Machine learning based rainfall prediction and alert system for farmers

SWE3004 – Software Design and Development Project

Submitted in partial fulfillment of the requirements for the degree of

M.Tech (Software Engineering)

in

Department of Software and Systems Engineering

by

Varun Kaarthikeyan S J

21MIS0406

Under the guidance of

Dr. Karthikeyan P

School of Computer Science Engineering and Information Systems

VIT, Vellore

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DECLARATION

I hereby declare that the SWE3004 – Software Design and Development Project entitled "**Machine learning based rainfall prediction and alert system for farmers**" submitted by me, for the award of the degree of M.Tech (Software Engineering) in Department of Software and Systems Engineering, School of Computer Science Engineering and Information Systems to VIT is a record of bonafide work carried out by me under the supervision of **Dr. Karthikeyan P, Associate Professor Sr – Grade 2, SCORE, VIT, Vellore.**

I further declare that the work reported in this project has not been submitted and will not be submitted, either in part or in full, for the award of any other degree or diploma in this institute or any other institute or university.

Place: Vellore

Date:

Signature of the Candidate

CERTIFICATE

This is to certify that the **SWE3004 – Software Design and Development Project** entitled "Machine learning based rainfall prediction and alert system for farmers" submitted by **Varun Kaarthikeyan S J – 21MIS0406**, SCORE, VIT, for the award of the degree of M.Tech (Software Engineering) in Department of Software and Systems Engineering, is a record of bonafide work carried out by him under my supervision during the period, 9.7.2025 to 14.11.2025, as per the VIT code of academic and research ethics.

The contents of this report have not been submitted and will not be submitted either in part or in full, for the award of any other degree or diploma in this institute or any other institute or university. The dissertation fulfill the requirements and regulations of the University and in my opinion meet the necessary standards for submission.

Place: Vellore

Date:

Signature of the VIT-SCORE - Guide

Internal Examiner **External Examiner**

Head of the Department

Department of Software and Systems Engineering

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It is indeed a pleasure to thank my parents and friends who persuaded and encouraged me to take up and complete my dissertation successfully. Last, but not least, I express my gratitude and appreciation to all those who have helped me directly or indirectly towards the successful completion of the dissertation**.**

Place: Vellore

Date: **Varun Kaarthikeyan S J**

Executive Summary

This project introduces a Machine Learning-Based Rainfall Prediction and Alert System designed to enhance climate-resilient farming by providing accurate, timely, and location-specific rainfall forecasts to farmers. Unpredictable weather severely impacts critical farming activities like irrigation, fertilization, and harvesting, leading to crop damage and financial losses.

The core of the system is the CatBoost algorithm, chosen for its high accuracy and efficiency in handling structured meteorological data. It uses user-provided inputs, including temperature, humidity, wind speed, climate conditions, and location, to predict the likelihood of rainfall. The system features a user registration module that captures the farmer's name, contact information, and location to enable personalized alerts.

The key feature is the automated alert mechanism, which immediately notifies registered farmers via email of the upcoming rainfall events. These real-time alerts empower farmers to make informed decisions- such as optimize irrigation schedules and safeguarding crops- thereby reducing crop loss and improving overall agriculture productivity and sustainability.

The technical implementation utilizes Python, Flask, and MySQL, with the ML model (CatBoost) being trained on historical weather data and saved as a pickle file. The system aims to bridge the gap between weather data and practical farm management, serving as a reliable decision-support system that enhances rural livelihood through proactive weather management. The development plan covers requirements analysis, system design, CatBoost model training, backend/frontend development, and alert module integration.

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CHAPTER 1

INTRODUCTION

Agriculture, particularly in developing nations, is highly dependent on weather conditions, especially rainfall. The increasing climate variability and unpredictable weather patterns present significant challenges for farmers in making timely decisions regarding irrigation, fertilization, and harvesting. To counter the risks posed by sudden, unanticipated rainfall-which can cause crop damage, resource wastage, and financial losses-this project introduces a Machine Learning-Based Rainfall Prediction and Alert system for Farmers. The system is specifically designed to support smarter, data-driven, agricultural practices.

1.1 Objective

The core objective is to deliver a reliable system for proactive weather management in farming. The key objectives are:

- Accurate Prediction: Utilize the CatBoost algorithm, a powerful gradient boosting technique, to analyze user-provided meteorological inputs (temperature, humidity, windspeed, climate type, pressure, and geographic location) and generate personalized rainfall forecasts.

- Personalized Forecasting: Register farmer details (name, location and contact information) to generate forecasts that are specific to their location.

- Automated Communication: Implement an automated alert mechanism to deliver timely notification via email to inform farmers of potential rainfall events.

- Supported Informed Action: Enable farmers to adjust their farming activities, optimize schedules, and plan efficiently based on the timely alerts.

1.2 Motivation

The primary motivation for this project stems from the need to migrate severe weather-related risks in agriculture. Traditional methods often fail to provide the high precision and timely alerts require for specific locations, leaving farmers vulnerable to sudden weather

changes. This project seeks to bridge the gap between data availability and its practical application.

By providing accurate, location-specific forecasts and immediate alerts, the system empowers farmers to:

- Reduce Weather-Related Risks: Make timely decisions, optimize irrigation schedules, safeguard crops, and plan harvests more efficiently.
- Improve Productivity and Sustainability: Improve overall productivity, reduce losses, and promote climate-resilient and sustainable agriculture.
- Enhance Decision-Making: Provide decision-making capabilities to farmers, especially those in remote and rural areas.

1.3 Background

The system's background is rooted in modern computational approaches for agricultural decision support. It leverages the efficiency of the CatBoost machine learning algorithm, which is partially effective with structured data and categorical features.

The functionality integrates three components:

- Data Analysis: Using the CatBoost model to analyze meteorological data and predict the likelihood of rainfall.
- User Registration: A module for farmers to register their contact and location details to receive personalized predictions.
- Alert System: An automated mechanism to send forecasts and alerts via email, serving as a direct communication tool.

This combination of machine learning with targeted communication acts as a decision-support system, aiming to bridge the gap between data and decision-making for sustainable agricultural resilience.

CHAPTER 2

DISSERTATION DESCRIPTION AND GOALS

2.1 Overview

The dissertation focuses on developing a Machine Learning-Based Rainfall Prediction and Alert System for Farmers. The primary aim is to enhance agriculture decision-making by providing accurate and timely rainfall forecasts. The system leverages the CatBoost algorithm for high-precision rainfall forecasting, utilizing user-provided meteorological data such as temperature, humidity, wind speed, and location.

A key feature is the automated alert mechanism, which sends personalized, location-specific notifications to farmers via email upon generating a forecast. This system is intended not only as a reliable weather forecasting tool but also as a decision-support system that enhances agricultural resilience and sustainability by empowering farmers to make timely and informed decisions regarding crop protection, irrigation scheduling, and harvesting.

2.2 Goals

- Accurate ML Model Development: To develop a machine learning model, primarily using CatBoost, capable of accurately predicting rainfall using multiple meteorological parameters.
- Real-Time Data Integration: To integrate real-time data inputs from sources like IoT sensors, weather APIs, and historical datasets to improve prediction accuracy.
- Automated Alert Implementation: To implement an automated alert system that sends timely notifications via email enabling them to take prevention measures.
- User Interface Creation: To create a user-friendly web-based front-end interface where farmers can input environmental parameters, register, and easily view rainfall prediction results.
- Agricultural Impact: To reduce crop loss and irrigation costs by enabling informed

decision-making based on accurate rainfall forecasts.

- System Scalability: To design a scalable and adaptable system that can be expanded to cover multiple regions and different climatic conditions.

CHAPTER 3

TECHNICAL SPECIFICATION

3.1 Software requirements

3.1.1 Functional requirements

- User Registration and Authentication: Farmers must be able to register using their name, email, phone number, and location. The system must validate the contact format.
- Weather Data Input: The system must allow the input of attributes such as temperature, humidity, pressure, wind, sunshine, and rainfall. Farmers must also be able to select their location.
- Prediction Module: The system must use the trained ML model (CatBoost) to predict rainfall based on the input attributes. Prediction results, displayed as "Rainy or sunny," should be shown on the web interface.
- Alerts and Notifications: If rainfall is predicted, the system must send personalized alert messages via Email, based on the farmer's registration details and location.
- Database Management: Farmer details (name, email, phone, location) must be stored securely in MySQL. Past weather inputs and prediction results should also be logged.
- Web Interface: The frontend, built with HTML/CSS/JS, must include separate pages for registration and prediction input, allowing farmers to easily enter data.

3.1.2 Non-functional requirements

- Performance: Prediction generation must take less than 3 seconds. The system should support at least 100 concurrent users.
- Scalability: Must support adding more users and integrating more weather attributes in the future. Must allow integration with live weather APIs.
- Security: Farmers' personal data must be stored securely. Passwords or API keys (e.g., for Gmail SMTP) should not be hardcoded.
- Reliability: The system should handle failed email delivery and retry automatically. Database connection errors should not crash the system.
- Usability: The UI must be simple, farmer-friendly, and mobile-responsive, with potential for local language support.
- Portability: Must run on Windows/Linux with Python 3 and work on low-cost hosting servers.

3.2 System requirements

This architecture illustrates the machine learning pipeline and the flow from raw dataset to final prediction and action.

3.2.1 Rainfall Dataset: Initial collection of historical and meteorological data.

3.2.2 Data Preprocessing: This stage involves Normalization and handling Missing Values.

3.2.3 Data Analysis: The data is split into Training and Testing sets.

3.2.4 Feature Extraction: Relevant features are selected from the processed data.

3.2.5 Train Learning Model: The extracted features are used to train the machine learning model, which is specified as CatBoost.

3.2.6 Build Model & Evaluate Performance: The model is built, and its performance is evaluated using appropriate metrics.

3.2.7 New Input & Prediction: The built model receives New Input data to make a Prediction based on the candidate model.

3.2.8 Output & Alert: The output is Rainfall Probability (Yes/No), which triggers the automated alert system to notify farmers.

3.3 Hardware requirement

- Processor : i5
- Speed : 3 GHz
- RAM : 8 GB (min)
- Hard Disk : 500 GB
- Key Board : Standard Windows Keyboard
- Mouse : Two or Three Button Mouse
- Monitor : SVGA

CHAPTER 4

DESIGN APPROACH AND DETAILS

4.1 Design approach

The design centers on an end-to-end Machine Learning pipelines integrated into a decision-support system. This approach involves sequential phases, starting with data acquisition and ending with real-time farmer alerts. The core idea is to combine the predictive power of a sophisticated algorithm with direct, personalized communication. The system uses a scalable architecture to allow for expansion to multiple regions and integration of more data sources over time.

