multiple soil nutrient parameters using machine learning. Several algorithms could be considered for this task, including **Linear Regression, Decision Trees, Support Vector Machines (SVM), and Random Forests**. After evaluating various models, **Random Forest Regression** was chosen due to its superior performance in handling complex, non-linear relationships in soil data. This report compares Random Forest with alternative models and explains why it is the best choice for this problem.

Understanding Random Forest Regression

Random Forest is an **ensemble learning algorithm** that constructs multiple decision trees during training and outputs the average of predictions (for regression tasks). It enhances the accuracy and robustness of predictions by reducing overfitting, which is common in single decision trees.

How Random Forest Works:

1. The dataset is randomly split into multiple **subsets** (bootstrap sampling).
2. A **decision tree** is trained on each subset, using a **random subset of features** at each split.
3. For regression tasks, the final prediction is obtained by **averaging** the outputs of all trees.
4. The algorithm improves generalization and **reduces variance**, making it suitable for real-world agricultural data with high variability.

Comparison with Other Machine Learning Models

1. Linear Regression

Overview: Linear Regression models the relationship between input features and output as a straight line.

Pros:

- Simple and easy to interpret.
- Works well for datasets with linear relationships.

Cons:

- Soil fertility is influenced by non-linear interactions between nutrients, which Linear Regression cannot capture.
- It assumes all features contribute independently, which is not true for soil properties.
- Poor accuracy when handling outliers or missing data.

Comparison: Random Forest outperforms Linear Regression because it captures **non-linear patterns** in soil data, making it more suitable for complex predictions.

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2. Decision Tree Regression

Overview: Decision Trees split data into branches based on feature values, creating a tree-like structure to make predictions.

Pros:

- Easy to understand and visualize.
- Works well with categorical and numerical data.
- Can handle missing data better than Linear Regression.

Cons:

- Prone to **overfitting**, meaning it memorizes training data rather than generalizing well.
- A single tree can be unstable, meaning small changes in data can lead to a completely different model.

Comparison: Random Forest is an **improvement over Decision Trees** because it uses multiple trees and averages their predictions, reducing overfitting and increasing accuracy.

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3. Support Vector Machine (SVM) Regression

Overview: SVM regression finds a hyperplane in high-dimensional space that best fits the data.

Pros:

- Works well for small to medium datasets.
- Can capture complex relationships if the correct kernel function is chosen.

Cons:

- Computationally expensive for large datasets.
- Requires careful tuning of hyperparameters (e.g., kernel selection) for optimal performance.
- Not as robust to noisy data as Random Forest.

Comparison: Random Forest is preferred over SVM because it **scales better** for large datasets, requires less fine-tuning, and is more resistant to noise in real-world soil data.

Why Random Forest is the Best Choice

After comparing the four models, **Random Forest Regression** was chosen for the following reasons:

1. **Captures Non-Linear Relationships:**
    - Soil fertility is influenced by complex interactions between nutrients. Random Forest can learn these non-linear dependencies better than Linear Regression or SVM.
2. **Handles Missing and Noisy Data Well:**
    - Soil data often contains missing or inconsistent values due to measurement errors. Random Forest is robust to such issues, unlike SVM and Decision Trees.
3. **Reduces Overfitting:**
    - Unlike a single Decision Tree, Random Forest averages multiple trees, **reducing variance** and improving generalization on unseen data.
4. **Feature Importance Analysis:**
    - Random Forest provides insights into **which nutrients contribute the most** to soil fertility, helping agronomists make informed decisions.
5. **Scalability:**
    - Unlike SVM, which struggles with large datasets, Random Forest can efficiently process thousands of soil samples.
6. **High Accuracy:**

- Random Forest consistently achieves higher **R^2 scores** and lower **Mean Squared Error (MSE)** compared to other models, making it more reliable for predictions.

Conclusion

Soil fertility prediction requires a model that can handle **complex interactions, noisy data, and non-linear relationships**. After evaluating **Linear Regression, Decision Tree Regression, and SVM**, we found that **Random Forest Regression** offers the best balance between **accuracy, robustness, and interpretability**. By leveraging an ensemble of decision trees, Random Forest provides more **reliable** and **generalized predictions** for soil health analysis, making it the ideal choice for this project.

Moving forward, this model can be further improved by **hyperparameter tuning**, **incorporating additional soil parameters**, and **expanding the dataset** for better generalization across different soil types.

Main Python File:

Coding and Reviewing code from mentors.

Input Felid Code:

```
import os
import pandas as pd
import numpy as np
from sklearn import preprocessing
from sklearn.ensemble import RandomForestRegressor
from sklearn.model_selection import train_test_split
from flask import Flask, request,
flash,render_template,url_for,redirect,jsonify
```

```
from sklearn.preprocessing import MinMaxScaler
from sklearn.ensemble import RandomForestClassifier
from sklearn.preprocessing import LabelEncoder
from sklearn import metrics
from database import init_db, save_crop_prediction,
save_soil_fertility
init_db()  # initialize database at app start
import pdfkit
from flask import render_template, make_response

# Path to wkhtmltopdf (update it according to your PC)
pdfkit_config = pdfkit.configuration(wkhtmltopdf='C:/Program
Files/wkhtmltopdf/bin/wkhtmltopdf.exe')
data=pd.read_csv('dataset.txt')
app = Flask(__name__)


@app.route('/')
def home():
   return render_template('ProjectHomepage.html')

@app.route('/crop')
def crop():
   return render_template('crop_prediction.html')

@app.route('/soilfertility',methods=['POST'])
def soilfertility():
   a0=float(request.form['0'])
   a1=float(request.form['1'])
   a2 =float(request.form['2'])
   a3 =float(request.form['3'])
   a4 =float(request.form['4'])
   a5=float(request.form['5'])
   a6=float(request.form['6'])
   a7 =float(request.form['7'])
```

```
    a8 =float(request.form['8'])
    a9 =float(request.form['9'])
    a10=float(request.form['10'])
    a11=float(request.form['11'])
    a12 =float(request.form['12'])
    a13=float(request.form['13'])


    if(a0==0 and a1==0 and a2==0 and a3==0 and a4==0 and a5==0
and a6==0 and a7==0 and a8==0 and a9==0 and a10==0 and a11==0
and a12==0 and a13==0):
        return
render_template('ProjectHomepage.html',prediction_text=0)
    X, Y = data[data.columns[1:]], data['Vegetation Cover']

dict={'NO3':[a0],'NH4':[a1],'P':[a2],'K':[a3],'SO4':[a4],'B':[a5],'Organic
Matter':[a6],'pH':[a7],'Zn':[a8],'Cu':[a9],'Fe':[a10],'Ca':[a11],'Mg':[a12
],'Na':[a13]}
    df1 = pd.DataFrame(dict)
    df = pd.concat([X, df1], ignore_index = True)
    df.reset_index()
    X=df
    scaler = MinMaxScaler()
    X, Y = scaler.fit_transform(X.values),
scaler.fit_transform(Y.values.reshape(-1,1))
    l1=[X[408]]
    X = X[:-1]

    X_train, X_test, Y_train, Y_test = train_test_split(X,Y,
test_size=0.10, random_state=43)

    forestRegressor =
RandomForestRegressor(criterion='squared_error', max_depth=8,
n_estimators=10, random_state=0)
    forestRegressor.fit(X_train, Y_train)
```

```
   y_pred = forestRegressor .predict(X_test)
   prediction = forestRegressor .predict(l1)
   print(l1)
   text=""
   recommendations1 = []
   recommendations2 = []
   if(prediction<90):
      if(a0<12.75 or a2<47 or a8<0.6 or a3<15 or a6<0.28 or a10<1):
         text="Your Soil is less fertile.You may try increasing these
nutrients "
      if(a0<12.75):
         text=text+"NO3, "
         recommendations1.append("Ammonium-based fertilizers-
These can be converted to nitrates by soil microbes. Fish emulsion-
This is a quick-acting, natural nitrogen fertilizer derived from fish
byproducts.Blood meal- This is a by-product of animal slaughter, rich
in nitrogen. Coffee grounds- Mixing coffee grounds into the soil helps
to increase the nitrogen content in the soil ")
         recommendations2.append("Urea (CH4N2O)-  A widely used
nitrogen fertilize/ Calcium Nitrate (Ca(NO32)) - Provides both calcium
and nitrate/ Ammonium Nitrate (NH4NO3) - A fast-acting nitrogen
source")
      if(a2<47):
         text=text+"P, "
         recommendations1.append("Apply Superphosphate or DAP
(Di-Ammonium Phosphate)/Animal Manure/Bone Meal/Fish
emulsion provides a phosphorus boost to plants with rapid results
when used as a foliar spray/Compost with worm castings is an
organic soil amendment that may add some phosphorus to soil, but
more importantly, it frees up existing phosphorus/Lime/Rock
Phosphate")
         recommendations2.append("Single Super Phosphate (SSP) -
Contains water-soluble phosphorus/ Di-Ammonium Phosphate (DAP)
- A high-phosphorus fertilizer/ Rock Phosphate - A slow-release,
natural phosphorus source")
```

