Smart Agriculture Decision Support System: A Machine Learning Framework for Sustainable Organic Farming

Under the guidance of
Prof. Latha B
Assistant professor
Department of Data Science
Aditya College of Engineering and Technology
Bangalore, India

SAHANA Y S
Department of Data Science
Aditya College of Engineering and Technology.
Bangalore, India
sahanays26@gmail.com

THALURU VEDAGNA
Department of Data Science
Aditya College of Engineering and Technology
Bangalore, India
thaluruvedagna1di23ds039@gmail.com

SINCHANA G V
Department of Data Science
Aditya College of Engineering and Technology
Bangalore, India
sinchana1di23ds036@gmail.com

ABSTRACT- Choosing what to grow, where and in which order is one of the most consequential decisions a farmer makes each season, yet the information needed to make it well is scattered across government portals, weather services and local experiences. This paper presents crop advisor, a web-based decision support platform that lets a user click a location on a map of India and receive crop guidance for that place without typing any location details. The platform combines four cooperating modules: a crop suitability ranker, an intercropping compatibility checker, a crop rotation planner and a nutrient recovery estimator, together with a yield forecasting module that projects productivity for the coming seasons. Users may accept the recommended crops or enter crops of their own choice, including common local names, and receive an explained assessment of that choice. A seven-day weather forecast for the selected point supports irrigation and sowing decisions. Authenticated access allows each user to keep a history of earlier recommendations. The system is built with python, flask, leaflet and SQLite, and is designed to be trained on the district wise area, production and yields statistics published by the directorate of economics and statistics, government of India. This paper describes the architecture, decision, logic and implementation of the prototype, reports the functional testing carried out so far, and sets out the evaluation plan for the model trained on real data.

KEYWORDS- Crop recommendation, Decision support system, Intercropping compatibility, Crop rotation, Precision agriculture, Weather integration.

I. INTRODUCTION

Agriculture remains central to food security and rural livelihoods in India, yet the choice of crop is still frequently made from habit, neighbourhood practice or short-term market signals. A poor choice affects the whole season. It can lead to low yield, heavy water demand, depleted soil nutrients or a build-up of pests that persists into following seasons. Rising climate variability makes these decisions harder,

because rainfall and temperature patterns that guided earlier generations are becoming less dependable [11], [12]. Data-driven tools can help. Machine learning methods have been applied widely to crop yield prediction, and recent systematic reviews describe how climate, soil and management variables are used together to estimate productivity [11], [12], [13]. However, many published systems stop at a single question, such as predicting yield for one crop, and they are rarely delivered as a simple tool that a farmer, extension worker or student can operate without technical training. Page 1 of 11Crop Advisor - Conference Paper Three practical questions arise in every farm plan. The first is which crop suits this location, soil and water situation. The second is whether two or more crops can be grown together. The third is what sequence of crops should follow over the coming seasons. Agronomic research shows that intercropping and rotation can raise land productivity and protect soil health [14], [15], but this knowledge is seldom turned into an interactive tool. Crop Advisor is proposed to close this gap.

The main objectives of the project are:

1. To let the user select a location by a single click on a map, removing manual data entry for place details.
2. To rank suitable crops for the chosen place using official yield history, soil, water and nutrient inputs.
3. To evaluate intercropping combinations and crop rotation plans that the user types or selects, and to explain the result.
4. To estimate nutrient removal, recovery options and expected yield for upcoming seasons.
5. To provide a secure, responsive web interface with weather information to support timing decisions.

II. LITERATURE SURVEY

A. Machine Learning in Agriculture

Liakos and co-authors reviewed the use of machine learning across agriculture and grouped applications into areas such as crop management, livestock management, water management and soil management [1]. Within crop management they identified yield prediction, disease detection, weed detection and crop quality as the most common tasks. Their review also noted that data quality and availability strongly influence how well such models perform in practice. Kamilaris and prenafeta-Boldu surveyed deep learning in agriculture and reached a similar conclusion, observing that results depend on the amount and relevance of the training data [2]. These surveys motivate the choice in the present work to anchor every recommendation in official, district-level data rather than in generic rules alone.

B. Ensemble and Statistical Forecasting

Random forests, introduced by Breiman, combine many decision trees trained on random subsets of the data and are widely used for regression problems with mixed numerical and categorical inputs [3]. They tolerate noisy features and give an estimate of feature importance, which is useful when explaining why a crop was ranked highly. For yearly yield series, classical time-series methods remain relevant. The autoregressive integrated moving average family described by Box and Jenkins models a series through its own past values and past errors [4]. Crop advisor adopts a simple trend-based forecast in the prototype and plans to compare it with a random forest and an ARIMA model on real data.