4.2 Materials

- Software: Python 3.x, Flask (web framework), MySQL (database), and VS Code.
- Libraries: Pandas, NumPy, CatBoost, Scikit-learn, PyMySQL, and Requests.
- Data: Historical rainfall data, geographical features, and key meteorological parameters (temperature, humidity, wind speed, pressure, etc.).

4.3 Methodology

- Data Preprocessing: This involves handling missing values, normalizing or scaling the data, and performing Feature Engineering. The dataset imbalance is addressed using the SMOTE technique.
- Model Selection: The CatBoost Classifier is selected for training, known for its efficiency with categorical features and high accuracy.
- Model Training and Evaluation: The data is split into training and testing sets. The model is trained, and its performance is assessed using metrics like Mean Absolute Error and Root Mean Squared Error.
- Deployment and Alerting: The trained model is saved as a pickle file (catml.pkl) and incorporated into the Flask-based web application. An automated module is set up using Gmail App Passwords to deliver timely alerts.

4.4 Codes and standards

The project adheres to stringent codes and standards across software engineering, machine learning, and agricultural application development. From a Software Development perspective, the system is primarily built using Python 3.x and the Flask framework,

implying adherence to Python's community standards for code quality, such as PEP 8 for readability. Crucially, the code is mandated to be modular, separating components like the ML model and database handling to ensure high maintainability. The core algorithm, CatBoost, is an open-source library and its use is subject to Apache License 2.0. Security standards are addressed by requiring that farmer personal data be stored securely in MySQL and that sensitive credentials, like API keys email (Gmail App Passwords), are not hardcoded .In Machine Learning, the methodology follows best practices, including rigorous Data Cleaning (handling missing values/outliers), Normalization, and the use of SMOTE to address dataset class imbalance (Rain vs. No Rain), a standard technique for improving model fairness and accuracy. Finally, as a Decision Support System, it adheres to high Performance standards, requiring predictions in less than 3 seconds and robust Reliability through mechanisms to handle database errors and retry failed Email delivery automatically, ensuring critical information reaches the farmers on time.

4.5 Constraints, Alternative, and Trade-offs

- Performance Constraint: The prediction must be generated quickly, specifically in less than 3 seconds.
- Data Imbalance: The implementation code explicitly addresses the imbalance in the target variable (RainTomorrow - Yes/No), which is a common constraint in meteorological datasets.
- Scalability Constrain: The system must support at least 100 concurrent users and must be adaptable to integrate more weather attributes and live weather APIs in the future.
- Security Constrain: Sensitive information like API keys for email (Gmail App Passwords) must not be hardcoded, posing a security implementation constraint.
- Prediction Algorithm:
    1. Chosen: CatBoost (Categorical Boosting).
    2. Alternatives Discussed: Decision trees, random forests, or linear regression.

The literature survey also explored LSTM, SVM, AdaBoost, GBDT, and XGBoost models.

- Imputation Method:

    1. Chosen: Random sample imputation for certain missing values ("Cloud," "Evaporation," "Sunshine") .

    2. Alternatives: Filling missing continuous features with the median was also used for other features.

- Prediction vs Accuracy

    Trade-off: The choice of CatBoost was based on its efficiency and high accuracy on structured datasets, indicating a choice for a robust ensemble model over simpler, less powerful options.

- Development Speed vs Security:

    Trade-off: The requirement not to hardcode credentials (using Gmail App Passwords and secure API keys) adds complexity and time to the backend development and configuration phase, but this is a necessary trade-off for Security and compliance .

CHAPTER 5

SCHEDULE, TASKS, AND MILESTONES

5.1 Project Timeline

Month	Phase	Activities	Duration
July 2025	Phase 1: Requirement Analysis	Gather functional and non-functional requirements; define project goals.	1 week
July 2025	Phase 2: System Design	Design the database (MySQL); create the ER diagram; design UI mockups/wireframes	1 week
July – August 2025	Phase 3: Model Training	Preprocess the dataset (cleaning, handling missing values, SMOTE); train the ML model (CatBoost); evaluate accuracy.	2 week
August 2025	Phase 4: Backend Development	Develop the Flask app; integrate the ML model; set up routes for prediction and registration APIs.	2 week
September 2025	Phase 5: Frontend Development	Build HTML/CSS forms for registration and prediction input	1 week
September 2025	Phase 6: Alert Module	Configure Gmail SMTP; test alerts for registered users.	2 week
October 2025	Phase 7: Testing	Conduct unit testing, integration testing; perform bug fixing.	1 week
October 2025	Phase 8 : Deployment and Documentation	Deploy the system on localhost/server; prepare the final project report and	1 week

		documentation.	

Table 5.1

5.2 Milestone Overview

Month	Phase(s)	Outcomes
July 2025	Phase 1 & phase 2	Foundation and Design Complete : * SRS Document (Requirement List) * Database Schema and UI Wireframes.
August 2025	Phase 3 & Phase 4	ML Model and Backend Infrastructure Ready : * Trained Rainfall Prediction Model (CatBoost) * Flask Backend with Working APIs.
September 2025	Phase 5 & Phase 6	User Interface and Alert System Functional : * Working Web UI (HTML/CSS forms) * Working Email Alert System Integrated.
October 2025	Phase 7 & Phase 8	Final System Delivery and Documentation : * Test Report and Debugged System * Working System Deployed * Project Documentation Completed.

Table 5.2

CHAPTER 6

DISSERTATION DEMONSTRATION

6.1 apk.py

```
from flask import Flask,render_template,url_for,request,jsonify
from flask_cors import cross_origin
import pandas as pd
import numpy as np
import datetime
import pickle
import smtplib
import getpass
HOST = "smtp.gmail.com"
PORT = 587

smtp = smtplib.SMTP(HOST,PORT)
smtp.starttls()
FROM_EMAIL = "farmtuner7@gmail.com"
PASSWORD = "uvgv mkud ovpb tlct"
smtp.login(FROM_EMAIL, PASSWORD)

import pymysql
mydb = pymysql.connect(host="localhost", user="root", password="12345",
database="users")
mycursor = mydb.cursor()

MESSAGE_RAIN ="""\
Subject: Weather Advisory and Farming Tips for Rainy Days
Dear farmer,
```

As we anticipate rainy weather in your area tomorrow, we wanted to offer some suggestions to help you prepare for the rain and its impact on your farm:

1.Field Preparation: Ensure proper drainage in your fields to prevent waterlogging. Check that your ditches and drains are clear of debris.

2.Crop Protection: If you have young or vulnerable crops, consider using covers or shelters to protect them from heavy rain and wind.

3.Equipment Check: Inspect your farming equipment, especially machinery used for irrigation and drainage, to ensure they are in good working condition.

4.Animal Shelter: If you have livestock, make sure they have adequate shelter to protect them from the rain and cold.

5.Soil Management: Be cautious of soil erosion. Consider planting cover crops or using mulch to protect the soil from heavy rain.

6.Harvest Preparation: If you have crops ready for harvest, consider harvesting them before the rain to prevent damage and ensure quality.

We hope these tips help you prepare for the rainy weather ahead. If you have any specific concerns or need further assistance, please feel free to reach out to us.

Stay safe and best of luck with your farming endeavors!

Warm regards,

FarmTuner."""

MESSAGE_SUNNY ="""\

Subject: Farming Tips for Sunny Weather

Dear farmer,

With sunny weather forecasted in your area tomorrow, we wanted to share some tips to help you make the most of the sunshine and keep your farm thriving:

1. Hydration for Crops and Livestock: Ensure your crops and livestock have an adequate water supply. Irrigate your fields early in the morning or late in the evening to minimize water loss from evaporation.

2. Sun Protection: If you're working outdoors, protect yourself from the sun's rays by wearing a hat, sunglasses, and sunscreen. Consider using sun shades on your equipment to prevent overheating.

3. Crop Care: Monitor your crops closely for signs of heat stress. Provide shade or cover for sensitive plants if necessary. Mulching can also help retain soil moisture and keep roots cool.

4. Livestock Comfort: Ensure your livestock have access to shaded areas and plenty of fresh, clean water to stay cool and hydrated.

5. Equipment Maintenance: Check your equipment regularly to prevent breakdowns due to overheating. Keep engines well-lubricated and ensure cooling systems are functioning properly.

6. Harvest Timing: Plan your harvests for early morning or late evening when temperatures are cooler to minimize heat stress on you and your workers.

7. Soil Moisture Management: Monitor soil moisture levels closely and adjust irrigation schedules as needed to prevent drought stress in your crops.

8. Fire Safety: With dry conditions, be vigilant about fire safety. Avoid activities that could spark fires, and have fire extinguishers or water sources readily available.

We hope these tips help you manage your farm effectively during sunny weather. If you have any specific concerns or need further assistance, please feel free to reach out to us.

Wishing you a successful and productive season!

Warm regards,

FarmTuner."""

```
smtp = smtplib.SMTP(HOST, PORT)
smtp.ehlo()
smtp.starttls()
smtp.login(FROM_EMAIL, PASSWORD)
app = Flask(__name__, template_folder="template")
model = pickle.load(open("./models/catml.pkl", "rb"))
print("Model Loaded")
@app.route("/",methods=['GET'])
@cross_origin()
def home():
    return render_template("index.html")
@app.route("/predict",methods=['GET', 'POST'])
@cross_origin()
def predict():
```

```
if request.method == "POST":
    # DATE
    date = request.form['date']
    day = float(pd.to_datetime(date).day)
    month = float(pd.to_datetime(date).month)
    # MinTemp
    minTemp = float(request.form['mintemp'])
    # MaxTemp
    maxTemp = float(request.form['maxtemp'])
    # Rainfall
    rainfall = float(request.form['rainfall'])
    # Evaporation
    evaporation = float(request.form['evaporation'])
    # Sunshine
    sunshine = float(request.form['sunshine'])
    # Wind Gust Speed
    windGustSpeed = float(request.form['windgustspeed'])
    # Humidity 9am
    humidity = float(request.form['humidity9am'])
    # Pressure 9am
    pressure= float(request.form['pressure9am'])
    # Pressure 3pm
    # Temperature 9am
    temp = float(request.form['temp9am'])
    # Temperature 3pm
    location = float(request.form['location'])
    # Cloud 9am
    cloud = float(request.form['cloud9am'])
```

```
# Cloud 3pm
# Wind Gust Dir
windGustDir = float(request.form['windgustdir'])
# Rain Today
rainToday = float(request.form['raintoday'])
input_lst = [location, minTemp , maxTemp , rainfall , evaporation , sunshine ,
            windGustDir , windGustSpeed ,
            humidity , pressure,  cloud ,  temp ,
            rainToday , month , day]
if location == 0:
   loc='Arakkonam'
elif location == 1:
   loc='Aruppukottai'
elif location == 2:
   loc='Avadi'
elif location == 3:
   loc='Chengalpattu'
elif location == 4:
   loc='Chennai'
elif location == 5:
   loc='Coimbatore'
elif location == 6:
   loc='Cuddalore'
elif location == 7:
   loc='Dindigul'
elif location == 8:
   loc='Erode'
elif location == 9:
```

```
            loc='Gudiyatham'
        elif location == 10:
            loc='Hosur'
        pred = model.predict(input_lst)
        output = pred
        query= "SELECT email FROM weather WHERE location =%s"
        mycursor.execute(query, (loc,))
        recipients = mycursor.fetchall()
        if output == 0:
            for recipient in recipients:
                smtp.sendmail(FROM_EMAIL, recipient[0], MESSAGE_SUNNY)
            smtp.quit()
            return render_template("after_sunny.html")
        else:
            for recipient in recipients:
                smtp.sendmail(FROM_EMAIL, recipient[0], MESSAGE_RAIN)
            smtp.quit()
            return render_template("after_rainy.html")

    return render_template("predictor.html")

@app.route("/insert",methods=['GET','POST'])
@cross_origin()
def insert():
    if request.method == "POST":
        name = request.form['name']
        email=request.form['email']
        location=request.form['location']
```

```
        mycursor.execute("INSERT INTO weather(name,email,location) VALUES
(%s,%s,%s)",(name,email,location))
        mydb.commit()
    return render_template("insert.html")
app.run()
if __name__=='__main__':
    app.run(debug=True)
```

