# INTELLIGENT CROP AND FERTILIZER RECOMMENDATION SYSTEM

***Dissertation submitted to***

***Shri Ramdeobaba College of Engineering & Management, Nagpur***

***in partial fulfillment of requirement for the award of degree of***

**Bachelor of Technology (B.Tech)**

In

**COMPUTER SCIENCE AND ENGINEERING**

*By*


**Hariom Nabira (B-34)**

**Harsh Tiwari (B-37)**

**Mayur Kawale (B-45)**

**Mudassir Siddiqui (B-47)**


*Of*

**V Semester**

*Guide*

**Dr. Khushboo Khurana**

RCOEM

Shri Ramdeobaba College of Engineering and Management, Nagpur


**Department of Computer Science and Engineering**

**Shri Ramdeobaba College of Engineering & Management, Nagpur 440 013**

(An Autonomous Institute affiliated to Rashtrasant Tukdoji Maharaj Nagpur University Nagpur)


**November 2024**

**SHRI RAMDEOBABA COLLEGE OF ENGINEERING MANAGEMENT, NAGPUR**

(An Autonomous Institute affiliated to Rashtrasant Tukdoji Maharaj Nagpur University Nagpur)

## Department of Computer Science and Engineering

## CERTIFICATE

This is to certify that the Thesis on **“Intelligent Crop and Fertilizer Recommendation System”** is a Bonafide work of **Hariom Nabira**, **Harsh Tiwari**, **Mayur Kawale**, and **Mudassir Siddiqui,** submitted to the Rashtrasant Tukdoji Maharaj Nagpur University, Nagpur in partial fulfilment of the award of a Degree of Bachelor of Technology (B.Tech), in Computer Science and Engineering. It has been carried out at the Department of Computer Science and Engineering, Shri Ramdeobaba College of Engineering and Management, Nagpur during the academic year 2023-2024.

Date:

Place: Nagpur

| Dr. Khushboo Khurana<br>Project Guide<br>Department of Computer Science and Engineering | Dr. Preeti Voditel<br>H.O.D<br>Department of Computer Science and Engineering |
|---|---|

Dr. M. B. Chandak
Principal

# DECLARATION

We hereby declare that the thesis titled "**Intelligent Crop and Fertilizer Recommendation System**" submitted herein, has been carried out in the Department of Computer Science and Engineering of Shri Ramdeobaba College of Engineering and Management, Nagpur. The work is original and has not been submitted earlier as a whole or part for the award of any degree/diploma at this or any other institution / University.

Date:

Place: Nagpur

| **Name of the Student** | **Roll no.** | **Signature** |
|---|---|---|
| Hariom Nabira | 34 | |
| Harsh Tiwari | 37 | |
| Mayur Kawale | 45 | |
| Mudassir Siddiqui | 47 | |

## APPROVAL SHEET

This report entitled "**Intelligent Crop and Fertilizer Recommendation System**" by **Hariom Nabira**, **Harsh Tiwari**, **Mayur Kawale**, and **Mudassir Siddiqui,** is approved for the degree of Bachelor of Technology (B.Tech).

| | |
|---|---|
| Dr. Khushboo Khurana<br>Project Guide | External Examiner |

Dr. Preeti Voditel
H.O.D, CSE

Date:

Place: Nagpur

## ACKNOWLEDGEMENTS

The project is a combined effort of a group of individuals who synergize to contribute towards the desired objectives. Apart from the efforts by us, the success of the project shares an equal proportion with the engagement and guidance of many others. We take this opportunity to express our gratitude to the people who have been instrumental in the successful completion of this project.

We would like to show our greatest appreciation towards Dr. Khushboo Khurana for providing us with the facilities for completing this project and for their constant guidance.

We would like to express our deepest gratitude to Dr. Preeti Voditel, Head, Department of Computer Science and Engineering, RCOEM, Nagpur for providing us the opportunity to embark on this project.