C. Software Tools for Implementation

The scikit-learn library provides consistent implementations of regression models, preprocessing tools utilities in python [5]. Flask is a lightweight web framework suited to serving model outputs through a small application programming interface [6]. Leaflet is an open-source library for interactive maps in the browser, supporting click events that return geographic coordinates [7]. Open-Meteo offers a freely accessible weather forecasting interface that returns current conditions and daily forecasts for any latitude and longitude [8]. Together these tools allow a complete decision support application to be built from open components.

D. Official Agricultural Data

The Directorate of Economics and Statistics under the ministry of Agriculture and Farmers

Welfare publishes crop statistics, including area, production and yield by state, district, crop and season [9]. The Soil Health Card programme provides nutrient information for farm holding [10]. Both are public sources of record and are suitable as a documented evidence base for a decision tool.

E. Research Gap and Proposed Approach

Much of the existing work concentrates on a single task, most often predicting the yield or recommending one crop from soil and climate attributes. Fewer systems connect crop choice with intercropping, rotation and nutrient replenishment in one workflow, and fewer still let the farmer enter an alternative plan and receive a reasoned comparison. Crop advisor addresses this gap by combining these functions, by typing location selection to a map click, and by adding live weather context in a single interface.

III. METHODOLOGY

The development followed requirement analysis, data selection, module design, implementation, testing and planned evaluation.

A. Requirement Analysis

The requirements were that location must be chosen on a map, results must be explained, the farmer must be able to enter their own crops, weather must be visible, and access must be protected by an account.

B. Data Sources

The training data will be the district-wise area, production and yield records from the Directorate of Economics and Statistics, restricted to recent years so that the model reflects current practice. Yield is computed or taken as production divided by area. Weather for a selected point is obtained at run time from Open-Meteo. Soil nutrient levels are entered by the user and may be read from a soil health card. In the prototype described here, yield histories are generated sample values used to exercise the software; they are not official statistics and no accuracy claims are made from them.

C. Pre-Processing

For each district and crop the yearly series is assembled, records with missing area or production are removed, and extreme values are checked. Crop names are standardised, and seasons are encoded as Kharif, Rabi or Zaid.

D. Crop Suitability Scoring

For each candidate crop in the selected region the system computes the relative yearly trend of yield and its variability. Let g be the fitted yearly growth of yield divided by its mean, and V the coefficient of variation of the series. The suitability score S is

$$S = 50 + a.g - b.v + F_soil + F_water - p_repeat,$$

Where F_soil rewards a match between the choosen soil and the soils the crop prefers, F_water rewards agreement between the crop's water need and the water available, and P_repeat penalises growing the same crop as in the previous season. The score is limited to the range 5 to 98. The weight a and b and the fir terms are heuristic in the prototype and are to be calibrated against held-out data once real records are loaded. Scores of 70 and above are rated highly suitable, 50 to 69 moderates, and below 50 risky.

E. Intercropping Compatibility

Each crop is assigned to a family, such as cereal, legume, oilseed or vegetable, and to a growing season. For every pair of chosen crops the module assigns a rating of good, Fair or poor from agronomic rules, for example that a legume supplies nitrogen to a cereal, that crops of the same family compete for the same nutrients, and that crops with different seasons will not share the field for long. Pair ratings are averaged into an overall compatibility score and verdict, and a tip recommends adding a legume where none is present.

F. Crop Rotation Planner

The user gives the previous crop and a crop for each season. The module walks through the sequence and checks three conditions: whether each crop belongs in the season chosen. It also tracks nitrogen, subtracting the amount removed by each crop and adding an assumed amount fixed by legumes. The result is a soil health score, a verdict of healthy, acceptable or weak rotation, and notes for each step.

G. Nutrient Recovery Estimation

A table of typical nitrogen, phosphorous and potassium removal per hectare is stored for each crop. The module reports removal for the recommended crop and compares it with the nutrient levels given by the user. Where a level is low, it suggests organic sources such as farmyard manure, compost, a legume cover crop or crop residue.

H. Yield Forecasting

In the prototype a least-squares line is fitted to each yearly series, and the next three values are projected with an error band equal to the residual standard deviation. For the real-data version, the line will be compared with a random forest regressor and an ARIMA mode. Models will be trained on earlier years and tested on the most recent years, and compared using mean absolute error, root mean square error and mean absolute percentage error. The model with the lowest error on the held-out years will be used.