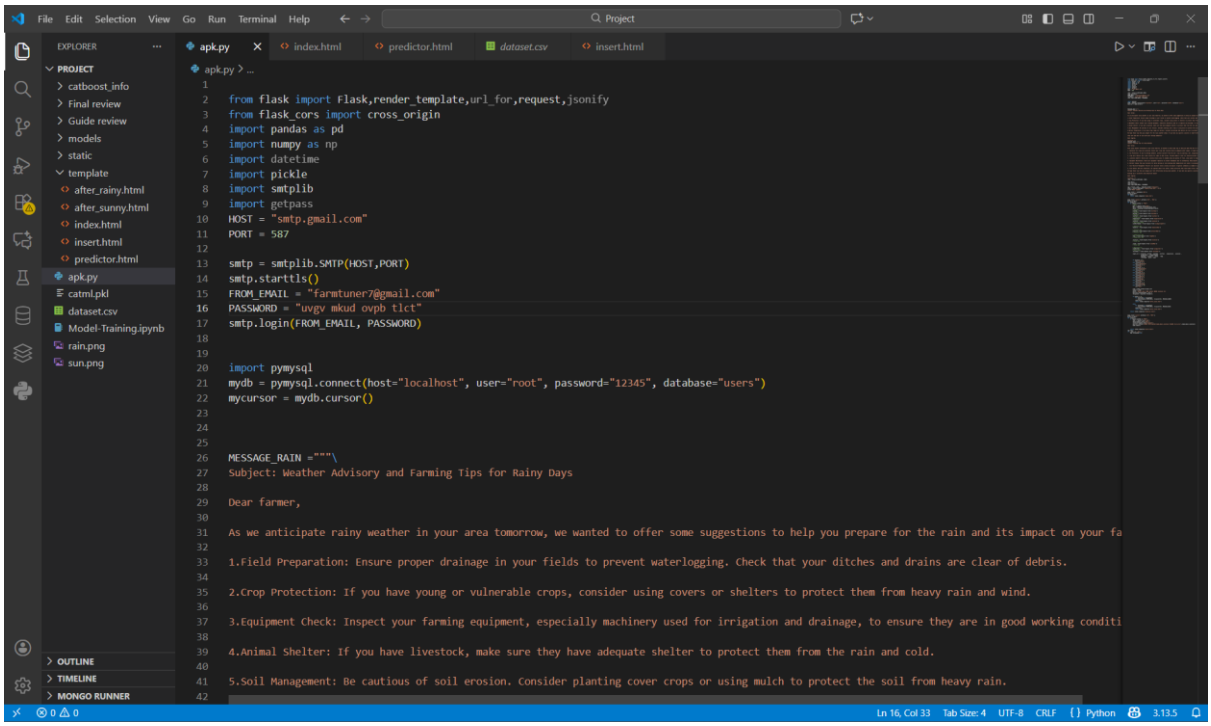


Fig 6.1

6.2 index.html

```
<html>
  <head>
    <link rel="stylesheet" href={{url_for('static',filename='indstyle.css')}}>
  </head>
  <body>
    <div class="farmtuner">
```

```
<img src="../static/farm.png" class="ico" position="absolute">
<img src="../static/title1.png" class="head">
    <nav>
      <a class="nv" href="/predict">Predictor</a>
      <a class="nv" href="/insert">Insert</a>
      <a class="nv" href="#about">About </a>
      <a class="nv" href="#info">Developers</a>
      <span></span>
    </nav>
    <div  id="home">Providing farmers with precise rainfall forecasts to foster a sustainable and abundant future</div>
</div>
<br><Br><Br><br><Br>
<div class="about" id="about" >
<div class="ab" style="color: rgb(255, 255, 255);margin-left: 10%;font-size: 20px;font-family: Verdana, Geneva, Tahoma, sans-serif;justify-content:baseline;"><br><br><br><br><br>
<div class="tp">About Our Rainfall Prediction Site</div><br>
Welcome to our rainfall prediction site!<br> We are dedicated to providing accurate and reliable rainfall
forecasts<Br> to help you plan your day effectively and stay<br> informed about weather conditions in your area.<br><br><br>
<div class="tp">Our Mission</div><br>
Our mission is to leverage the power of data and technology to deliver<br> precise rainfall predictions that enable individuals,
businesses, and communities <br>to make informed decisions and mitigate the impact of weather-related events.<br><br><br>
<div class="tp">How It Works</div><br>
Our site utilizes advanced weather modeling techniques and real-time data <br>from
```

```
meteorological stations to generate detailed rainfall
   predictions for different regions.<br> By analyzing historical weather patterns and current atmospheric conditions, we strive<br> to offer the
   most accurate forecasts possible.
  </div></div>
  <div class="info" id="info">
   <div class="ds" style="position:absolute;color:white;margin-top:35px;font-size: 20px;font-family: Verdana, Geneva, Tahoma, sans-serif;">
     <img src="../static/dev.png" height="650px" width="600px">
     <div style="margin-left: 700px; margin-top: 200px; position: absolute;margin-top: -70%;">
       <div class="developer" style="color: aliceblue;font-size: 30px;margin-top: 1%;">DEVELOPERS</div>
       </div>
   </div>
  </div>
 </body>
</html>
```

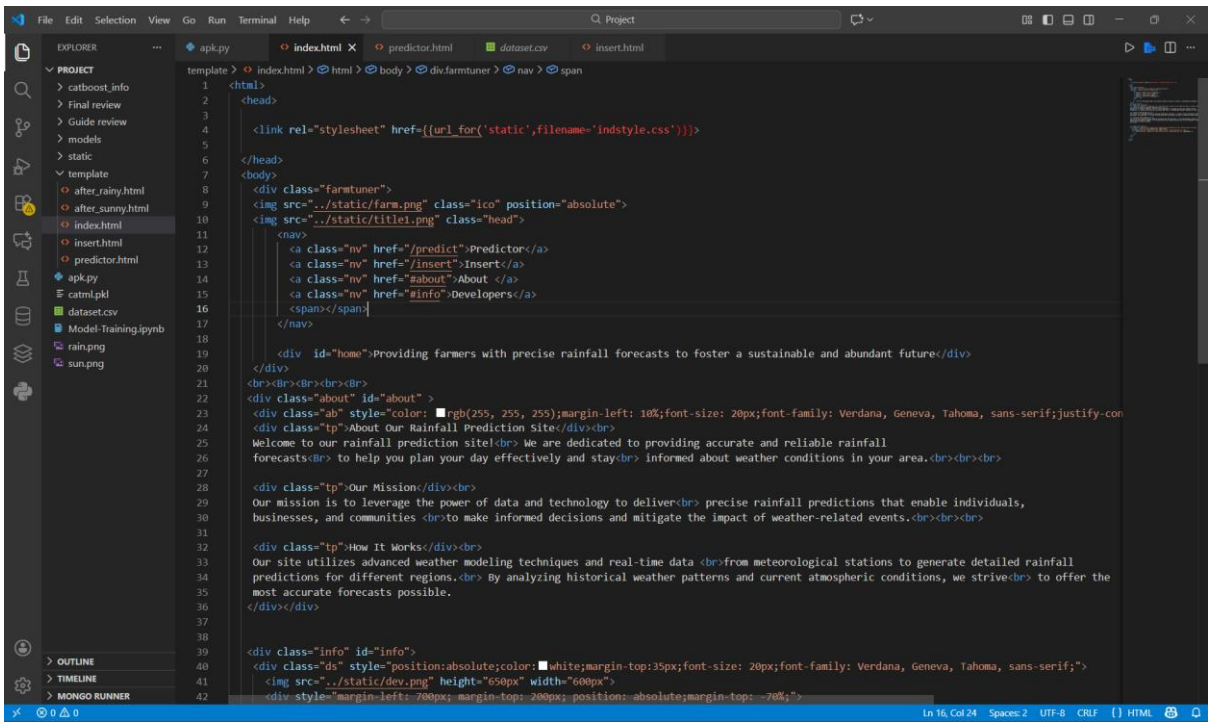


Fig 6.2

6.3 insert.html

```
<!DOCTYPE html>
<html lang="en">
<head>
   <title>Farmer records</title>
   <link rel="stylesheet" href={{url_for('static',filename='ins.css')}}>
</head>
<body>
  <img src="../static/topic.png" alt="topic" class="insert">
   <div class="navi">
  <form class="form" action="/insert", method="POST"><br><Br>
      Enter Farmer's Name : <input type="text" id="name" name="name"><br><Br>
      Enter Farmer's Email : <input type="email" id="email" name="email"><br><br>
      Select Location :
```

```
      <select class="location" id="location" name="location">
        <option selected>Select Location</option>
        <option value= "Arakkonam">Arakkonam</option>
        <option value= "Aruppukottai">Aruppukottai</option>
        <option value= "Avadi">Avadi</option>
        <option value= "Chengalpattu">Chengalpattu</option>
        <option value= "Chennai">Chennai</option>
        <option value= "Coimbatore">Coimbatore</option>
        <option value= "Cuddalore">Cuddalore</option>
        <option value= "Dindigul">Dindigul</option>
        <option value= "Erode">Erode</option>
        <option value= "Gudiyatham">Gudiyatham</option>
        <option value= "Hosur">Hosur</option>
    </select>
    <br><Br>
      <input type="submit" class="sub" value="Insert Record">
  </form>
</div>
</body>
</html>
```