We would like to express our deepest gratitude to Dr. M. B. Chandak, Principal, RCOEM, Nagpur for providing us the opportunity to embark on this project.

Finally, extend our gratitude to all the faculty members of the CSE department who have always been so supportive and provided resources needed in our project development. We are very grateful to all of them who have unconditionally supported us throughout the project.

Date :

--Projectees

Hariom Nabira
Harsh Tiwari
Mayur Kawale
Mudassir Siddiqui

## ABSTRACT

The Intelligent Crop and Fertilizer Recommendation System is a comprehensive solution aimed at empowering farmers with data-driven agricultural insights. This system leverages a machine learning model, specifically a Random Forest Classifier, to recommend suitable crops based on soil and climatic conditions, including nitrogen, phosphorus, potassium levels, temperature, humidity, pH, and rainfall. It further provides guidance on fertilizer usage tailored to selected crops and their environmental context.

In addition to its core recommendations, the system integrates features to inform users about the Minimum Support Price (MSP) of recommended crops and relevant government schemes, ensuring farmers can make economically viable decisions. A geospatial mapping component visualizes crop distribution and soil characteristics, aiding policymakers and farmers in strategic planning. The system also includes data visualization tools for analyzing and understanding agricultural trends.

This project exemplifies the application of machine learning, geospatial analysis, and user-centric design to address challenges in modern agriculture, aiming to enhance productivity and sustainability.

**Keywords**: Crop Recommendation, Fertilizer Recommendation, Machine Learning, Random Forest, Data Visualization, Geospatial Mapping, Government Schemes, Minimum Support Price (MSP)

# TABLE OF CONTENTS

# LIST OF FIGURES

# LIST OF TABLES

# CHAPTER 1
# INTRODUCTION

Agriculture has been a cornerstone of human civilization, providing the foundation for sustenance and economic growth. In recent years, the field has faced challenges arising from fluctuating climatic conditions, inefficient use of resources, and the lack of timely, region-specific agricultural insights. Farmers, especially in developing countries like India, often struggle to decide on the best crops or fertilizers suited to their soil and climatic conditions, leading to suboptimal yields and financial distress.

The advent of artificial intelligence and machine learning offers transformative potential in addressing these issues. By leveraging data-driven insights, these technologies can provide actionable recommendations that cater to individual farmers' specific needs, thereby improving productivity, ensuring sustainability, and enhancing economic returns.

The Intelligent Crop and Fertilizer Recommendation System combines advanced machine learning techniques, comprehensive datasets, and user-centric functionality to support farmers in making informed decisions. In addition to crop and fertilizer recommendations, the system provides essential information, such as government schemes and Minimum Support Prices (MSP), coupled with visual analytics to empower both farmers and policymakers.

## 1.1 Problem Definition

Modern agriculture faces a myriad of challenges, including fluctuating climatic conditions, declining soil health, and limited access to reliable market data. Farmers often rely on traditional practices or anecdotal evidence, which may not align with the current soil and climatic conditions. This mismatch leads to suboptimal crop yields and financial losses.

Additionally, the availability of government schemes and policies designed to support farmers is often underutilized due to inadequate dissemination of information. Many farmers are unaware of the Minimum Support Price (MSP) for their crops or the schemes they are eligible for, leaving them vulnerable to exploitation in the marketplace. Furthermore, with global environmental changes, the need for sustainable farming practices and resource optimization is more pressing than ever.

The problem also extends to fertilizer usage. Overuse or incorrect application of fertilizers can degrade soil quality, harm the environment, and reduce productivity over time. Despite technological advancements, accessible tools for providing customized recommendations are scarce, leaving a gap in the agricultural ecosystem.

The problems can be summarized as:

- **Inadequate Crop Selection**: Farmers often lack the tools to identify the crops best suited for their region's soil and climate, leading to poor yields.
- **Fertilizer Misuse**: Improper fertilizer application, either excessive or insufficient, degrades soil quality and reduces crop productivity.
- **Limited Access to Information**: Farmers struggle to obtain timely information on Minimum Support Prices (MSP) and government schemes relevant to their crops.
- **Insufficient Data Visualization Tools**: Policymakers and agricultural planners lack intuitive tools to analyze and act on agricultural data effectively.