I. Weather Integration

When the user clicks the map, the browser requests a seven-day forecast for that point. The server calls the weather service and returns current temperature, humidity and wind, and daily maximum and minimum temperature, rainfall and rain probability. The total expected rainfall is converted into a short tip: heavy rain advises delaying irrigation, little rain advises planning irrigation, and moderate rain advises moderate irrigation.

J. Authentication and Data Handling

User register with a name, email address and a password of at least eight characters. Passwords are stored only as salted hashes, never in readable form, so even the administrator cannot view them. The sign-in and registration pages include a show and hide control that lets users check what they typed before submitting. All pages and data interfaces require a signed-in session, and each user's recommendation history is stored against their account.

IV. EXISTING SYSTEM

At present a farmer or student seeking crop guidance relies on a mix of sources.

A. Printed and Advisory Material: Extension leaflets and advisory bulletins describe suitable crops for a region in general terms. They are not specific to a plot, a season or the current weather.

B. Government Data Portals: Official publish detailed statistics, but the data is presented as large tables intended for analytics. Turning a table of area, production and yield into a decision requires skills and time that many users do not have.

C. Weather Applications: General weather applications show forecasts but do not relate them to sowing, irrigation or the water needs of a particular crop.

D. Single-Purpose Recommenders: Some tools predict one best crop from soil and climate values. They typically ask the user to type numerical values for every input and rarely explain their output.

E. Limitations of the Existing Approach:

- Information is spread across several unrelated sources.
- Location and soil details usually have to be entered by hand.
- Crop choice, intercropping and rotation are treated as separate problems.
- Recommendations are rarely explained, so users cannot judge how far to trust them.
- The farmer cannot test a plan of their own and see its likely consequences.

V. PROPOSED SYSTEM

Crop Advisor is web platform that guides a user from a map click to a complete set of crop decisions.

A. Key Components

1. **Interactive Map:** The user clicks any point in India. The system records the coordinates, identifies the region and carries the location through all later pages.
2. **Input Collection:** Soil type, water availability, soil nutrient level, previous crop and farm size are chosen from simple lists. Weather for the point is fetched automatically.

3. **Central Decision Engine:** Pre-processes the inputs, scores candidate crops and calls the four modules.
4. **Crop Suitability Module:** Ranks crops for the region and gives each a score from 0 to 100 and a rating of highly suitable, moderate or risky.
5. **Intercropping Compatibility Module:** Judges how well-chosen crop grow together.
6. **Crop Rotation Planner:** Checks a kharif, rabi and Zaid sequence for soil health.
7. **Nutrient Recovery Estimator:** Estimates nutrient removal and suggests organic replacement.
8. **Yield Forecasting Module:** Projects yield for the next three years with an error range.
9. **Weather Module:** Shows current conditions and a seven- day forecast with an irrigation tip.
10. **Account and History Module:** Provides registration, login and a record of past recommendations

B. User- Choice Mode

In the intercropping and rotation pages the user may tap crops from a list, type crop names separated by commas, or do both. A dictionary of common synonyms maps local names to standard crop names, and the page shows how each entry was understood. Names that are not recognised are listed so that the user can correct them rather than receiving a silent wrong answer.

C. Summary

By joining location selection, evidence- based ranking, user- defined scenarios and compare options and understand the reasons behind each result.

VI. ADVANTAGES

1. **Single Click Location:** The map removes the need to type region details.
2. Integrated Decisions: Crop choice, intercropping, rotation and nutrients are handled together.
3. **Explained Results:** Every verdict is accompanied by reasons, so the user can judge it.
4. **Farmer Choice:** Users can enter their own crops and test them, including by local name.
5. **Weather Aware:** A seven- day forecast supports irrigation and sowing decisions.
6. **Evidence Based:** The design relies on official district- level statistics.
7. **Secure Access:** Passwords are hashed and every data interface requires sign-in.
8. **Easy Use:** Choices are made from lists and the layout suits mobile screens.
9. **Open Components:** Only free and open tools are required.
10. **Extensible:** New crops, regions, data sources and modules can be added.

VII. CONCLUSION

Crop Advisor presents an integrated approach to crop decision making in which a single map click leads to ranked crop suggestions, intercropping and rotation checks, nutrient advice, yield projections and a weather forecast. Its user- choice mode allows farmers and students to test their own plans and see the reasoning behind each verdict. The prototype has been built and functionally tested, and the next stage is to train and evaluate the forecasting models on official recent data and to report their accuracy. With that evidence, the platform can serve as a practical and transparent decision aid that connects open agricultural data with the everyday choices of farmers.

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