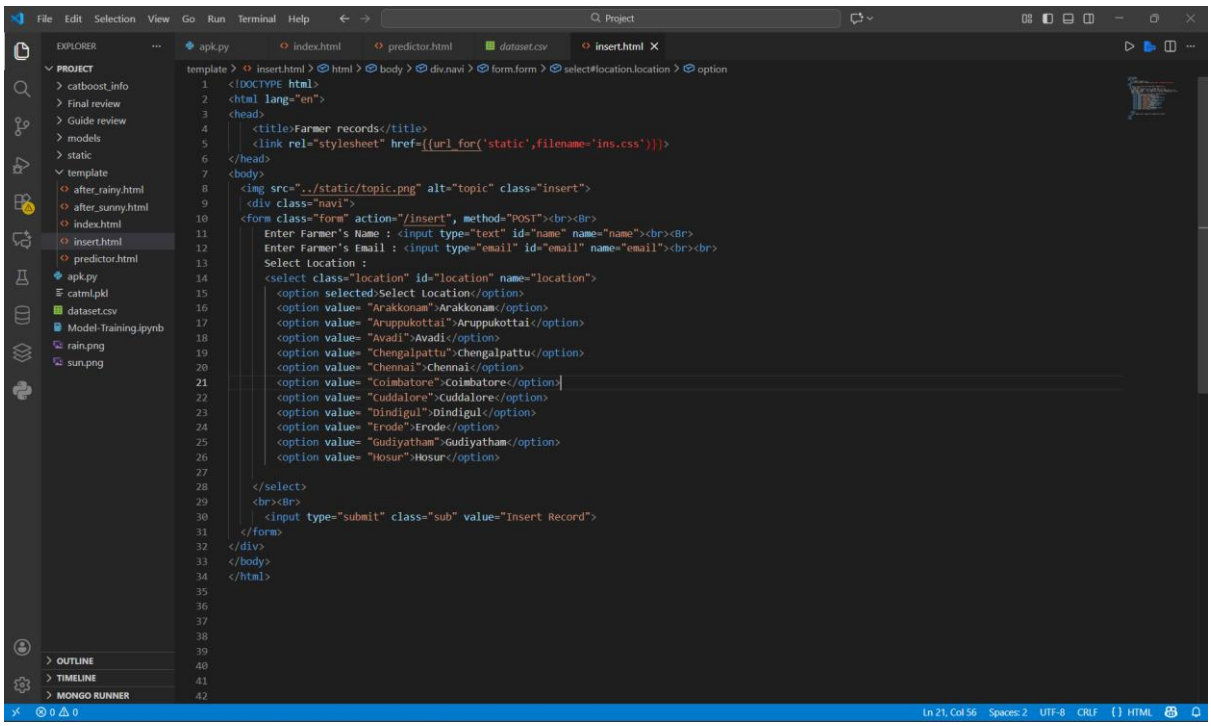


Fig 6.3

6.4 predictor.html

```
<html>
<head>
   <link rel="stylesheet" href={{url_for('static',filename='predictor.css')}}>
   <title>Rain Prediction</title>
</head>
<body>
   <img src="../static/predic.png" class="img">
   <section id="prediction-form">
      <form class="form" action="/predict", method="POST">
         <img class="pred" src="../static/pred.png" class="title">
         <div class="form-container">
                  <div class="form-item">
                  <label for="date" class="date">Date</label><br>
                  <input type="date" class="form-control" id="date" name="date"><br><br>
```

```
                <label for="mintemp" class="mintemp"> Minimum temperature</label><br>
                <input type="text" class="form-control" id="mintemp"
name="mintemp"><Br><Br>
                <label for="maxtemp" class="maxtemp">Maximum
Temperature</label><br>
                <input type="text" class="form-control" id="maxtemp"
name="maxtemp"><Br><Br>
                <label for="rainfall" class="rainfall">Rainfall</label><br>
                <input type="text" class="form-control" id="rainfall"
name="rainfall"><Br><Br>
                <label for="evaporation" class="evaporation">Evaporation</label><br>
                <input type="text" class="form-control" id="evaporation"
name="evaporation"><Br><Br>
                <label for="sunshine" class="sunshine">Sunshine</label><br>
                <input type="text" class="form-control" id="sunshine"
name="sunshine"><Br><Br>
                <label for="windgustspeed" class="windgustspeed">Wind Speed</label><br>
                <input type="text" class="form-control" id="windgustspeed"
name="windgustspeed"><Br><Br>
            </div>
            <div class="half">
                <label for="humidity9am" class="humidity9am">Humidity</label><Br>
                <input type="text" class="form-control" id="humidity9am"
name="humidity9am"><Br><Br>

                <label for="pressure9am" class="pressure9am">Pressure</label><Br>
                <input type="text" class="form-control" id="pressure9am"
name="pressure9am"><Br><Br>
```

```
                <label for="temp9am" class="temp9am">Temperature</label><Br>
                <input type="text" class="form-control" id="temp9am"
name="temp9am"><Br><Br>

                <label for="cloud9am" class="cloud9am">Cloud</label><Br>
                <input type="text" class="form-control" id="cloud9am"
name="cloud9am"><Br><Br>

                <label for="location" class="location"
name="location">Location</label><Br>
                <select class="location" id="location" name="location" aria-
label="Location">
                    <option selected>Select Location</option>
                    <option value= 0>Arakkonam</option>
                    <option value= 1>Aruppukottai</option>
                    <option value= 2>Avadi</option>
                    <option value= 3>Chengalpattu</option>
                    <option value= 4>Chennai</option>
                    <option value= 5>Coimbatore</option>
                    <option value= 6>Cuddalore</option>
                    <option value= 7>Dindigul</option>
                    <option value= 8>Erode</option>
                    <option value= 9>Gudiyatham</option>
                    <option value= 10>Hosur</option>

                </select><br><br>
```

```
            <label for="windgustdir" class="windgustdir" name = "windgustdir">Wind Direction</label><br>
            <select class="windgustdir" id="windgustdir" name = "windgustdir" aria-label="Wind Gust Direction">
                <option selected>Select Wind Direction</option>
                <option value= 3>N</option>
                <option value= 4>W</option>
                <option value= 7>S</option>
                <option value= 15>E</option>
                <option value= 1>NW</option>
                <option value= 11>NE</option>
                <option value= 9>SW</option>
                <option value= 12>SE</option>
                <option value= 0>NNW</option>
                <option value= 6>NNE</option>
                <option value= 8>SSW</option>
                <option value= 10>SSE</option>
                <option value= 2>WNW</option>
                <option value= 5>WSW</option>
                <option value= 14>ENE</option>
                <option value= 13>ESE</option>
            </select><br><br>

            <label for="raintoday" class="raintoday" name="raintoday">Rain Today</label><br>
            <select class="raintoday" id="raintoday" name="raintoday" aria-label="Rain Today">
                <option selected>Did it Rain Today</option>
```

```
                    <option value= 1>Yes</option>
                    <option value= 0>No</option>
                </select>
            </div>
            <button type="submit" class="sub" style="margin-left:40%;">Predict</button>
        </form>
    </div>
    <div>
        <h1><center> {{ prediction }} </center></h1>
    </div>
</body>
</html>
```

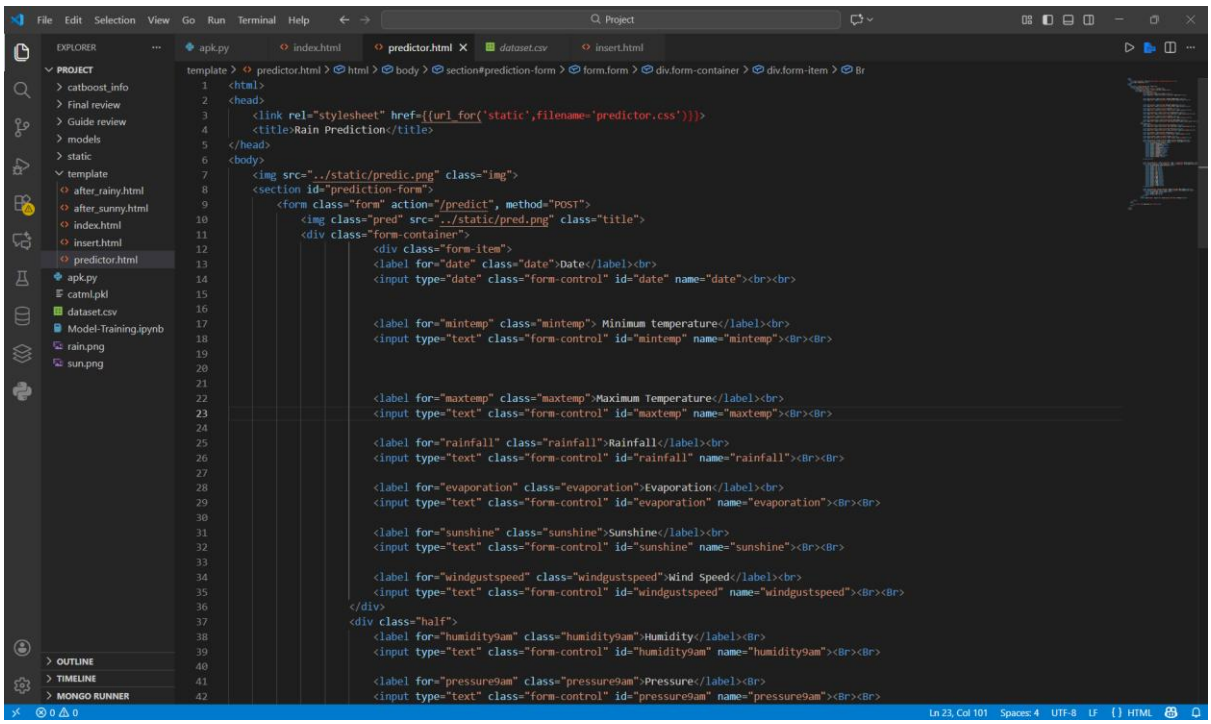


Fig 6.4

CHAPTER 7

COST ANALYSIS and RESULT & DISCUSSION

7.1 Cost Analysis

The cost analysis for the Machine Learning-Based Rainfall Prediction and Alert System demonstrates a high degree of cost-efficiency, particularly when relying solely on the Email Alert option. Since the entire development stack—comprising Python 3.x, Flask, MySQL, VS Code, and libraries like CatBoost and Pandas—is free and open-source software , there are no software licensing costs . The most significant financial consideration becomes the Operational and Deployment costs. The system is explicitly required to run on a low-cost hosting server, which represents the main recurring expense for hosting the application and the MySQL database. The Email Alert Service, which uses protocols like Gmail SMTP/App Passwords, can typically be managed at no direct cost, especially at a small to medium scale, as long as the service's daily sending quotas are respected. Consequently, the project's financial outlay is highly contained, focused almost entirely on minimal server hosting fees, making the overall solution extremely cost-effective and sustainable for long-term use.