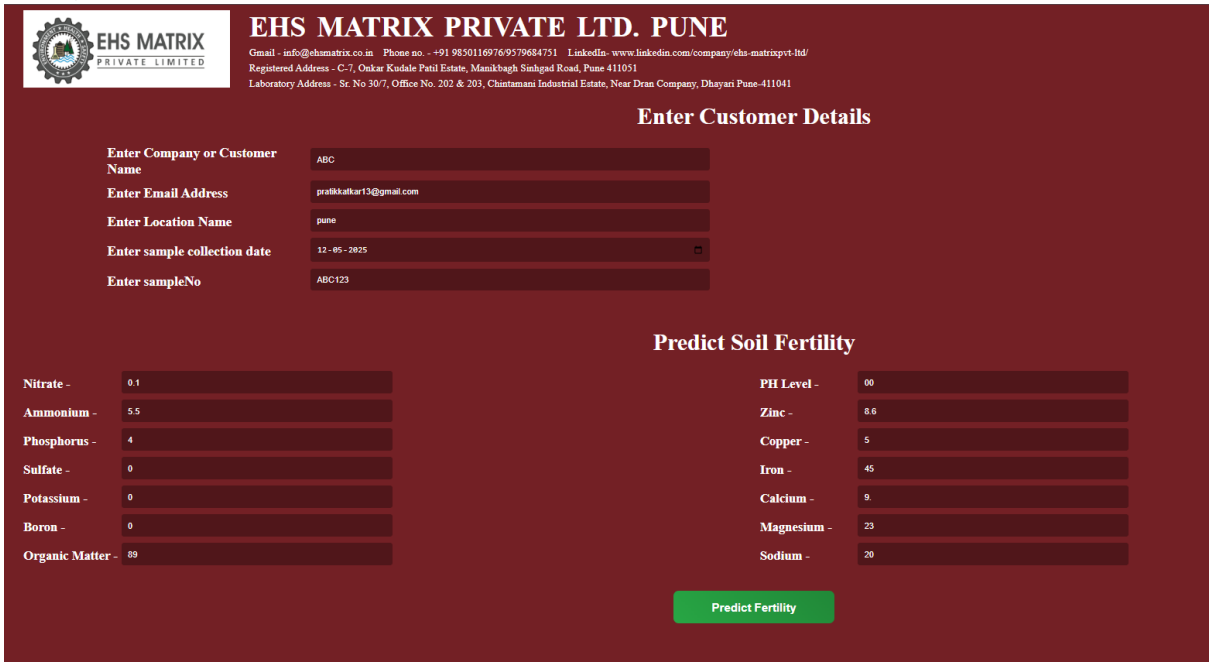
```
    if(a8<0.6):
        text=text+"Zn, "
        recommendations1.append("Add zinc sulfate: This is a
common and effective way to supplement zinc in the soil. However,
be cautious of over-fertilization, as excessive zinc can be toxic to
plants./If your soil is acidic, applying lime can help improve zinc
availability. However, be aware that excessive lime can also lead to
zinc deficiency in alkaline soils. /Choose zinc-efficient crops: Planting
crops that are naturally efficient in absorbing zinc, such as corn")
        recommendations2.append("Zinc Sulfate (ZnSO₄) - The most
common zinc fertilizer/ Zinc Chelates (Zn-EDTA) - A highly
bioavailable form of zinc/ Zinc Oxide (ZnO) - A slow-releasing zinc
source")
    if(a3<15):
        text=text+"K, "
        recommendations1.append("Use Phosphorus-Rich Fertilizers:
Apply balanced fertilizers with a phosphorus content (e.g., 10-20-10
NPK) according to soil test results and plant requirements./ Legumes
and Cover Crops: Incorporate legumes like clover or beans, which fix
atmospheric nitrogen and release phosphorus, into your crop
rotation./ Incorporate compost, manure, or peat moss into the soil
to release phosphorus gradually.")
        recommendations2.append("Muriate of Potash (KCl) - Most
commonly used potassium fertilizer /Sulphate of Potash (K₂SO₄) -
Provides both potassium and sulfur/ Potassium Nitrate (KNO₃) -
Contains both potassium and nitrogen")
    if(a6<0.28):
        text=text+"Organic Matter, "
        recommendations1.append("Animal manure (FYM, poultry
manure, etc.) can be used as a natural fertilizer, adding organic
matter and nutrients to the soil./ Using earthworms to convert
organic waste into compost (vermicomposting) is another effective
method./ Biogas slurry can be used as a source of organic matter and
nutrients./ Plant cover crops like legumes, grasses, or clover, which
add organic matter and nutrients when incorporated into the soil.")
```

```
        recommendations2.append("Farmyard Manure (FYM) - Rich in nutrients and organic carbon/ Compost - Decomposed organic waste that enhances soil health/ Vermicompost - Nutrient-rich compost from earthworms")
    if(a10<1):
        text=text+"Fe, "
        recommendations1.append("Optimize phosphorus fertilization: Phosphorus and iron can react together to form insoluble iron phosphates, which can tie up iron./ Select iron-efficient crop varieties: Choose crop varieties that are less sensitive to iron deficiency./ Maintain Soil pH: Iron availability is affected by soil pH. Maintain a slightly acidic to neutral soil pH (around 6.0-7.0) to optimize iron uptake.")
        recommendations2.append("Ferrous Sulfate (FeSO₄) - The most common iron supplement/ Iron Chelates (Fe-EDTA, Fe-DTPA) - Highly available iron forms/ Ferric Oxide (Fe₂O₃) - A natural iron source in some soils")


  save_soil_fertility({
  'NO3': a0, 'NH4': a1, 'P': a2, 'K': a3, 'SO4': a4, 'B': a5,
  'Organic_Matter': a6, 'pH': a7, 'Zn': a8, 'Cu': a9, 'Fe': a10,
  'Ca': a11, 'Mg': a12, 'Na': a13,
  'prediction_score': float(prediction),
  'message': text
  })

  if(prediction>=90):
    text="Your soil is high fertile. Keep regular fertilization methods as of now to stand soil as it is"
  if(prediction>0 and prediction<1):
    return render_template('Results.html',content=text,co = recommendations2, c=recommendations1, prediction_text=np.round(prediction*100).astype(int))
```

Output Screenshots:



Recommendations:

- **Create a database where each value can be stored separately so that can be fetched at any time.**
- **Make auto stored all PDF in one folder.**
- **Make another ML model for soil - water - humidity crops prediction system.**
- **Integrating both the models.**
- **User friendliness Increasing.**

EHS MATRIX PRIVATE LTD.

Report: Developing an automatic soil fertility prediction and report printing portal. (Dt. 21/03/25 – 14/05/25)

Understanding the crop testing parameters.