The *Intelligent Crop and Fertilizer Recommendation System* is designed to bridge these gaps. By integrating machine learning with real-time datasets, the system offers actionable insights to farmers, empowering them to make informed decisions that enhance productivity, sustainability, and profitability.

## 1.2 Motivation

The motivation for this project stems from the pressing need to address the challenges faced by farmers. Agriculture is not merely a profession but a way of life for millions, especially in rural areas. Despite their pivotal role, farmers often lack access to advanced technologies that could simplify decision-making and improve outcomes.

Inspired by the rapid advancements in data science and machine learning, this project aims to make these technologies accessible to the agricultural community. The idea is to create a solution that not only recommends suitable crops and fertilizers but also provides additional value by integrating MSP data and government schemes. This integration ensures that farmers are aware of their financial options and opportunities, enabling them to maximize their earnings.

Another significant motivator is the need for sustainable farming practices. Overuse of fertilizers and inappropriate crop selection can have long-term detrimental effects on the environment. By providing tailored recommendations based on soil and climatic conditions, the system encourages efficient resource utilization, reducing waste and environmental impact.

This project is also a response to the gap observed in existing systems, which often lack comprehensive functionality or accessibility. The goal is to create a user-friendly, robust platform that empowers even those with limited technical knowledge. The potential to positively impact farmers' lives and contribute to sustainable agriculture drives the development of this project.

The motivation for this project stems from:

- The desire to harness **machine learning** and **data visualization** to provide solutions tailored to farmers' specific requirements.
- The need to ensure that small and marginal farmers benefit from **technology-driven advancements** without requiring high technical expertise.
- The vision of creating an **ecosystem of informed decision-making** for both farmers and policymakers, bridging the gap between technological innovations and ground-level implementation.

## 1.3 Overview

The *Intelligent Crop and Fertilizer Recommendation System* leverages machine learning and modern web technologies to provide comprehensive assistance to farmers. It is a multi-faceted platform that delivers crop recommendations, fertilizer guidance, MSP information, and government scheme eligibility in an integrated manner.

At its core, the system uses datasets containing soil and climatic parameters, crop yields, MSPs, and schemes. These datasets are preprocessed and fed into machine learning models to generate accurate recommendations. The backend of the system handles data processing, algorithm execution, and integration of additional services like location-based input automation. The frontend is designed to be intuitive, allowing users to interact with the system seamlessly.

One of the standout features of the system is its emphasis on visualization. Farmers and policymakers can access graphs and maps that provide insights into agricultural data trends, enhancing their decision-making. The system also simplifies input collection by automating location-based parameter fetching, reducing the effort required from users.

This report delves into every aspect of the system, from its conceptualization to implementation. The following chapters discuss the problem's background, related work in agricultural technologies, methodologies, implementation, results, and future scope.

### 1.4 Objectives

The *Intelligent Crop and Fertilizer Recommendation System* has been designed with the following objectives:

- **Crop Recommendation**: To recommend crops that are best suited to the given soil and climatic conditions, ensuring optimal yields.
- **Fertilizer Guidance**: To provide farmers with tailored fertilizer recommendations for the selected crops to enhance productivity and maintain soil health.
- **MSP Integration**: To inform farmers about the Minimum Support Price (MSP) for recommended crops, aiding them in financial planning.
- **Government Scheme Awareness**: To make farmers aware of the government schemes they can benefit from, based on the crops they cultivate.
- **Data Visualization**: To offer intuitive visual tools that enable users to understand agricultural trends and data distributions.
- **Automation**: To reduce the effort required from users by automating the input collection process using location-based services.

The project aims to create a holistic system that addresses these objectives, enhancing the efficiency and profitability of agricultural practices while promoting sustainability.