7.2 Result and Discussion

The project’s results and subsequent discussion focus on validating the core hypothesis: the accuracy of the CatBoost model in predicting rainfall and the effectiveness of the Automated Alert System in supporting farmers.

7.2.1 Results of Machine Learning Model

- Prediction Model: The core outcome is the successfully Trained Model , which is saved as “catml.pkl” for deployment.
- Performance Metrics: The CatBoost model was evaluated using the Area Under the Curve (AUC) as the evaluation metric during training.
- Imbalance Handling: The application of the SMOTE technique successfully resolved the class imbalance in the original data, which is a critical step in ensuring the model’s high accuracy and preventing bias towards the “No Rain” majority class.

7.2.2 Discussion and System Effectiveness

- Enhanced Agricultural Decision Support: The developed system acts as reliable decision-support system that directly addresses the problem od unpredictable weather.
    1. Timely and Accurate Forecasts: By leveraging the CatBoost model, the system provides accurate and location-specific rainfall projections. This enables farmers to transition from traditional, generalized forecasting methods to data-driven decision-making.
    2. Proactive Planning: The accuracy of the forecasts, supported by the inclusion of multiple meteorological parameters (temperature, humidity, pressure, etc), empowers farmers to make timely and informed decisions regarding crop protection, irrigation scheduling, sowing, and harvesting.
- Practical Deployment and Usability: This project successfully bridges the gap between the complex data science model and practical farming application.
    1. Automated Communication: The Automated Alert System successfully delivers notifications via email, ensuring critical information reaches in real-time and overcomes the limitation of existing system that fail to integrate real-time alerts.
    2. System Qualities: The final deployed system is confirmed to be secure, scalable, and user-friendly, meeting the non-functional requirements to support at least 100 concurrent users and allow for future expansion.

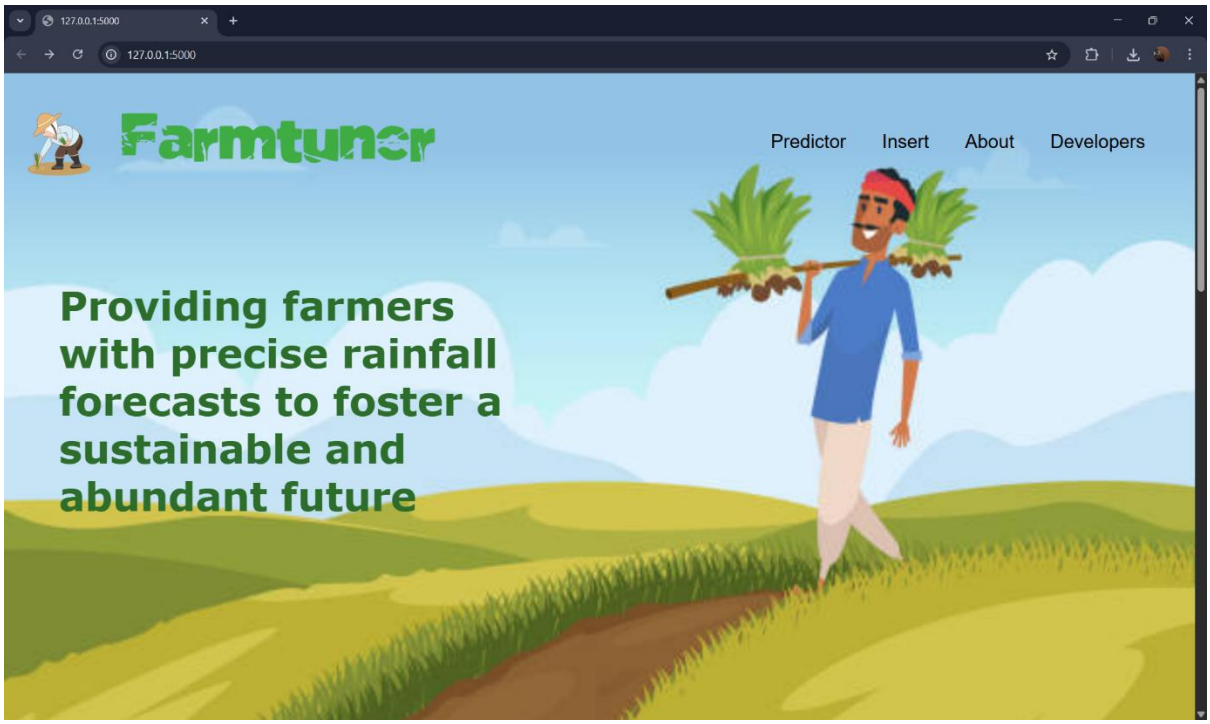
7.2.3 Security and Compliance

- Secure Storage: Farmer's personal data must be stored securely in the MySQL database.
- Alert Delivery Reliability: The system is designed to handle failures in external communication. It must be capable of automatically retrying failed email delivery to ensure that critical rainfall alerts reach the farmers.
- Code Integrity: The code is designed to be modular to allow for easier auditing updates, and, maintenance, which contributes to long-term compliance and security.
- Transparency: The system provides personalised alerts based on the farmer's registration and location, implying transparent data usage.
- Scalability for Growth: The design in scalable and adaptable to cover multiple regions

and integrate more data, allowing it to conform to broader standard if deployed commercially.

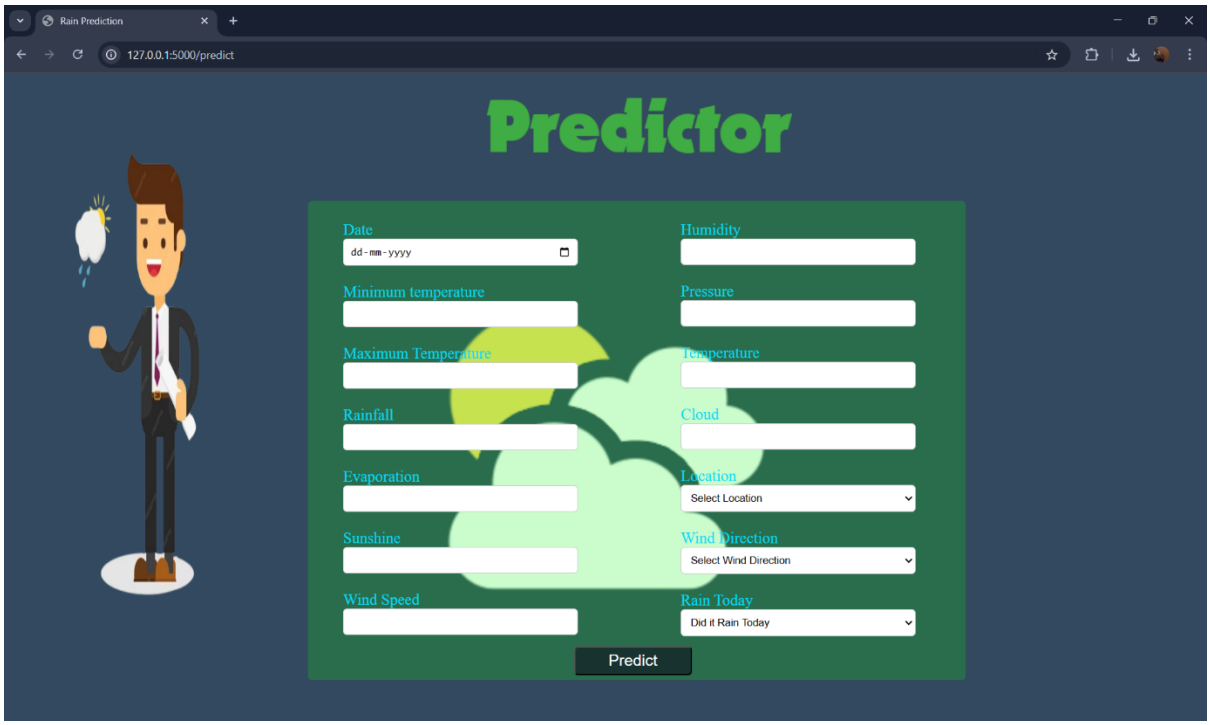
7.3 Output

Homepage

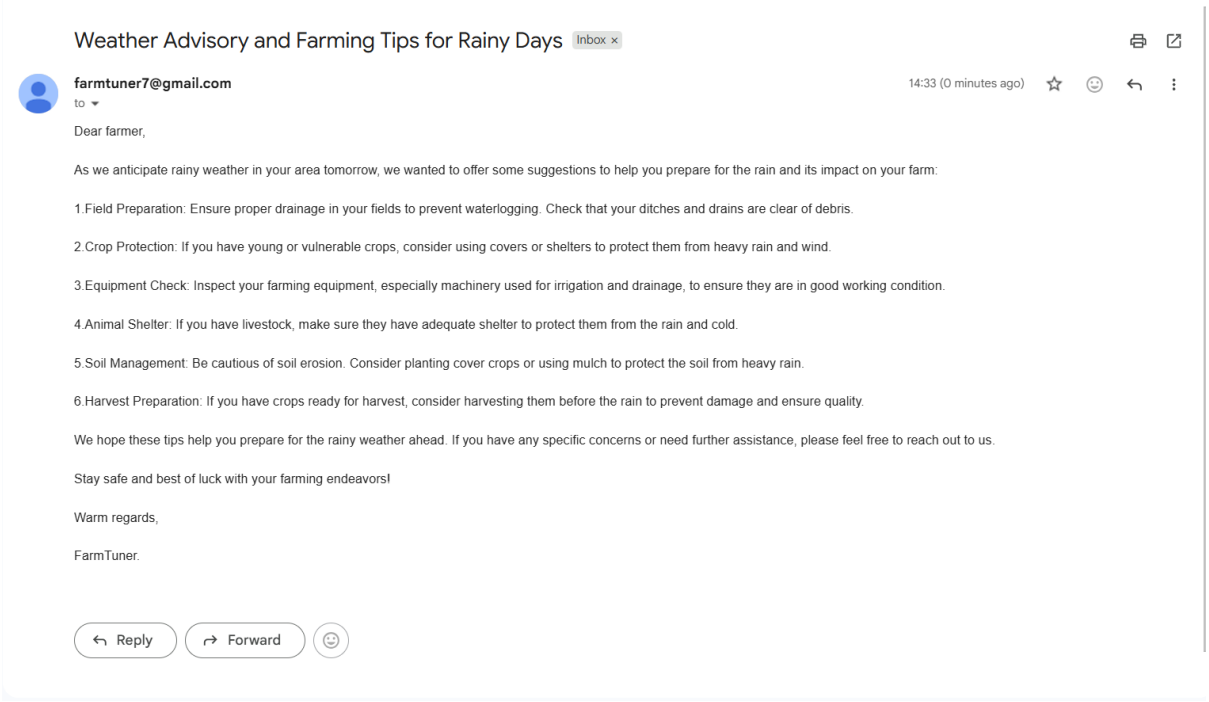


Farmer’s record insertion page

Rainfall predictor



Mail sent to farmer – rainy day



Weather Advisory and Farming Tips for Rainy Days Inbox ×

farmtuner7@gmail.com 14:33 (0 minutes ago)

to

Dear farmer,

As we anticipate rainy weather in your area tomorrow, we wanted to offer some suggestions to help you prepare for the rain and its impact on your farm:

1.Field Preparation: Ensure proper drainage in your fields to prevent waterlogging. Check that your ditches and drains are clear of debris.