1. **Nitrogen:**
   Nitrogen is a key nutrient for plant growth, especially for leaf and stem development. It plays a crucial role in photosynthesis and the formation of amino acids and proteins. Low nitrogen levels can lead to yellowing leaves and stunted growth, while excess nitrogen may delay flowering and fruiting.
2. **Phosphorous:**
   Phosphorous supports strong root development and helps in the formation of flowers, seeds, and fruits. It is essential for energy transfer and overall plant metabolism. A deficiency in phosphorus can result in poor root systems, slow growth, and weak yields.
3. **Potassium:**
   Potassium enhances disease resistance, water regulation, and the overall health of crops. It aids in enzyme activation and improves crop quality, especially in fruits and grains. Deficient potassium often results in poor drought tolerance and weak stalks.
4. **PH level:**
   Soil pH determines the availability of nutrients to plants. Most crops prefer a pH between 6.0 and 7.5 for optimal nutrient absorption. If the pH is too acidic or too alkaline, it can lock essential nutrients in the soil, leading to poor crop growth.
5. **Humidity:**

Humidity influences the rate of transpiration and water uptake by plants. High humidity can increase the risk of fungal diseases, while low humidity may lead to faster drying and water stress. Optimal humidity levels vary depending on the crop type.

6. **Temperature :**

   Temperature affects seed germination, growth rate, flowering, and fruiting. Each crop has a specific temperature range within which it grows best. Extreme temperatures, whether hot or cold, can reduce yield or even halt growth entirely.

7. **Ranifall:**

   Rainfall provides the necessary water for plant uptake and nutrient transport. Consistent and adequate rainfall supports healthy crop cycles, but too much can lead to waterlogging, while too little causes drought stress. Crop selection must align with local rainfall patterns.

Preparing Database

Dataset: 2700 entries of each parameter.

N,P,K,temperature,humidity,ph,rainfall,label

90,42,43,20.87974371,82.00274423,6.502985292000001,202.9355362,rice

85,58,41,21.77046169,80.31964408,7.038096361,226.6555374,rice

60,55,44,23.00445915,82.3207629,7.840207144,263.9642476,rice

74,35,40,26.49109635,80.15836264,6.980400905,242.8640342,rice

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77,52,17,24.86374934,65.7420046,5.714799723,75.82270467,maize
……

Choosing the ML Algorithm.

Why Random Forest Was Chosen for Soil Fertility Prediction

Introduction

Soil fertility prediction is a crucial task in modern agriculture, enabling farmers and agronomists to optimize fertilizer use, improve crop yields, and enhance soil health. The goal of this project is to predict soil fertility (vegetation cover) based on multiple soil nutrient parameters using machine learning. Several algorithms could be considered for this task, including **Linear Regression, Decision Trees, Support Vector Machines (SVM), and Random Forests**. After

evaluating various models, **Random Forest Regression** was chosen due to its superior performance in handling complex, non-linear relationships in soil data. This report compares Random Forest with alternative models and explains why it is the best choice for this problem.

Understanding Random Forest Regression

Random Forest is an **ensemble learning algorithm** that constructs multiple decision trees during training and outputs the average of predictions (for regression tasks). It enhances the accuracy and robustness of predictions by reducing overfitting, which is common in single decision trees.

How Random Forest Works:

5. The dataset is randomly split into multiple **subsets** (bootstrap sampling).
6. A **decision tree** is trained on each subset, using a **random subset of features** at each split.
7. For regression tasks, the final prediction is obtained by **averaging** the outputs of all trees.
8. The algorithm improves generalization and **reduces variance**, making it suitable for real-world agricultural data with high variability.

Comparison with Other Machine Learning Models

1. Linear Regression

Overview: Linear Regression models the relationship between input features and output as a straight line.

Pros:

- Simple and easy to interpret.
- Works well for datasets with linear relationships.

Cons:

- Soil fertility is influenced by non-linear interactions between nutrients, which Linear Regression cannot capture.
- It assumes all features contribute independently, which is not true for soil properties.
- Poor accuracy when handling outliers or missing data.

Comparison: Random Forest outperforms Linear Regression because it captures **non-linear patterns** in soil data, making it more suitable for complex predictions.

---

2. Decision Tree Regression

Overview: Decision Trees split data into branches based on feature values, creating a tree-like structure to make predictions.

Pros:

- Easy to understand and visualize.
- Works well with categorical and numerical data.
- Can handle missing data better than Linear Regression.

Cons:

- Prone to **overfitting**, meaning it memorizes training data rather than generalizing well.
- A single tree can be unstable, meaning small changes in data can lead to a completely different model.

Comparison: Random Forest is an **improvement over Decision Trees** because it uses multiple trees and averages their predictions, reducing overfitting and increasing accuracy.

---

3. Support Vector Machine (SVM) Regression

Overview: SVM regression finds a hyperplane in high-dimensional space that best fits the data.

Pros:

- Works well for small to medium datasets.
- Can capture complex relationships if the correct kernel function is chosen.

Cons:

- Computationally expensive for large datasets.
- Requires careful tuning of hyperparameters (e.g., kernel selection) for optimal performance.
- Not as robust to noisy data as Random Forest.

Comparison: Random Forest is preferred over SVM because it **scales better** for large datasets, requires less fine-tuning, and is more resistant to noise in real-world soil data.

Why Random Forest is the Best Choice

After comparing the four models, **Random Forest Regression** was chosen for the following reasons:

7. **Captures Non-Linear Relationships:**
    - Soil fertility is influenced by complex interactions between nutrients. Random Forest can learn these non-linear dependencies better than Linear Regression or SVM.
8. **Handles Missing and Noisy Data Well:**

- Soil data often contains missing or inconsistent values due to measurement errors. Random Forest is robust to such issues, unlike SVM and Decision Trees.

9. **Reduces Overfitting:**
   - Unlike a single Decision Tree, Random Forest averages multiple trees, **reducing variance** and improving generalization on unseen data.
10. **Feature Importance Analysis:**
    - Random Forest provides insights into **which nutrients contribute the most** to soil fertility, helping agronomists make informed decisions.
11. **Scalability:**
    - Unlike SVM, which struggles with large datasets, Random Forest can efficiently process thousands of soil samples.
12. **High Accuracy:**
    - Random Forest consistently achieves higher **R^2 scores** and lower **Mean Squared Error (MSE)** compared to other models, making it more reliable for predictions.

Conclusion

Soil fertility prediction requires a model that can handle **complex interactions, noisy data, and non-linear relationships**. After evaluating **Linear Regression, Decision Tree Regression, and SVM**, we found that **Random Forest Regression** offers the best balance between **accuracy, robustness, and interpretability**. By leveraging an ensemble of decision trees, Random Forest provides more **reliable** and **generalized predictions** for soil health analysis, making it the ideal choice for this project.

Moving forward, this model can be further improved by **hyperparameter tuning**, **incorporating additional soil parameters**, and **expanding the dataset** for better generalization across different soil types.

