



International Journal of Innovative Research in Science Engineering and Technology (IJIRSET)

(A Monthly, Peer Reviewed, Refereed, Scholarly Indexed, Open Access Journal)



Impact Factor: 8.699

Volume 14, Issue 12, December 2025

Digital – Agri

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ABSTRACT: Digital agriculture focuses on intelligently analysing farm conditions to recommend suitable crops and improve land productivity. It involves evaluating soil parameters, weather behaviour, and irrigation factors to generate reliable guidance for cultivation. In this work, the approach presented provides automated crop suggestions and field layout generation for farmers. The system processes user inputs along with real-time environmental data using a rule-based scoring model that identifies crops best suited for the given land conditions. The output is an 8×8 grid representation that visually marks the recommended crop for each section of the farmland. Crop planning is carried out in two stages: the first stage analyses soil, climate, season and water availability to determine crop suitability scores, and the second stage allocates crops across the grid and generates a long-term rotation plan.

KEYWORDS: Crop recommendation, Precision farming, Rule-based scoring, Grid-based planning, Digital agriculture.

I. INTRODUCTION

The manual selection of crops based only on tradition or personal judgement is still the most common practice and is prone to errors, low productivity and unpredictable outcomes, including growing crops that are unsuitable for the soil or climate. Such outdated methods are no longer sufficient in a modern agricultural world where scientific data and accurate planning play a major role in improving farm performance and ensuring better yields. Digital crop recommendation has emerged as a more practical and reliable approach with the advancement of decision-support technologies. In this project, we aim to build an intelligent crop-planning system where suitable crops are identified automatically using soil details, weather conditions and seasonal information. The system assists in reducing guesswork, and the chances of making wrong crop choices are significantly lower due to the integration of real-time data and rule-based scoring supported by environmental analysis. The development of the application was done using modern tools such as Next.js, Node.js, and MongoDB, along with APIs that provide live weather updates to enhance user experience. This approach offers a smarter, accurate and highly scalable method of planning cultivation for farms of all sizes. It presents a superior alternative to older crop-selection practices by providing scientific guidance, visual land-grid layouts and long-term rotation planning, making it suitable for farmers, institutions or any agricultural setting that requires informed and efficient decision-making.

II. LITERATURE SURVEY

The concept of data-driven crop recommendation systems was first explored in early decision-support studies, where researchers used soil and climatic parameters to guide crop selection based on predefined rules [1]. These early models focused on analysing environmental attributes and propagating suitability scores across different land conditions. Later, machine-assisted recommendation techniques were introduced, using structured rule sets and agronomic thresholds to determine which crops best matched the soil and seasonal profiles of a region [2]. This approach combined soil compatibility assessment with environmental synthesis and produced more reliable outcomes compared to manual judgement. In [3], the authors split the decision process into soil analysis and climatic evaluation, processing both components separately before merging them into a unified suitability index. Techniques using morphological or spatial mapping were explored in [4] to extract local variations across farmland, enabling more precise segmentation for agricultural planning. In [5], the crop-selection technique was combined with location-based weather inputs and simple filtering rules that identify the most promising crops for cultivation. The method

demonstrated strong resilience to changing climate patterns, soil imbalance and seasonal fluctuations. Work presented in [6] applied grid-based regional mapping to divide farmland into smaller units and assign diversity-aware crop recommendations using a scoring mechanism.

III. PROPOSED METHODOLOGY

The system combines a set of rules with live environmental data to give farm-specific crop suggestions. Farmers provide important information such as soil type, pH, water availability, farm location, season, and land size. The system then gathers real-time weather updates and merges them with the soil details to understand the field conditions accurately. A scoring system evaluates each crop by looking at factors like soil suitability, climate, crop rotation, expected harvest, and resource needs. The suggested crops are displayed using a Land Box Layout, where each section of the field is assigned 7 the efficient and sustainable farming. The most suitable crop for the platform shows results in a colour-coded map and includes a three-year cultivation plan with estimated yields to help farmers plan long-term. With support for multiple languages such as Kannada, Hindi, Telugu, and English, 8 the system is easy to use for farmers across different regions. Overall, it offers a simple, organised, and practical approach to crop planning and land management.