2.Crop Protection: If you have young or vulnerable crops, consider using covers or shelters to protect them from heavy rain and wind.

3.Equipment Check: Inspect your farming equipment, especially machinery used for irrigation and drainage, to ensure they are in good working condition.

4.Animal Shelter: If you have livestock, make sure they have adequate shelter to protect them from the rain and cold.

5.Soil Management: Be cautious of soil erosion. Consider planting cover crops or using mulch to protect the soil from heavy rain.

6.Harvest Preparation: If you have crops ready for harvest, consider harvesting them before the rain to prevent damage and ensure quality.

We hope these tips help you prepare for the rainy weather ahead. If you have any specific concerns or need further assistance, please feel free to reach out to us.

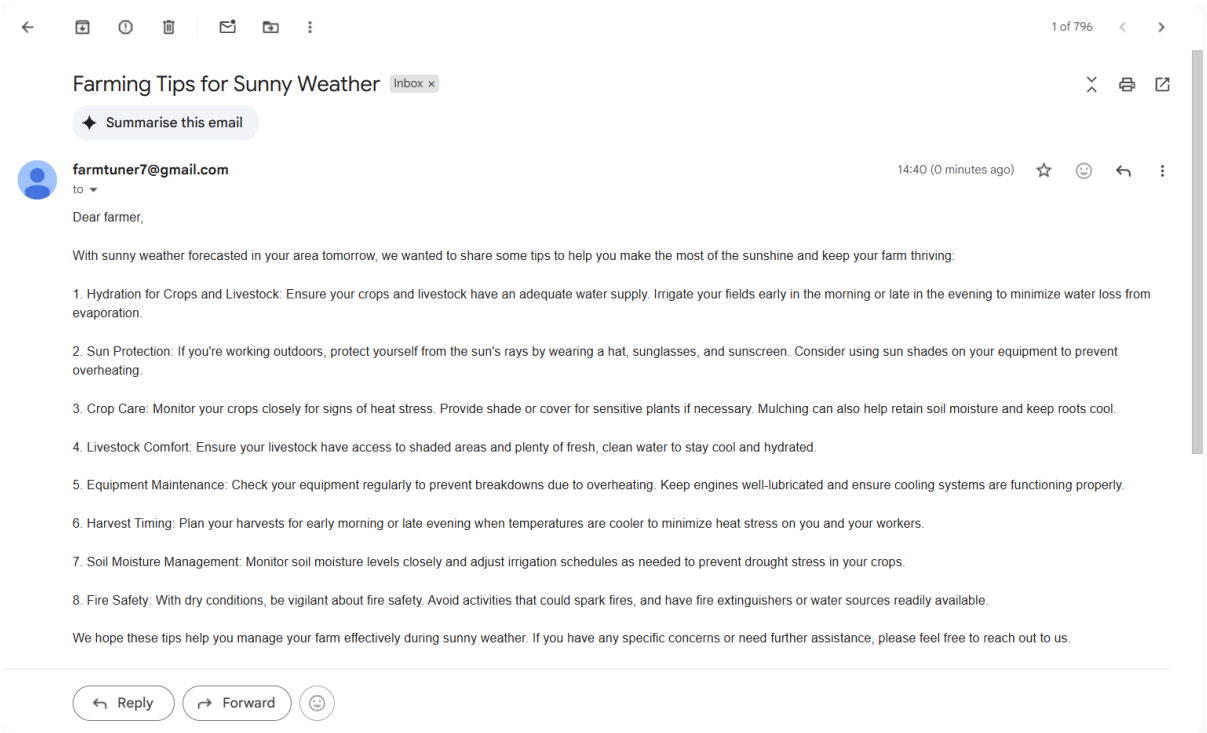
Stay safe and best of luck with your farming endeavors!

Warm regards,

FarmTuner.

Reply Forward

Mail sent to farmer - sunny day



1 of 796

Farming Tips for Sunny Weather Inbox ×

Summarise this email

farmtuner7@gmail.com 14:40 (0 minutes ago)

to

Dear farmer,

With sunny weather forecasted in your area tomorrow, we wanted to share some tips to help you make the most of the sunshine and keep your farm thriving:

1. Hydration for Crops and Livestock: Ensure your crops and livestock have an adequate water supply. Irrigate your fields early in the morning or late in the evening to minimize water loss from evaporation.

2. Sun Protection: If you're working outdoors, protect yourself from the sun's rays by wearing a hat, sunglasses, and sunscreen. Consider using sun shades on your equipment to prevent overheating.

3. Crop Care: Monitor your crops closely for signs of heat stress. Provide shade or cover for sensitive plants if necessary. Mulching can also help retain soil moisture and keep roots cool.

4. Livestock Comfort: Ensure your livestock have access to shaded areas and plenty of fresh, clean water to stay cool and hydrated.

5. Equipment Maintenance: Check your equipment regularly to prevent breakdowns due to overheating. Keep engines well-lubricated and ensure cooling systems are functioning properly.

6. Harvest Timing: Plan your harvests for early morning or late evening when temperatures are cooler to minimize heat stress on you and your workers.

7. Soil Moisture Management: Monitor soil moisture levels closely and adjust irrigation schedules as needed to prevent drought stress in your crops.

8. Fire Safety: With dry conditions, be vigilant about fire safety. Avoid activities that could spark fires, and have fire extinguishers or water sources readily available.

We hope these tips help you manage your farm effectively during sunny weather. If you have any specific concerns or need further assistance, please feel free to reach out to us.

Reply Forward

CHAPTER 8

SUMMARY

The Machine Learning-Based Rainfall Prediction and Alert System for Farmers is designed to mitigate the severe impact of unpredictable weather patterns on agriculture by providing accurate, timely, and hyper-local forecasts. The central problem addressed is the vulnerability of farming practices to sudden rainfall, which leads to crop damage, resource wastage, and financial losses, compounded by the imprecision of traditional forecasting methods.

The system introduces a data-driven solution, utilizing the powerful CatBoost algorithm for high-precision rainfall forecasting. The system analyzes user-provided meteorological inputs, including temperature, humidity, wind speed, pressure, and geographic location. A structured Machine Learning Methodology is followed, including rigorous data preprocessing, addressing class imbalance using SMOTE, and feature engineering before training the model.

The key outcome and functionality is the automated alert mechanism, which is triggered upon a rainfall prediction. This mechanism delivers personalized, real-time notifications directly to registered farmers via email. This critical empowers farmers to take proactive measures- such as adjusting irrigation schedules, safeguarding crops, and planning harvests- thereby reducing crop loss and promoting climate-resilient farming.

The technical implementation is based on Python, Flask, and MySQL, ensuring the system is scalable, secure, and adheres to a low-cost hosting requirement. The successful deployment delivers a working web application, a trained CatBoost model, and a functional alert system, ultimately bridging the gap between weather data and practical agricultural decision-making.