Main Python File:

```
@app.route('/predict', methods=['POST'])
def predict():
    # Load dataset
    data = pd.read_csv('Crop.csv')

    # Encoding labels
    label1 = data.iloc[:, 7]
    label_encoder = LabelEncoder()
    encoded_crops = label_encoder.fit_transform(label1)

    # Training starts
    X = data.iloc[:, 0:7]
    y = encoded_crops

    # Train-test split
    X_train1, X_test, y_train1, y_test = train_test_split(X, y,
test_size=0.2, random_state=1)
    X_train, X_val, y_train, y_val = train_test_split(X_train1, y_train1,
test_size=0.2, random_state=2022)

    # Random Forest model
    RF = RandomForestClassifier()
    RF.fit(X_train, y_train)

    # Predictions
    if request.method == 'POST':
        N = float(request.form['N'])
        P = float(request.form['P'])
        K = float(request.form['K'])
        temperature = float(request.form['temperature'])
        humidity = float(request.form['humidity'])
        ph = float(request.form['ph'])
        rainfall = float(request.form['rainfall'])
```

```
    prediction_data = [[N, P, K, temperature, humidity, ph, rainfall]]
    prediction = RF.predict(prediction_data)
    predicted_crop =
label_encoder.inverse_transform(prediction)[0]

    crop_info_detailed = {
      "rice": {
            "days_to_harvest": 120,
            "description": (
              "Rice is a staple food crop widely cultivated in India,
particularly in states like Maharashtra during the Kharif season. "
              "It requires abundant water, hence is grown in areas
with good rainfall or irrigation facilities. "
              "The crop is usually transplanted in puddled fields to
ensure root anchoring and weed suppression. "
              "It thrives in a hot and humid climate with
temperatures ranging between 20°C to 35°C. "
              "Fertile alluvial or clayey loam soils with good water
retention are ideal for rice. "
              "It demands significant labor, especially during
transplanting and harvesting stages. "
              "Rice is harvested after the grains mature and turn
golden yellow, typically in about 3-4 months."
            )
          },

      "maize": {
            "days_to_harvest": 90,
            "description": (
              "Maize, also known as corn, is a versatile crop used
for food, fodder, and industrial purposes. "
              "It is cultivated across Maharashtra during the Kharif
and Rabi seasons. "
              "Maize requires well-drained loamy soil and grows
best in regions receiving moderate rainfall. "
```

```
                "The crop prefers warm weather with a temperature range of 18°C to 27°C. "
                "It is relatively drought-resistant but benefits from proper irrigation at key growth stages. "
                "Maize is a high-yielding crop when managed with proper fertilizers and pest control. "
                "It is typically harvested when the husks turn brown and the kernels are hard and glossy."
            )
        },

    "jute": {
            "days_to_harvest": 150,
            "description": (
                "Jute is a long, soft, shiny vegetable fiber that can be spun into coarse, strong threads. "
                "It is mainly grown in humid and warm climates, requiring a high level of rainfall (150-200 cm). "
                "Although not commonly grown in Maharashtra, experimental cultivation has shown promise in suitable pockets. "
                "The crop is typically sown in spring and harvested in late summer or early autumn. "
                "It prefers well-drained alluvial soils that are rich in nutrients. "
                "Jute is eco-friendly and used in making gunny bags, ropes, and carpets. "
                "After harvesting, the fiber is extracted through a process called retting, where stalks are soaked in water."
            )
        },

    "cotton":{
            "days_to_harvest": 180,
            "description": (
```

```
                "Cotton is a major cash crop cultivated extensively in
Maharashtra, particularly in Vidarbha and Marathwada. "
                "It requires a warm climate and is best suited for
black cotton soil rich in lime, potash, and humus. "
                "Cotton is grown during the Kharif season and thrives
with 600-1000 mm of rainfall. "
                "It is sensitive to waterlogging, so well-drained fields
are essential. "
                "The crop is prone to pests like bollworms and
requires integrated pest management. "
                "Harvesting starts when the bolls burst open,
revealing white fluffy fibers. "
                "Cotton is crucial to the textile industry and
generates employment in both agriculture and industry."
                )
            },

        "coconut":{
                "days_to_harvest": 365,
                "description": (
                "Coconut is a perennial tropical crop grown in coastal
regions with high humidity. "
                "In Maharashtra, it is cultivated mainly in the Konkan
region. "
                "The crop requires well-drained sandy or alluvial soil
and thrives in areas with over 1500 mm rainfall annually. "
                "It takes about a year or more for the fruits to mature
for harvesting. "
                "Regular watering, manuring, and protection from
pests like rhinoceros beetles are important for good yields. "
                "Coconuts are harvested monthly once the trees start
bearing fruit after 5-6 years. "
                "The crop is valued for its oil, water, coir, and as a key
ingredient in various cuisines."
                )
```

```
        },


    "papaya": {
            "days_to_harvest": 150,
            "description": (
              "Papaya is a fast-growing fruit crop ideal for
tropical and subtropical climates. "
              "It is cultivated in many parts of Maharashtra due
to its short growth cycle and market demand. "
              "Well-drained sandy loam soils with a pH of 6-7 are
best suited for papaya. "
              "The plant begins bearing fruit within 5-6 months
after planting and continues for several years. "
              "It requires regular irrigation and protection from
frost and strong winds. "
              "Papaya is rich in vitamins A and C and is used for
both direct consumption and processing. "
              "The crop also contains an enzyme, papain, used in
meat tenderization and pharmaceuticals."
            )
          },


    "orange": {
            "days_to_harvest": 240,
            "description": (
              "Orange is a popular citrus fruit widely grown in
Nagpur, known as the 'Orange City'. "
              "The crop prefers deep loamy soil and subtropical
climates with moderate rainfall. "
              "Oranges require 7-8 months from flowering to
harvest. "
              "Irrigation, proper fertilization, and pest control are
critical for healthy fruit development. "
```

```
                    "Trees are pruned and managed to maintain shape and encourage better fruiting. "
                    "Oranges are a good source of Vitamin C and have high market value. "
                    "They are consumed fresh and also processed into juice and marmalade."
                )
            },

        "apple":{
                "days_to_harvest": 180,
                "description": (
                    "Apple is a temperate fruit crop not naturally suited to Maharashtra’s tropical climate but grown experimentally in cooler regions. "
                    "It requires chilling hours to break dormancy, hence best suited to hilly areas. "
                    "Apples grow in well-drained loamy soils with adequate organic matter. "
                    "Proper pruning and training are required to ensure sunlight penetration and air circulation. "
                    "Pollination is usually aided by bees, and cross-pollination enhances fruit set. "
                    "Apples are harvested when they attain full size and color. "
                    "They are consumed raw, used in baking, and processed into juice and cider."
                )
            },


        "muskmelon": {
                "days_to_harvest": 80,
                "description": (
```

```
                "Muskmelon is a warm-season fruit crop commonly
grown in Maharashtra during the summer. "
                "It requires well-drained sandy loam soil and a hot,
dry climate for best growth. "
                "Irrigation should be carefully managed, especially
during flowering and fruit setting stages. "
                "The fruit is harvested when it develops a sweet
aroma and the netting on the skin is well developed. "
                "Muskmelons are rich in vitamins and water
content, making them ideal for hydration. "
                "They are consumed fresh and are commonly used
in salads and beverages. "
                "It's a short-duration crop giving quick returns to
farmers."
            )
        },

    "watermelon": {
            "days_to_harvest": 90,
            "description": (
                "Watermelon is a popular summer fruit grown
extensively in Maharashtra under warm and dry conditions. "
                "It prefers sandy loam soil with good drainage and
full sunlight. "
                "Water management is crucial; less water during
ripening ensures sweeter fruits. "
                "Harvesting is done when the fruit shows a yellow
patch at the bottom and makes a dull sound on tapping. "
                "It is known for its high water content and cooling
properties. "
                "Watermelons are consumed fresh or as juice and
are high in antioxidants. "
                "It's a fast-growing vine crop ideal for short
growing seasons."
            )
```

```
        },

    "grapes": {
            "days_to_harvest": 140,
            "description": (
              "Grapes are a commercial fruit crop widely cultivated in Maharashtra, especially in Nashik. "
              "They require a dry climate during the ripening stage and grow best in loamy, well-drained soil. "
              "Proper canopy management and pruning are crucial for quality yield. "
              "Irrigation must be controlled during ripening to prevent fruit cracking. "
              "Grapes are harvested when berries are fully colored and sweet. "
              "They are consumed fresh, dried as raisins, or used for making wine and juices. "
              "Pest management is essential, particularly for mealybugs and fungal diseases."
            )
        },


    "mango": {
            "days_to_harvest": 150,
            "description": (
              "Mango is the king of fruits and a major summer crop in Maharashtra, especially in Konkan and Marathwada. "
              "It prefers well-drained lateritic or loamy soil and thrives in tropical conditions. "
              "Mango trees require minimal irrigation once established, and flowering is triggered by dry spells. "
              "The fruit is harvested when mature, indicated by swelling shoulders and color change. "
```

```
                "Mangoes are used for fresh consumption, pickles, pulp, and juice. "
                "Alphonso and Kesar are famous varieties from Maharashtra. "
                "Regular pruning and pest control help ensure quality production."
            )
        },

    "banana": {
            "days_to_harvest": 100,
            "description": (
                "Banana is a year-round fruit crop grown in Maharashtra, particularly in Jalgaon district. "
                "It prefers warm, humid conditions and rich loamy soil with good water retention. "
                "Banana plants need frequent irrigation and fertilization for optimal growth. "
                "The crop is harvested when fingers are well-developed and angles are rounded. "
                "Bananas are consumed raw, used in snacks, processed as puree and chips. "
                "Tissue culture planting is popular for uniform growth and disease resistance. "
                "The crop requires staking or propping to support heavy bunches."
            )
        },

    "pomegranate": {
            "days_to_harvest": 100,
            "description": (
                "Pomegranate is a drought-tolerant fruit crop extensively cultivated in Maharashtra, especially in Solapur and Ahmednagar. "
```

```
                    "It grows well in light loamy to black soil with
good drainage. "
                    "The crop is highly profitable due to its high
market value and export potential. "
                    "It is pruned and irrigated systematically for
flowering and fruiting control. "
                    "Fruits are harvested when the skin turns red
and the fruit gives a metallic sound. "
                    "Pomegranates are consumed fresh, juiced, or
used in syrups and medicinal extracts. "
                    "Fruit cracking and bacterial blight are common
issues requiring proper care."
                )
            },

        "lentil": {
                "days_to_harvest": 100,
                "description": (
                    "Lentil is a cool-season legume grown as a rabi crop
in Maharashtra. "
                    "It prefers well-drained loamy soil with neutral to
slightly alkaline pH. "
                    "It is drought-tolerant and requires minimal
irrigation. "
                    "The crop is sown in November and harvested in
February–March. "
                    "Lentils are a rich source of protein and are
consumed in various forms like dal and sprouts. "
                    "Proper pest and weed management ensures a
healthy yield. "
                    "It helps fix nitrogen in the soil, improving soil
fertility."
                )
            },
```

```
        "blackgram": {
                "days_to_harvest": 90,
                "description": (
                  "Blackgram, also known as urad dal, is a kharif or
rabi pulse grown across Maharashtra. "
                  "It thrives in loamy to clayey soils with good
moisture-retention capacity. "
                  "It is often grown under rainfed conditions with
minimal inputs. "
                  "The plant improves soil health by fixing
atmospheric nitrogen. "
                  "It is harvested when the pods turn black and dry. "
                  "Used in Indian cuisine for dals, idlis, and vadas. "
                  "It is also used as a green manure and intercrop in
cotton or sugarcane fields."
                )
              },

        "mungbean": {
                "days_to_harvest": 65,
                "description": (
                  "Mungbean (moong) is a short-duration pulse
widely grown in summer and kharif seasons. "
                  "It prefers well-drained loamy or sandy soils with
neutral pH. "
                  "Being drought-resistant, it is suitable for dryland
farming. "
                  "Mungbean requires less water and gives a quick
return to farmers. "
                  "The crop is ready when pods turn brown and dry.
"
                  "It is rich in protein and is used for dal, sprouts, and
sweets. "
```