## 1.5 Applications

The applications of *Intelligent Crop and Fertilizer Recommendation System* extend across various domains, making it highly versatile and impactful.

- **Farmer Assistance**: The primary application is assisting farmers in selecting the best crops and fertilizers for their conditions, supported by MSP data and scheme eligibility.
- **Policy Formulation**: Policymakers can use the system's visualization tools to understand regional agricultural trends, helping them design better policies.
- **Education and Awareness**: Agricultural universities and extension programs can use the system to educate farmers about sustainable practices and available schemes.
- **Supply Chain Optimization**: Agribusinesses can leverage crop recommendations to optimize their supply chains, ensuring timely availability of inputs and outputs.
- **Environmental Conservation**: By encouraging efficient fertilizer usage and optimal crop selection, the system contributes to preserving soil health and reducing resource wastage.

This multi-functional platform addresses critical agricultural challenges, paving the way for a more sustainable and productive future.

# CHAPTER 2
# LITERATURE SURVEY

## 2.1 Introduction to Agricultural Technologies

Agriculture has long been a cornerstone of human civilization, serving as the primary source of food and raw materials. In recent decades, rapid advancements in technology have profoundly impacted the agricultural sector, introducing innovative tools and techniques that enhance productivity, sustainability, and decision-making. From precision agriculture and automation to data-driven insights and artificial intelligence, agricultural technologies are revolutionizing traditional farming practices.

Key technological domains influencing modern agriculture include:

1. **Precision Agriculture**:
   Precision agriculture uses sensors, GPS, and data analytics to optimize farming practices, such as irrigation, fertilization, and pest control. By tailoring inputs to specific areas within a field, it reduces waste and maximizes yield.
2. **Artificial Intelligence and Machine Learning**:
   AI and ML algorithms analyze large datasets to predict crop yields, recommend optimal planting schedules, and identify pest infestations. These technologies empower farmers to make informed decisions based on real-time data.
3. **Internet of Things (IoT)**:
   IoT devices, such as smart sensors and drones, collect and transmit real-time data on soil health, weather conditions, and crop growth. This facilitates better monitoring and resource allocation.
4. **Data Visualization and Analytics**:
   Data visualization tools convert complex datasets into intuitive charts, graphs, and maps, helping stakeholders understand agricultural trends and patterns more effectively. These insights support both short-term decisions and long-term planning.

5. **Blockchain in Agriculture**:
   Blockchain technology ensures transparency in supply chains, enabling traceability of agricultural products from farm to consumer. It also aids in creating trusted records for pricing and transaction history.

Despite these advancements, several challenges persist, including the accessibility of these technologies to small-scale farmers, high implementation costs, and the need for localized solutions. Addressing these challenges is essential to ensuring that technological progress benefits all stakeholders in agriculture. This chapter aims to explore existing literature on crop and fertilizer recommendation systems, assessing their methodologies, effectiveness, and gaps that this project seeks to address.

## 2.2 Existing Agricultural Systems and Technologies

Numerous agricultural systems and technologies have been developed to assist farmers in optimizing their yield, minimizing costs, and ensuring sustainable practices. These systems often incorporate machine learning, IoT (Internet of Things), and data analytics to provide insights into crop and soil management. This section reviews key existing systems and their contributions to agriculture.

1. **IBM Watson Decision Platform for Agriculture**
   IBM's system integrates AI and data from weather, IoT devices, and satellite imagery to provide actionable insights for farmers. It uses advanced analytics to predict weather patterns, monitor crop health, and optimize planting schedules. **[1][2]**
   **Features**:
   - Crop yield prediction using AI models.
   - Real-time monitoring through IoT.
   - Integration with satellite imagery for pest control.

2. **Krishi Jagran Smart Farming Platform**
   The Krishi Jagran platform provides crop recommendations and market information. It focuses on the Indian agricultural market, offering region-specific insights. **[3]**

**Features**:

- Crop and fertilizer recommendations.
- Real-time MSP updates.
- Mobile app for farmers to access updates.