A rule-based crop recommendation technique is used for evaluating the suitability of crops, which considers soil characteristics, seasonal factors and weather conditions together. The analysis is done in such a manner that it assigns the best crop to each section of the land grid by comparing environmental inputs with predefined crop requirements. The algorithm follows a scoring-based procedure. First, the system identifies the farmland parameters using user input and live API data and then computes suitability values for every crop. For each crop, a score is generated based on soil match, pH range, irrigation type and seasonal behaviour. It begins allocating crops to the grid starting from the highest scoring options by mapping them to grid sections. This process is repeated until the entire 8×8 land layout is filled with the most appropriate crop for each region. The algorithm automatically generates the final grid layout without user interaction, producing a structured map that contains only the recommended crop arrangement for the farmland.

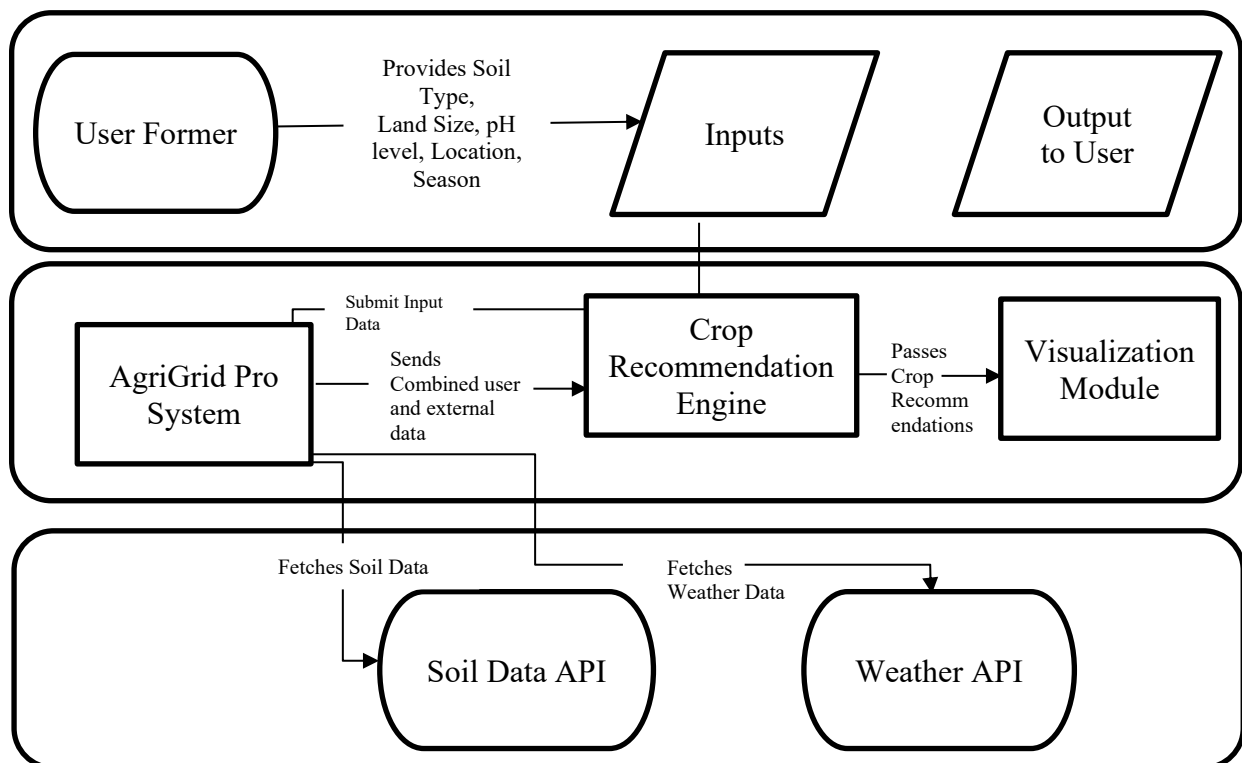


Fig. 1 Data Flow Diagram

The flow diagram illustrates how the AI-Based Smart Crop Grid Planner operates. The process begins when the farmer, the primary user, enters essential details such as soil type, land area, pH level, location, irrigation availability, and the current season through the Input Module. These inputs are sent to the core system, the Agri Grid Pro, which serves as the main processing component. The system then interacts with external data sources, including the Soil Data API and Weather API, to retrieve updated information about soil characteristics and local climate conditions. Once the user and environmental data are collected, they are processed by the Crop Recommendation Engine. Using AI-driven rules and scoring algorithms, this engine identifies the 30 most suitable crops for each section of the land. The results are sent to the Visualisation Module, which generates an interactive, colour-coded Land Box Layout showing the recommended crop placement. Finally, the Output Module presents this visual map along with detailed crop suggestions, enabling farmers to make well-informed, data-based decisions for efficient and sustainable farming, both long-term preservation of user data of all modules.