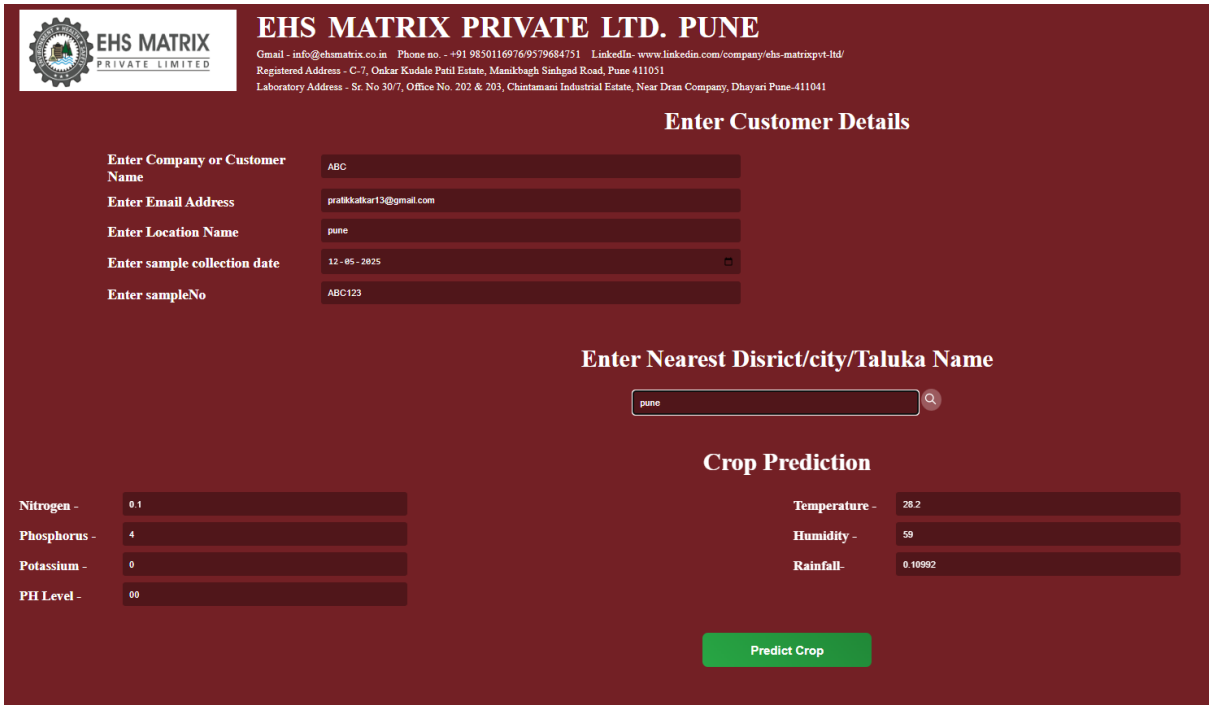
```
                    "It also enhances soil fertility through nitrogen
fixation."
                )
            },

        "mothbeans": {
                "days_to_harvest": 70,
                "description": (
                    "Mothbeans are hardy leguminous crops suited for
arid and semi-arid regions of Maharashtra. "
                    "They tolerate drought and poor soils, thriving in
sandy or light loam. "
                    "They are usually grown in the kharif season under
rainfed conditions. "
                    "Pods are harvested when fully matured and dried.
"
                    "The beans are used in traditional dishes like matki
usal and are highly nutritious. "
                    "Mothbeans are also useful as green manure and
fodder. "
                    "Minimal input and early maturity make it a low-
risk crop."
                )
            },

        "pigeonpeas": {
                    "days_to_harvest": 150,
                    "description": (
                        "Pigeonpea (tur/arhar) is a major pulse crop
grown in kharif season across Maharashtra. "
                        "It grows well in black cotton soil and medium
rainfall regions. "
                        "It is deep-rooted and drought-tolerant, making
it ideal for dryland farming. "
```