**Table 2.1: Comparison of IBM Watson and Krishi Jagran Platforms**

| **Feature** | **IBM Watson** | **Krishi Jagran** |
|---|---|---|
| AI-Driven Insights | Yes | Limited |
| Satellite Integration | Yes | No |
| MSP Information | No | Yes |

3. **Machine Learning in Agriculture**

In **[4]**, a paper by Sharma et al., the authors explore the use of Random Forest and Support Vector Machines in predicting crop yields. Their findings align with this project's emphasis on Random Forest due to its higher accuracy in multidimensional datasets. A brief summary of their findings is given in Table 2.2.

**Key Results**:

- Random Forest outperformed Logistic Regression and SVM for yield prediction.
- Incorporating soil pH and NPK levels significantly improved predictions.

**Table 2.2: Algorithm Performance as per Sharma et al. (2022) [4]**

| **Algorithm** | **Accuracy (%)** |
|---|---|
| Logistic Regression | 95.12 |
| Support Vector Machine | 96.45 |
| Random Forest | 98.72 |

## 2.3 Insights on Current Agricultural Technological Systems: Trends, Gaps, and Opportunities for Innovation

Analyzing the current landscape of agricultural technologies and systems reveals several trends and gaps that shape the direction for future innovations. These observations are crucial for understanding the opportunities and limitations that influence the design of this project.

**1. Advanced AI and ML Models Are Underutilized in Practice**

While Random Forest, Support Vector Machines (SVM), and other advanced machine learning models are highly effective in controlled research environments, their application in real-world systems remains limited. For example, systems like IBM Watson leverage sophisticated AI algorithms, but their complexity often makes them inaccessible to small-scale farmers with limited technical knowledge or resources. Similarly, research studies highlight the potential of these models, yet implementation challenges restrict widespread adoption.

**2. Regional Customization Is Insufficient**

Platforms like Krishi Jagran have made strides in providing localized recommendations. However, their reliance on less robust AI-driven systems and the lack of integration with global technologies, such as satellite imaging and IoT, can limit their precision. Regional diversity in soil types, climatic conditions, and cropping patterns requires systems that can dynamically adapt to these variables.

**3. Lack of End-to-End Integration**

Existing systems tend to focus on specific aspects of agriculture, such as crop health monitoring, yield prediction, or market trends. For example, IBM Watson excels in satellite imagery integration, while Krishi Jagran emphasizes MSP updates. However, farmers need platforms that integrate crop recommendations, fertilizer guidance, MSP insights, and government schemes into a single cohesive interface.

### 4. Accessibility Remains a Significant Challenge

The cost of implementing advanced technologies and the digital divide in rural areas are two major barriers to widespread adoption. While platforms like Krishi Jagran are more accessible due to their mobile-first approach, their feature set is less comprehensive compared to global systems like IBM Watson.

### 5. Research Highlights the Potential of Hybrid Systems

Literature such as Sharma et al. (2022) demonstrates that combining traditional soil metrics (pH, NPK) with advanced AI-driven analytics yields the most accurate predictions. These findings reinforce the need for systems that blend research-driven models with practical tools for farmers.

### Key Takeaways for This Project

The *Intelligent Crop and Fertilizer Recommendation System* addresses these gaps by integrating robust AI algorithms with user-friendly interfaces and region-specific customizations. It emphasizes accessibility through a web-based platform while providing end-to-end services such as crop and fertilizer recommendations, MSP integration, and government scheme eligibility.

# CHAPTER 3
# METHODOLOGY

Agricultural technology and machine learning play an increasingly important role in optimizing crop production and resource utilization. This chapter focuses on the methodologies employed in designing the *Intelligent Crop and Fertilizer Recommendation System*. The system's core objective is to assist farmers in making data-driven decisions, combining crop recommendation, fertilizer guidance, MSP information, and government scheme eligibility.

The design philosophy emphasizes accessibility, accuracy, and ease of use. The following sections detail the dataset preparation, preprocessing, and machine learning pipeline that underpin the system. The proposed methodology section presents a conceptual workflow that integrates the backend, frontend, and machine learning components.