Algorithms Used: The AI-Based Smart Crop Grid Planner uses a rule-based recommendation system to select the best crops for each section of the farmland. Instead of complex machine learning models, it relies on predefined agricultural rules based on soil science, climate suitability, and best farming practices. This approach ensures accurate, reliable, and easy-to-understand recommendations for farmers.

1. **Input Analysis:** The process begins by collecting essential information from the farmer. Farmers are asked to provide details such as soil type, total land area, soil pH, exact farm location, irrigation availability, and the current agricultural season. These inputs form the foundation for all subsequent analysis.
2. **Real-Time Data Integration:** Once the initial inputs are collected, the system retrieves real-time environmental information through external APIs. The OpenWeatherMap API provides current weather details, including temperature, humidity, and rainfall, specific to the farm's location. Simultaneously, the Soil Grids API gathers additional soil characteristics such as texture, organic matter, and nutrient levels. Using live data ensures that crop recommendations are accurate and relevant, rather than relying on static or outdated datasets.
3. **Crop Scoring and Grid Allocation:** The core of the conditions, rather than the system, is a scoring-based algorithm that evaluates the suitability of different crops for each section of the farm. It considers factors such as soil type, optimal pH range, water requirements, crop rotation needs, estimated yield, and market value. The system first checks soil and climate compatibility, then incorporates crop rotation to ensure long-term soil health. It also calculates potential yield and economic viability, combining these factors into an overall score. Crops that meet more criteria receive higher scores, indicating better suitability for the land. After scoring, the farmland is divided into a modular land grid layout, allowing detailed allocation of crops across different sections. Each grid cell is assigned the crop with the highest score, ensuring optimal compatibility, productivity, and efficient use of resources on a micro scale.
4. **Output Generation:** The algorithm produces a visual output in the form of a colour-coded interactive land grid, showing the suggested crop distribution for easy understanding. Along with the grid, the system provides details such as seed quantity, fertiliser requirements, irrigation schedule, and estimated yield for each section. This gives farmers a complete plan for planting and managing their resources efficiently. **JWT (JSON Web Token)-Based Authentication.** JWT is a safe Token-based authentication system that manages user sessions. In AgriGrid Pro, the JWT ensures that tokens are created upon successful login and securely stored on the client side. These tokens ensure that every DB hit to the backend is authorised, so only logged-in individuals can view their own personalised information, crop history and reports. This enhances security as well as scalability of the system.
5. **Bcrypt Hashing Algorithm:** To securely store user credentials, the project uses the bcrypt password-hashing library. When farmers sign up, their passwords are encrypted, and during login, the system verifies the entered password against the stored hash. This ensures that sensitive user information remains protected, even if the database is exposed.

Testing:

Software testing is a crucial phase in the development of the AI-Based Smart Crop Grid Planner, ensuring that the system functions correctly and meets all specified requirements. The testing process focuses on validating the system's functionality, performance, user experience, and the accuracy of crop recommendations. Since the system relies heavily on real-time data, API integration, and automated decision-making, extensive testing is conducted to verify the reliability, precision, and consistency of each module. This ensures that farmers can trust the recommendations for planning.

1. Unit Testing and use the platform effectively for the crop. Each component of the system, such as the input form validation, integration with weather and soil APIs, and the rule-based crop scoring engine, was tested individually. The testing included valid data, invalid entries, and boundary cases to ensure that each function handles errors correctly and consistently generates accurate results. Integration Testing

2. Validation Testing 26 Integration testing was carried out to ensure that all the main modules—User Input, Weather and Soil Data, Crop Recommendation Engine, and Visualisation—worked smoothly together. This testing confirmed that data flowed correctly between the modules and that the system accurately interpreted recommendations. System Testing