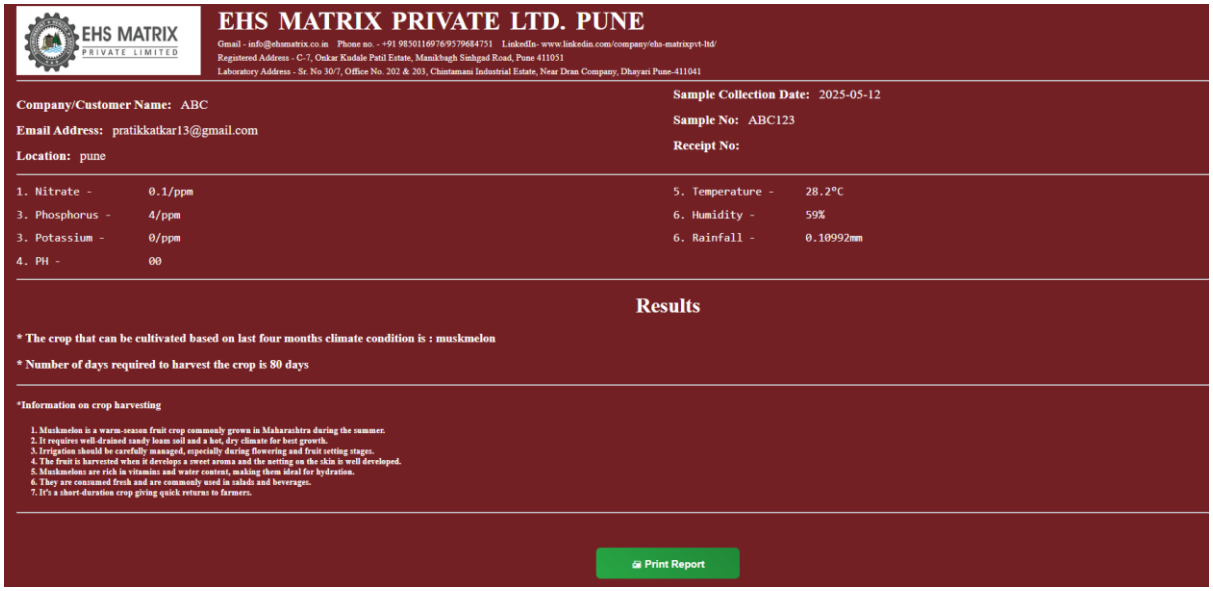
```
                    "It is often intercropped with cereals or oilseeds.
"
                    "Harvested when pods turn brown and dry. "
                    "It is a staple pulse in Indian cuisine and used in
dals and curries. "
                    "The crop also improves soil health through
nitrogen fixation."
                )
            },

        "kidneybeans": {
                "days_to_harvest": 110,
                "description": (
                    "Kidney beans (rajma) are grown in
Maharashtra's cooler and higher-altitude regions. "
                    "They require well-drained loamy soil and
moderate temperatures (15°C–25°C). "
                    "Excess moisture and waterlogging must be
avoided. "
                    "The crop is usually sown in the rabi or summer
season in appropriate climates. "
                    "Harvesting occurs when pods mature and dry. "
                    "Kidney beans are rich in protein and fiber, used
in gravies and curries. "
                    "They require boiling or pressure cooking before
consumption."
                )
            },

        "chickpea": {
                "days_to_harvest": 100,
                "description": (
                    "Chickpea (chana) is a key rabi pulse grown
extensively in Maharashtra. "
```

```
                    "It thrives in black cotton soil with good moisture
retention. "
                    "Cool, dry weather is ideal during flowering and
pod formation. "
                    "It requires minimal irrigation and is suited for low-
input farming. "
                    "Harvesting is done when plants turn brown and
pods dry out. "
                    "Chickpeas are used in curries, snacks, and flour
(besan). "
                    "The crop also improves soil fertility through
biological nitrogen fixation."
                )
            },

        "coffee": {
                "days_to_harvest": 270,
                "description": (
                    "Coffee is not a native crop of Maharashtra but is
grown in experimental farms and some cooler, shaded regions. "
                    "It requires a tropical climate with moderate
temperature (15°C–30°C) and shade. "
                    "Grows best in well-drained loamy soil rich in
organic matter. "
                    "Regular irrigation and mulching are necessary
during dry periods. "
                    "Coffee berries are harvested once they turn bright
red. "
                    "Beans are extracted through pulping, fermented,
and dried before roasting. "
                    "Arabica and Robusta are the main varieties, used
for preparing beverages."
                )
            }
    }
```

```
    if predicted_crop in crop_info_detailed:
        info = crop_info_detailed[predicted_crop]

    save_crop_prediction({
        'N': N, 'P': P, 'K': K, 'temperature': temperature, 'humidity':
humidity,
        'ph': ph, 'rainfall': rainfall,
        'predicted_crop': predicted_crop,
        'days_to_harvest': info['days_to_harvest'],
        'description': info['description']
    })
    return render_template('Result2.html', details=info ,
predicted_crop=predicted_crop)

if __name__ == "__main__":
    app.run(debug=True)
```

Output Screenshots:





EHS MATRIX PRIVATE LIMITED

EHS MATRIX PRIVATE LTD. PUNE

Gmail - info@ehsmatrix.co.in Phone no. - +91 9850116976/9579684751 LinkedIn- www.linkedin.com/company/ehs-matrixpvt-ltd/
Registered Address - C-7, Onkar Kudale Patil Estate, Manikbagh Sinhgad Road, Pune 411051
Laboratory Address - Sr. No 30/7, Office No. 202 & 203, Chintamani Industrial Estate, Near Dran Company, Dhayari Pune-411041

Company/Customer Name: ABC
Email Address: pratikkatkar13@gmail.com
Location: pune

Sample Collection Date: 2025-05-12
Sample No: ABC123
Receipt No:

1. Nitrate -	0.1/ppm	5. Temperature -	28.2°C
3. Phosphorus -	4/ppm	6. Humidity -	59%
3. Potassium -	0/ppm	6. Rainfall -	0.10992mm
4. PH -	00		

Results

*** The crop that can be cultivated based on last four months climate condition is : muskmelon**

*** Number of days required to harvest the crop is 80 days**

***Information on crop harvesting**

1. Muskmelon is a warm-season fruit crop commonly grown in Maharashtra during the summer.
2. It requires well-drained sandy loam soil and a hot, dry climate for best growth.
3. Irrigation should be carefully managed, especially during flowering and fruit setting stages.
4. The fruit is harvested when it develops a sweet aroma and the netting on the skin is well developed.
5. Muskmelons are rich in vitamins and water content, making them ideal for hydration.
6. They are consumed fresh and are commonly used in salads and beverages.
7. It's a short-duration crop giving quick returns to farmers.

Print Report

Recommendations :

- **Create a database where each value can be stored separately so that can be fetched at any time.**
- **Make auto stored all PDF in one folder.**
- **User friendliness Increasing.**

EHS MATRIX PRIVATE LTD.

Report: Developing an automatic soil fertility prediction and report printing portal. (Dt. 15/05/25 – 04/06/25)

Choosing SQLite Database:

SQLite is a lightweight, server less, self-contained relational database engine used widely for embedded systems, web apps, and desktop applications. It stores the entire database in a single **.SQLite or .dB** file, requiring no server installation or setup.

Advantages of SQLite -

- **Server less Architecture** – No need for a separate server process or system.
- **Zero Configuration** – No setup or installation needed; just include the SQLite library.
- **Cross-Platform** – Works on Windows, Linux, macOS, Android, iOS, etc.
- **Fast & Lightweight** – Great for read-heavy operations; ideal for mobile or local apps.
- **Reliable & Stable** – Uses ACID transactions, ensuring database integrity.
- **Portable Database File** – Entire database in a single file; easy to back up and transfer.
- **Public Domain** – Free to use for commercial and personal projects.
- **Built-in SQL Support** – Supports most standard SQL operations.
- **Great for Testing & Prototypes** – Quickly spin up local databases without external dependencies.

- **Scalable for Small to Medium Apps** – Can handle multiple gigabytes of data efficiently.

Why not other Database –

- **MySQL/PostgreSQL -** Overkill for small, local projects; requires server, user setup, and networking.
- **Mongo DB -** No relational structure; not suitable for normalized soil/crop data.
- **Oracle/MS SQL Server -** Heavy enterprise-level databases — unnecessary complexity for lightweight needs.

SQLite is suitable because of following results-

1. **Lightweight & Embedded**
   SQLite runs in-process with your application no server setup is needed. Ideal for small projects or offline applications.
2. **Zero Configurations**
   Unlike MySQL or PostgreSQL, SQLite doesn't require a database server to install, start, or configure. Just import and use.
3. **Portable File-based Storage**
   The entire database is stored in a single .db file, which makes it easy to **back up, copy, or transfer** — great for internships, demos, or school projects.
4. **Fast for Small Datasets**
   Since your data (e.g., soil readings, crop recommendations) is modest in volume, SQLite offers excellent performance.
5. **Perfect for Flask Apps**
   SQLite integrates seamlessly with Flask via Flask-SQLAlchemy, reducing setup and allowing you to focus on logic instead of DB infrastructure.