CHAPTER 9

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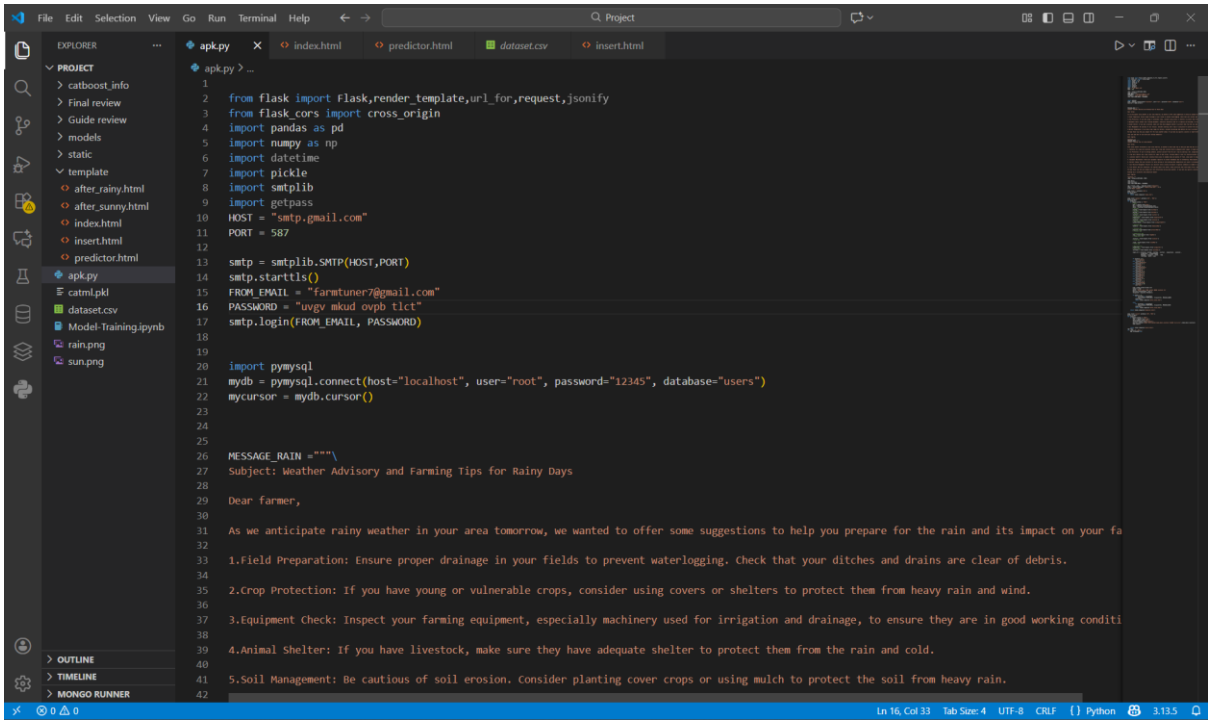
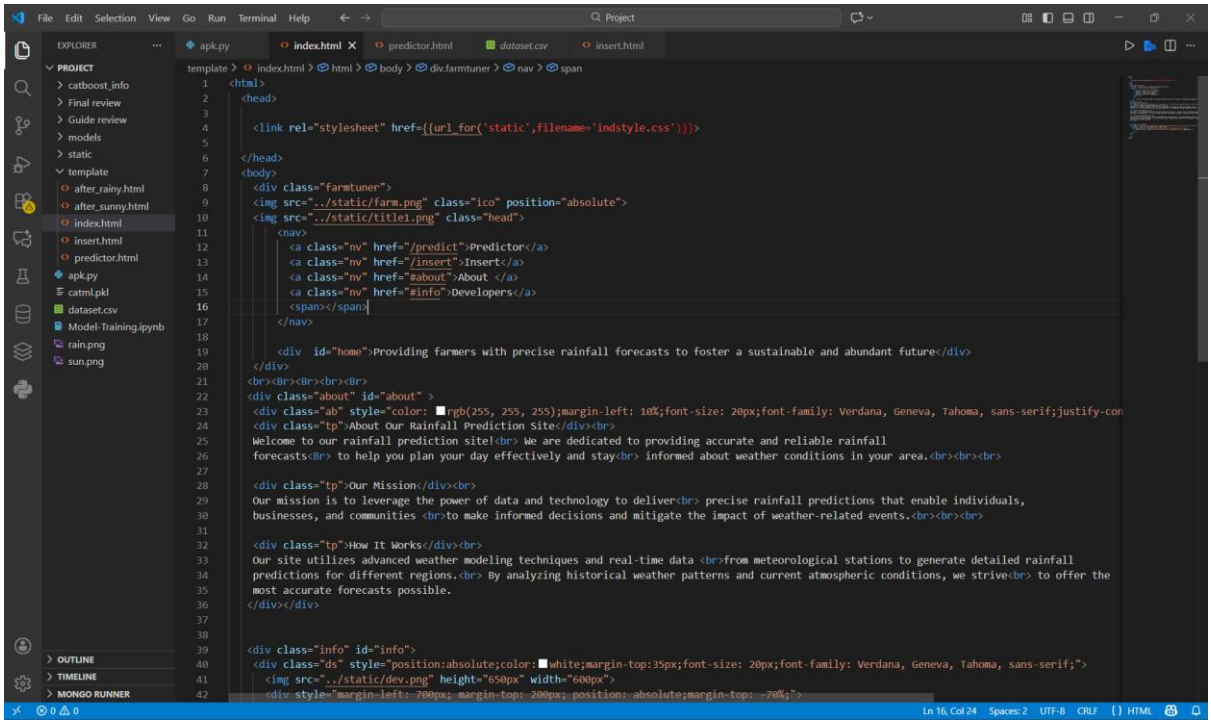
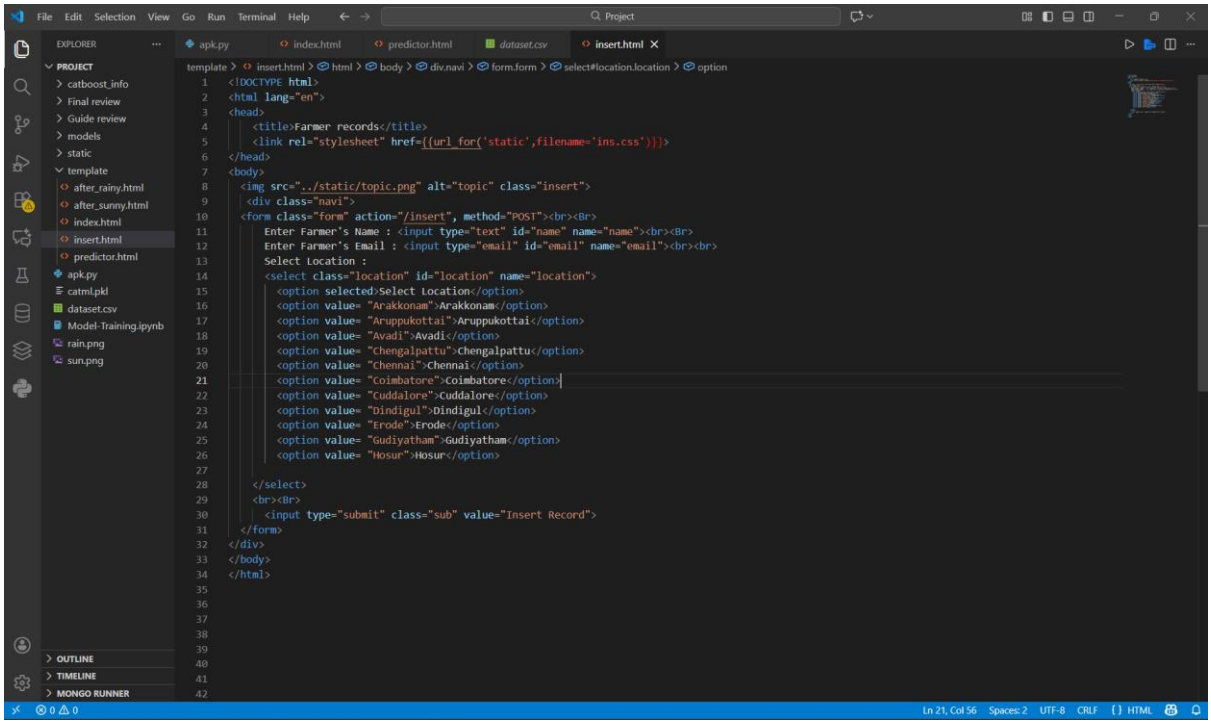
APPENDIX A



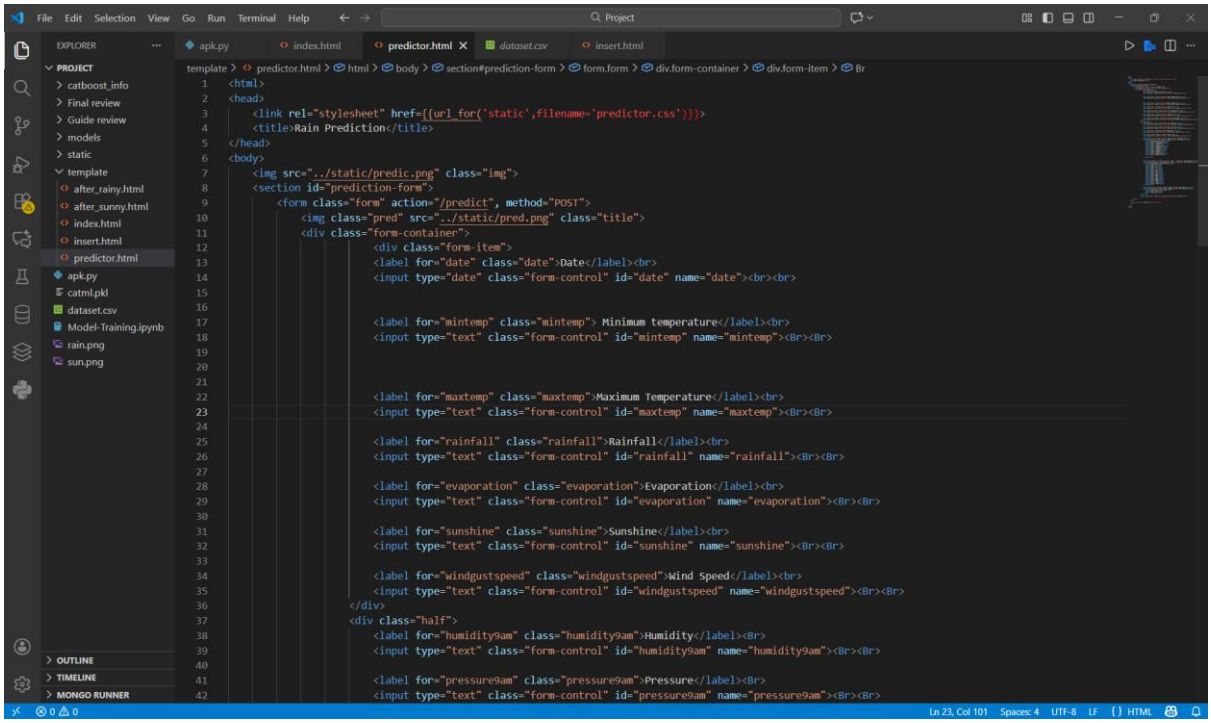
```
from flask import Flask,render_template,url_for,request,jsonify
from flask_cors import cross_origin
import pandas as pd
import numpy as np
import datetime
import pickle
import smtplib
import getpass
HOST = "smtp.gmail.com"
PORT = 587

smtp = smtplib.SMTP(HOST,PORT)
smtp.starttls()
FROM_EMAIL = "farmtuner7@gmail.com"
PASSWORD = "uvgv mkud ovpb tlct"
smtp.login(FROM_EMAIL, PASSWORD)


import pymysql
mydb = pymysql.connect(host="localhost", user="root", password="12345", database="users")
mycursor = mydb.cursor()



MESSAGE_RAIN ="""\
Subject: Weather Advisory and Farming Tips for Rainy Days

Dear farmer,

As we anticipate rainy weather in your area tomorrow, we wanted to offer some suggestions to help you prepare for the rain and its impact on your fa

1.Field Preparation: Ensure proper drainage in your fields to prevent waterlogging. Check that your ditches and drains are clear of debris.

2.Crop Protection: If you have young or vulnerable crops, consider using covers or shelters to protect them from heavy rain and wind.

3.Equipment Check: Inspect your farming equipment, especially machinery used for irrigation and drainage, to ensure they are in good working conditi

4.Animal Shelter: If you have livestock, make sure they have adequate shelter to protect them from the rain and cold.

5.Soil Management: Be cautious of soil erosion. Consider planting cover crops or using mulch to protect the soil from heavy rain.
```