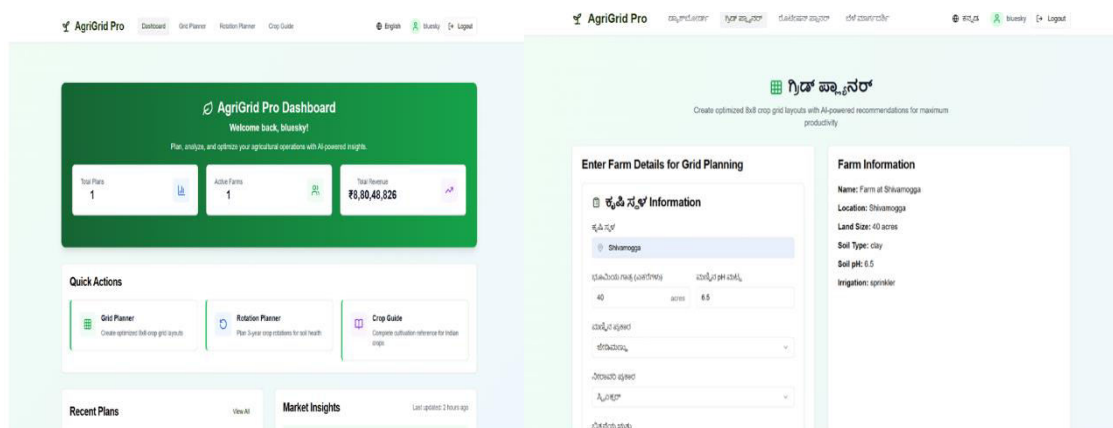
3. Acceptance Testing API responses to generate proper crop samples. Users were invited to try the application to check how easy it was to use, how clear the crop suggestions were, and how smoothly the visual interface responded. The layout and interaction flow proved simple enough for farmers and non-technical users, showing that system 23 is intuitive and easy to navigate. Across these testing phases, the platform performed reliably — delivering stable, accurate, and efficient crop suggestions. The results confirmed that the AI-Based Smart Crop Grid Planner meets its functional goals and is ready for real-world practical use.

Test Cases:

Test Case ID	Description	Input	Expected Output	Result
TC-01	Validate user login with valid details	Soil type: "clay", pH: 5.8, Season: "summer"	User logged in successfully, dashboard shown	Pass
TC-02	Handle invalid credentials	Soil type: "sandy", pH: 20, Season: "kharif"	Display error: "Invalid pH value"	Pass
TC-03	Whether the weather data was successfully fetched	Location: "Shivamogga"	Weather data retrieved from OpenWeatherMap API	Pass
TC-04	Handle API failure	Location: Invalid	Display error: "Unable to fetch weather data"	Pass
TC-05	Correct crop recommendation	Soil: Sandy, pH: 8.5, Irrigation: Medium	Recommended crops: "Maize"	Pass
TC-06	Grid generation accuracy	Land size: 2 acre	Grid generated with assigned crops	Pass
TC-07	Rule-based engine handling edge cases	Soil: Sandy, pH: 8, Medium irrigation	Resistant crops	Pass
TC-08	Colour coding correctness	Grid with multiple crops	Different colours for different crops	Pass

IV. EXPERIMENTAL RESULTS

The image shows the Digital Agri dashboard, where farmers can access tools like the Grid Planner, 3-Year Rotation Planner, and Crop Guide. The dashboard also provides quick updates on recent plans and current market trends.



HOME PAGE

PLANNING PAGE

The displayed interface shows the Farm Details Input section of Digital-Agri, where the user enters key information such as land size, soil category, pH value and irrigation type. After these details are provided, the system generates a concise Farm Information summary that includes the location, soil properties and other relevant parameters. This processed profile forms the basis for creating an optimised grid-based crop plan tailored to the specific characteristics of the farm.

V. CONCLUSION

This report on the implementation of an AI-driven crop recommendation and land-allocation system demonstrates how data analytics and automation can work together to support real-time agricultural decision-making. The rule-based algorithm that evaluates soil, climate and irrigation parameters replaces guess-based crop selection and enables more scientific, reliable and sustainable planning for farmers, especially in regions where traditional methods often lead to inconsistent results. The system performed well across various soil profiles and seasonal conditions, reflecting strong stability during testing and implementation. It also reduces the risk of unsuitable crop choices, which is a frequent limitation of older manual farming practices.

The visual 8×8 grid layout further enhances the usability of the system by providing farmers with clear, immediate feedback on crop placement. Technologies such as Next.js, Node.js, weather APIs and MongoDB make the solution practical, cost-effective and scalable without requiring specialised equipment. In short, the system meets its primary objectives: improving crop selection accuracy, reducing manual effort, and increasing long-term farming efficiency. It can be applied in small and large farms where structured planning is required. The scope of the system can be expanded further with enhancements such as yield prediction, satellite-based monitoring or automated market-price integration.

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