15 Basic SQLite commands –

1. **CREATE TABLE – Define a new table**

CREATE TABLE soil_fertility (id INTEGER PRIMARY KEY, NO3 REAL, NH4 REAL);

2. **INSERT INTO – Add new data to a table**

   INSERT INTO soil_fertility (NO3, NH4) VALUES (12.5, 2.1);

3. **SELECT – Retrieve data from one or more columns**

   SELECT NO3, NH4 FROM soil_fertility;

4. **UPDATE – Modify existing data**

   UPDATE soil_fertility SET NO3 = 13.8 WHERE id = 1;

5. **DELETE – Remove rows from a table**

   DELETE FROM soil_fertility WHERE id = 5;

6. **DROP TABLE – Remove a table completely**

   DROP TABLE crop_predictions;

7. **ALTER TABLE – Modify table schema (like add a column)**

   ALTER TABLE crop_predictions ADD COLUMN remarks TEXT;

8. **WHERE – Filter records by condition**

   SELECT * FROM crop_predictions WHERE predicted_crop = 'Rice';

9. **ORDER BY – Sort query results**

   SELECT * FROM soil_fertility ORDER BY prediction_score DESC;

10. **LIMIT – Restrict number of rows returned**

    SELECT * FROM crop_predictions LIMIT 10;

11. **DISTINCT – Aggregate rows with same values**

    SELECT DISTINCT predicted_crop FROM crop_predictions;

12. **GROUP BY –**

    SELECT predicted_crop, COUNT(*) FROM crop_predictions GROUP BY predicted_crop;

13. **LIKE – Pattern matching for search**

    SELECT * FROM crop_predictions WHERE predicted_crop LIKE 'W%';

14. **BETWEEN – Filter data within a range**

    SELECT * FROM soil_fertility WHERE prediction_score BETWEEN 60 AND 90;

15. **JOIN – Combine data from multiple tables**

    SELECT s.NO3, c.predicted_crop
    FROM soil_fertility s
    JOIN crop_predictions c ON s.id = c.id;

Steps for Building and integrating Database –

1. Understanding which type of Database will suite the project by having a thorough research on it.
2. Connected SQLite and created two tables named as crop_prediction and soil_fertility.
3. Created two functions as save_crop_prediction and save_soil_fertility.
4. Called those two functions in main python file under respective routing function after the predication is done.
5. DB aslo stores the time stramp at which data is being inserted.

Code –

Database file

```
import sqlite3

def init_db():
    conn = sqlite3.connect('agriculture.db')
    cursor = conn.cursor()
    # Create table for crop prediction
    cursor.execute('''
        CREATE TABLE IF NOT EXISTS crop_predictions (
```

```
        id INTEGER PRIMARY KEY AUTOINCREMENT,
        N REAL, P REAL, K REAL,
        temperature REAL, humidity REAL, ph REAL, rainfall REAL,
        predicted_crop TEXT,
        days_to_harvest INTEGER,
        description TEXT,
        prediction_time TIMESTAMP DEFAULT CURRENT_TIMESTAMP
    )
''')
# Create table for soil fertility
cursor.execute('''
    CREATE TABLE IF NOT EXISTS soil_fertility (
        id INTEGER PRIMARY KEY AUTOINCREMENT,
        NO3 REAL, NH4 REAL, P REAL, K REAL, SO4 REAL, B REAL,
        Organic_Matter REAL, pH REAL, Zn REAL, Cu REAL, Fe REAL,
        Ca REAL, Mg REAL, Na REAL,
        prediction_score REAL,
        message TEXT,
        timestamp TIMESTAMP DEFAULT CURRENT_TIMESTAMP
    )
''')
conn.commit()
conn.close()
```

```
def save_crop_prediction(data):
    conn = sqlite3.connect('agriculture.db')
    cursor = conn.cursor()

    cursor.execute('''
        INSERT INTO crop_predictions (
            N, P, K, temperature, humidity, ph, rainfall,
            predicted_crop, days_to_harvest, description
        ) VALUES (?, ?, ?, ?, ?, ?, ?, ?, ?, ?)
    ''', (
        data['N'], data['P'], data['K'], data['temperature'],
data['humidity'], data['ph'], data['rainfall'],
        data['predicted_crop'], data['days_to_harvest'],
data['description']
    ))
    conn.commit()
    conn.close()
def save_soil_fertility(data):
    conn = sqlite3.connect('agriculture.db')
    cursor = conn.cursor()
    cursor.execute('''
        INSERT INTO soil_fertility (
            NO3, NH4, P, K, SO4, B, Organic_Matter, pH, Zn, Cu, Fe, Ca,
Mg, Na, prediction_score, message
```

```
        ) VALUES (?, ?, ?, ?, ?, ?, ?, ?, ?, ?, ?, ?, ?, ?, ?, ?)
    ''', (
        data['NO3'], data['NH4'], data['P'], data['K'], data['SO4'],
data['B'],
        data['Organic_Matter'], data['pH'], data['Zn'], data['Cu'],
data['Fe'],
        data['Ca'], data['Mg'], data['Na'], data['prediction_score']*100,
data['message']
    ))
    conn.commit()
    conn.close()
```

Function calling for inserting values –

```
from database import init_db, save_crop_prediction,
save_soil_fertility

init_db()

save_soil_fertility({
        'NO3': a0, 'NH4': a1, 'P': a2, 'K': a3, 'SO4': a4, 'B': a5,
        'Organic_Matter': a6, 'pH': a7, 'Zn': a8, 'Cu': a9, 'Fe': a10,
        'Ca': a11, 'Mg': a12, 'Na': a13,
        'prediction_score': float(prediction),
         'message': text
    })
  save_crop_prediction({
```

'N': N, 'P': P, 'K': K, 'temperature': temperature, 'humidity': humidity,

'ph': ph, 'rainfall': rainfall,

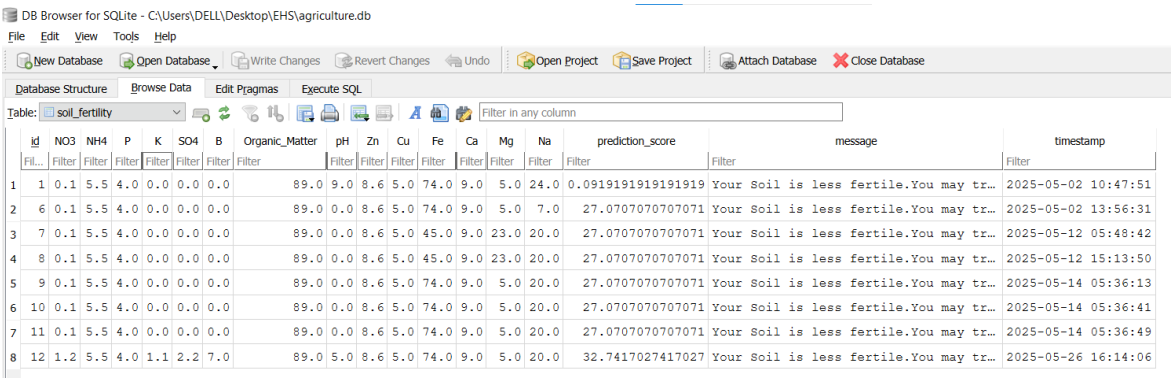
'predicted_crop': predicted_crop,

'days_to_harvest': info['days_to_harvest'],

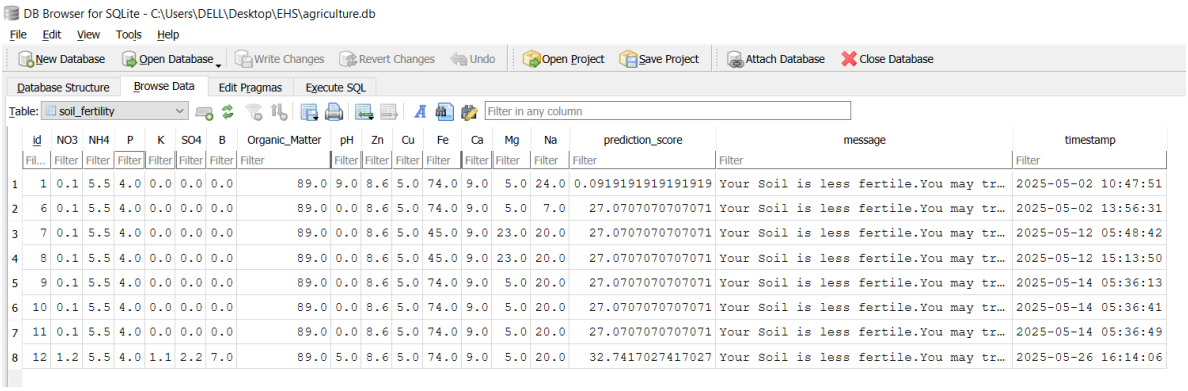
'description': info['description']