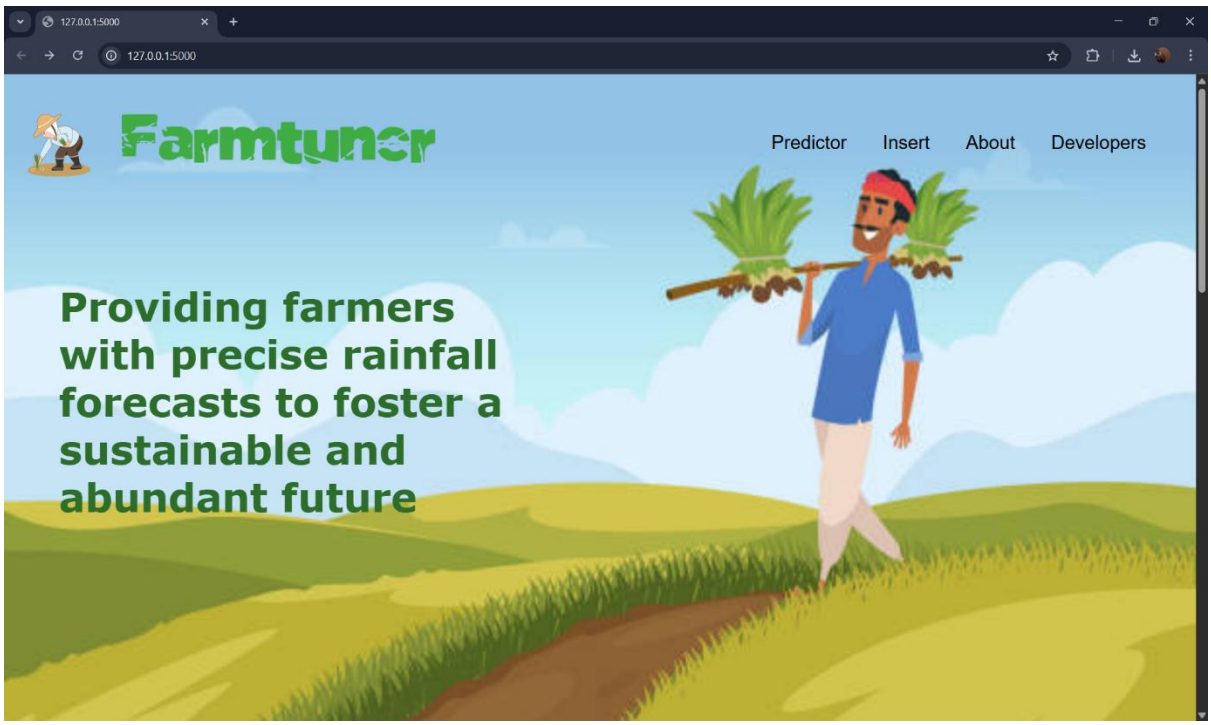
```
<html>
  <head>

    <link rel="stylesheet" href={{url_for('static',filename='indstyle.css')}}>

  </head>
  <body>
    <div class="farmtuner">
    <img src="../static/farm.png" class="ico" position="absolute">
    <img src="../static/title1.png" class="head">
        <nav>
            <a class="nv" href="/predict">Predictor</a>
            <a class="nv" href="/insert">Insert</a>
            <a class="nv" href="#about">About </a>
            <a class="nv" href="#info">Developers</a>
            <span></span>
        </nav>

        <div  id="home">Providing farmers with precise rainfall forecasts to foster a sustainable and abundant future</div>
    </div>
    <br><Br><Br><br><Br>
    <div class="about" id="about" >
     <div class="ab" style="color: rgb(255, 255, 255);margin-left: 10%;font-size: 20px;font-family: Verdana, Geneva, Tahoma, sans-serif;justify-con
     <div class="tp">About Our Rainfall Prediction Site</div><br>
     Welcome to our rainfall prediction site!<br> We are dedicated to providing accurate and reliable rainfall
     forecasts<Br> to help you plan your day effectively and stay<br> informed about weather conditions in your area.<br><br><br>

     <div class="tp">Our Mission</div><br>
     Our mission is to leverage the power of data and technology to deliver<br> precise rainfall predictions that enable individuals,
     businesses, and communities <br>to make informed decisions and mitigate the impact of weather-related events.<br><br><br>

     <div class="tp">How It Works</div><br>
     Our site utilizes advanced weather modeling techniques and real-time data <br>from meteorological stations to generate detailed rainfall
     predictions for different regions.<br> By analyzing historical weather patterns and current atmospheric conditions, we strive<br> to offer the
     most accurate forecasts possible.
    </div></div>


    <div class="info" id="info">
     <div class="ds" style="position:absolute;color:white;margin-top:35px;font-size: 20px;font-family: Verdana, Geneva, Tahoma, sans-serif;">
       <img src="../static/dev.png" height="650px" width="600px">
       <div style="margin-left: 700px; margin-top: 200px; position: absolute;margin-top: -70%;">
```



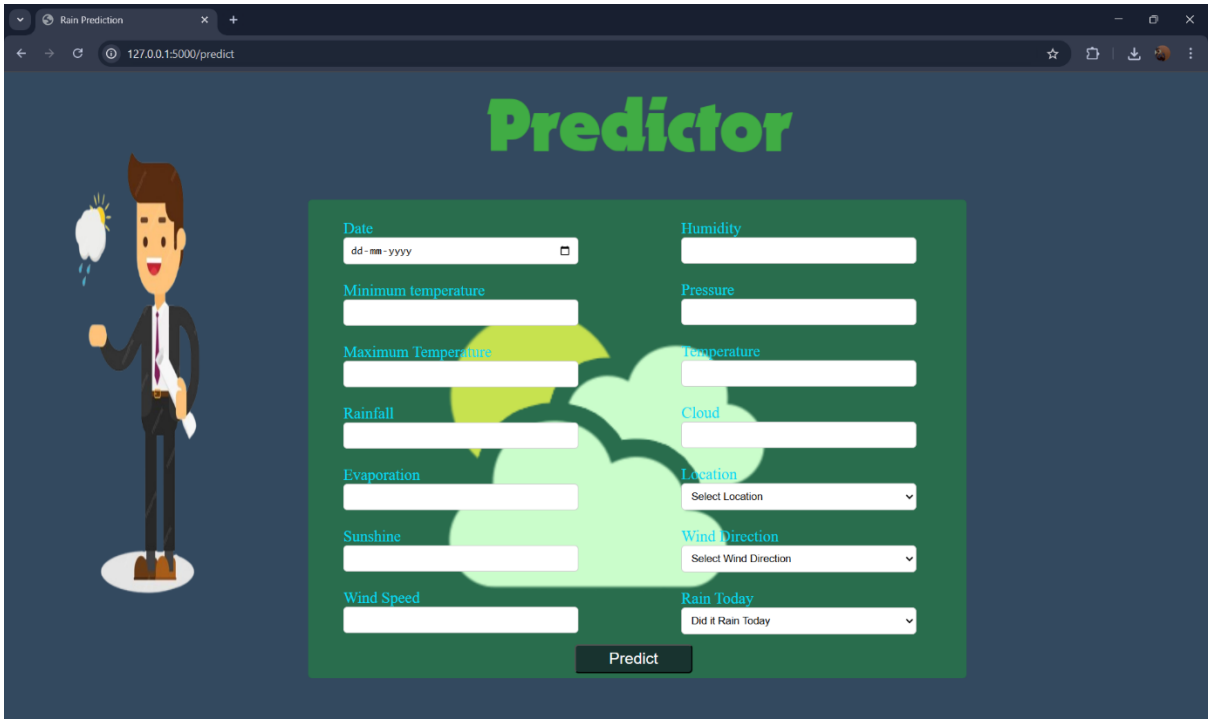
```
<!DOCTYPE html>
<html lang="en">
<head>
    <title>Farmer records</title>
    <link rel="stylesheet" href={{url_for('static',filename='ins.css')}}>
</head>
<body>
  <img src="../static/topic.png" alt="topic" class="insert">
   <div class="navi">
  <form class="form" action="/insert", method="POST"><br><Br>
      Enter Farmer's Name : <input type="text" id="name" name="name"><br><Br>
      Enter Farmer's Email : <input type="email" id="email" name="email"><br><br>
      Select Location :
      <select class="location" id="location" name="location">
        <option selected>Select Location</option>
        <option value= "Arakkonam">Arakkonam</option>
        <option value= "Aruppukottai">Aruppukottai</option>
        <option value= "Avadi">Avadi</option>
        <option value= "Chengalpattu">Chengalpattu</option>
        <option value= "Chennai">Chennai</option>
        <option value= "Coimbatore">Coimbatore</option>
        <option value= "Cuddalore">Cuddalore</option>
        <option value= "Dindigul">Dindigul</option>
        <option value= "Erode">Erode</option>
        <option value= "Gudiyatham">Gudiyatham</option>
        <option value= "Hosur">Hosur</option>

    </select>
    <br><Br>
      <input type="submit" class="sub" value="Insert Record">
  </form>
</div>
</body>
</html>
```



```
<html>
<head>
    <link rel="stylesheet" href={{url_for('static',filename='predictor.css')}}>
    <title>Rain Prediction</title>
</head>
<body>
    <img src="../static/predic.png" class="img">
    <section id="prediction-form">
        <form class="form" action="/predict", method="POST">
            <img class="pred" src="../static/pred.png" class="title">
            <div class="form-container">
                        <div class="form-item">
                        <label for="date" class="date">Date</label><br>
                        <input type="date" class="form-control" id="date" name="date"><br><br>


                        <label for="mintemp" class="mintemp"> Minimum temperature</label><br>
                        <input type="text" class="form-control" id="mintemp" name="mintemp"><Br><Br>



                        <label for="maxtemp" class="maxtemp">Maximum Temperature</label><br>
                        <input type="text" class="form-control" id="maxtemp" name="maxtemp"><Br><Br>

                        <label for="rainfall" class="rainfall">Rainfall</label><br>
                        <input type="text" class="form-control" id="rainfall" name="rainfall"><Br><Br>

                        <label for="evaporation" class="evaporation">Evaporation</label><br>
                        <input type="text" class="form-control" id="evaporation" name="evaporation"><Br><Br>

                        <label for="sunshine" class="sunshine">Sunshine</label><br>
                        <input type="text" class="form-control" id="sunshine" name="sunshine"><Br><Br>

                        <label for="windgustspeed" class="windgustspeed">Wind Speed</label><br>
                        <input type="text" class="form-control" id="windgustspeed" name="windgustspeed"><Br><Br>
                    </div>
                    <div class="half">
                        <label for="humidity9am" class="humidity9am">Humidity</label><Br>
                        <input type="text" class="form-control" id="humidity9am" name="humidity9am"><Br><Br>

                        <label for="pressure9am" class="pressure9am">Pressure</label><Br>
                        <input type="text" class="form-control" id="pressure9am" name="pressure9am"><Br><Br>
```


127.0.0.1:5000
127.0.0.1:5000
Farmtuner
Predictor
Insert
About
Developers
Providing farmers with precise rainfall forecasts to foster a sustainable and abundant future


Farmer records
127.0.0.1:5000/insert
Insert Farmer Records :
Enter Farmer's Name :
Enter Farmer's Email :
Select Location :
Select Location
Insert Record


Rain Prediction
127.0.0.1:5000/predict
Predictor
Date
dd-mm-yyyy
Minimum temperature
Maximum Temperature
Rainfall
Evaporation
Sunshine
Wind Speed
Humidity
Pressure
Temperature
Cloud
Location
Select Location
Wind Direction
Select Wind Direction
Rain Today
Did it Rain Today
Predict