})

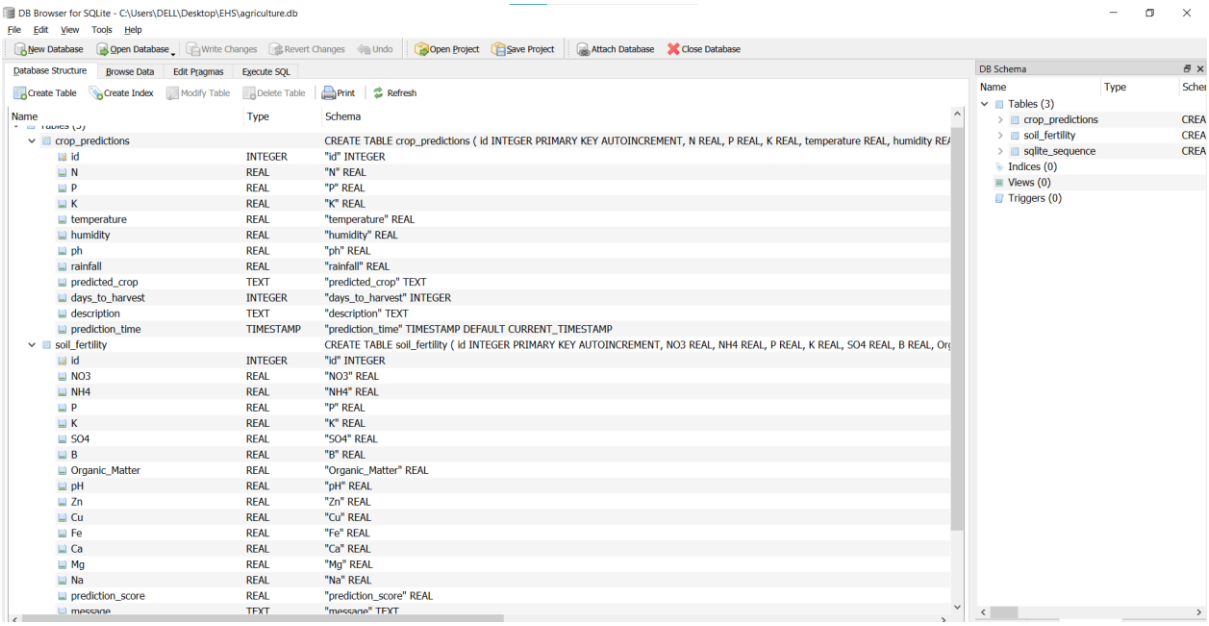
Screenshot –



	id	NO3	NH4	P	K	SO4	B	Organic_Matter	pH	Zn	Cu	Fe	Ca	Mg	Na	prediction_score	message	timestamp
1	1	0.1	5.5	4.0	0.0	0.0	0.0	89.0	9.0	8.6	5.0	74.0	9.0	5.0	24.0	0.0919191919191919	Your Soil is less fertile.You may tr…	2025-05-02 10:47:51
2	6	0.1	5.5	4.0	0.0	0.0	0.0	89.0	0.0	8.6	5.0	74.0	9.0	5.0	7.0	27.0707070707071	Your Soil is less fertile.You may tr…	2025-05-02 13:56:31
3	7	0.1	5.5	4.0	0.0	0.0	0.0	89.0	0.0	8.6	5.0	45.0	9.0	23.0	20.0	27.0707070707071	Your Soil is less fertile.You may tr…	2025-05-12 05:48:42
4	8	0.1	5.5	4.0	0.0	0.0	0.0	89.0	0.0	8.6	5.0	45.0	9.0	23.0	20.0	27.0707070707071	Your Soil is less fertile.You may tr…	2025-05-12 15:13:50
5	9	0.1	5.5	4.0	0.0	0.0	0.0	89.0	0.0	8.6	5.0	74.0	9.0	5.0	20.0	27.0707070707071	Your Soil is less fertile.You may tr…	2025-05-14 05:36:13
6	10	0.1	5.5	4.0	0.0	0.0	0.0	89.0	0.0	8.6	5.0	74.0	9.0	5.0	20.0	27.0707070707071	Your Soil is less fertile.You may tr…	2025-05-14 05:36:41
7	11	0.1	5.5	4.0	0.0	0.0	0.0	89.0	0.0	8.6	5.0	74.0	9.0	5.0	20.0	27.0707070707071	Your Soil is less fertile.You may tr…	2025-05-14 05:36:49
8	12	1.2	5.5	4.0	1.1	2.2	7.0	89.0	5.0	8.6	5.0	74.0	9.0	5.0	20.0	32.7417027417027	Your Soil is less fertile.You may tr…	2025-05-26 16:14:06



	id	NO3	NH4	P	K	SO4	B	Organic_Matter	pH	Zn	Cu	Fe	Ca	Mg	Na	prediction_score	message	timestamp
1	1	0.1	5.5	4.0	0.0	0.0	0.0	89.0	9.0	8.6	5.0	74.0	9.0	5.0	24.0	0.0919191919191919	Your Soil is less fertile.You may tr…	2025-05-02 10:47:51
2	6	0.1	5.5	4.0	0.0	0.0	0.0	89.0	0.0	8.6	5.0	74.0	9.0	5.0	7.0	27.0707070707071	Your Soil is less fertile.You may tr…	2025-05-02 13:56:31
3	7	0.1	5.5	4.0	0.0	0.0	0.0	89.0	0.0	8.6	5.0	45.0	9.0	23.0	20.0	27.0707070707071	Your Soil is less fertile.You may tr…	2025-05-12 05:48:42
4	8	0.1	5.5	4.0	0.0	0.0	0.0	89.0	0.0	8.6	5.0	45.0	9.0	23.0	20.0	27.0707070707071	Your Soil is less fertile.You may tr…	2025-05-12 15:13:50
5	9	0.1	5.5	4.0	0.0	0.0	0.0	89.0	0.0	8.6	5.0	74.0	9.0	5.0	20.0	27.0707070707071	Your Soil is less fertile.You may tr…	2025-05-14 05:36:13
6	10	0.1	5.5	4.0	0.0	0.0	0.0	89.0	0.0	8.6	5.0	74.0	9.0	5.0	20.0	27.0707070707071	Your Soil is less fertile.You may tr…	2025-05-14 05:36:41
7	11	0.1	5.5	4.0	0.0	0.0	0.0	89.0	0.0	8.6	5.0	74.0	9.0	5.0	20.0	27.0707070707071	Your Soil is less fertile.You may tr…	2025-05-14 05:36:49
8	12	1.2	5.5	4.0	1.1	2.2	7.0	89.0	5.0	8.6	5.0	74.0	9.0	5.0	20.0	32.7417027417027	Your Soil is less fertile.You may tr…	2025-05-26 16:14:06



Suggestions –

- Testing of all input fields and applying validation rules for input fields based on their min and max values and units.
- Accuracy Testing with online modules if possible .
- Make auto stored all pdf in one folder by giving button (Webkit HTML to PDF - wkhtmltopdf implementation).
- User friendliness Increasing.