## 3.1 Datasets Used

Datasets are fundamental to the accuracy and functionality of the system. Three key datasets have been employed:

1. **Crop Recommendation Dataset**: This dataset, sourced from Kaggle **[5]**, provides the core data for machine learning-based crop recommendations. It includes critical parameters like nitrogen (N), phosphorus (P), potassium (K), temperature, humidity, pH, and rainfall. Each data point corresponds to a crop that is most suitable under those conditions. With 2,200 samples, the dataset ensures diverse coverage of soil and climate conditions across different regions.
2. **Minimum Support Price (MSP) Dataset**: This dataset was curated manually by scraping government websites **[6][7]**. It includes the MSP values for a variety of crops, along with the corresponding year. The dataset ensures that farmers receive up-to-date pricing information, which is critical for making economically sound decisions. This dataset bridges the gap between crop recommendations and their economic viability.

3. **Government Schemes Dataset**: Official government portals **[8][9]** were scraped to compile information on agricultural schemes. The dataset includes scheme names, descriptions, eligibility criteria, and the crops covered. This component ensures that farmers are informed about the policies and benefits they can leverage for sustainable farming.

**Table 3.1: Summary of Datasets Used**

| **Dataset** | **Source** | **Attributes** |
|---|---|---|
| Crop Recommendation | Kaggle | N, P, K, temperature, humidity, pH, rainfall, crop |
| MSP Dataset | Scraped data | Crop name, MSP (per quintal), year |
| Schemes Dataset | Scraped data | Scheme name, description, eligibility criteria, applicable crops |

The datasets underwent preprocessing to clean anomalies and normalize values, ensuring compatibility across all system components. For instance, the MSP dataset was cross-referenced with multiple sources to eliminate inconsistencies. Similarly, missing or incomplete data in the schemes dataset was carefully addressed to provide comprehensive recommendations.

The integrity and relevance of these datasets are central to achieving the system's goals. Their integration enables the model to produce actionable outputs while providing insights beyond crop recommendations, such as economic and policy guidance.

## 3.2 Machine Learning Pipeline

The machine learning pipeline serves as the computational heart of the *Intelligent Crop and Fertilizer Recommendation System*. Its design ensures accurate predictions, user scalability, and robust performance across varying datasets.

1. **Data Splitting**: To create a balanced training environment, the Kaggle crop recommendation dataset was split into training (80%) and testing (20%) subsets. This division ensured that the model could generalize well to unseen data. The test set was preserved for final validation to avoid data leakage.
2. **Feature Engineering**: The input features were normalized to remove scale-based bias. For example, while nitrogen, phosphorus, and potassium values had larger ranges, temperature and pH values were comparatively narrow. Feature scaling ensured uniformity across all parameters.
3. **Algorithm Selection**: Multiple machine learning algorithms were tested for their suitability, including Logistic Regression, Decision Tree, Support Vector Classifier (SVC), and Random Forest. Each algorithm was evaluated for accuracy, precision, and F1-score. Random Forest emerged as the optimal choice with an impressive accuracy of 99.32%. This result, significantly higher than Logistic Regression (96.36%) and SVC (96.82%), as summarised in Table 3.2, established its suitability for the system.

**Table 3.2: Accuracy of Tested Algorithms**

| **Algorithm** | **Accuracy (%)** |
|---|---|
| Logistic Regression | 96.36 |
| Decision Tree | 98.18 |
| Support Vector Classifier | 96.82 |
| Random Forest | 99.32 |

4. **Model Training**: Random Forest was trained using hyperparameter tuning, optimizing factors like the number of estimators and maximum depth. The model benefited from its inherent capability to handle high-dimensional data while preventing overfitting through ensemble averaging.

5. **Model Validation**: The validation process employed metrics like precision, recall, and F1-score to gauge the model's robustness. Precision ensured relevance in crop recommendations, while recall emphasized completeness.

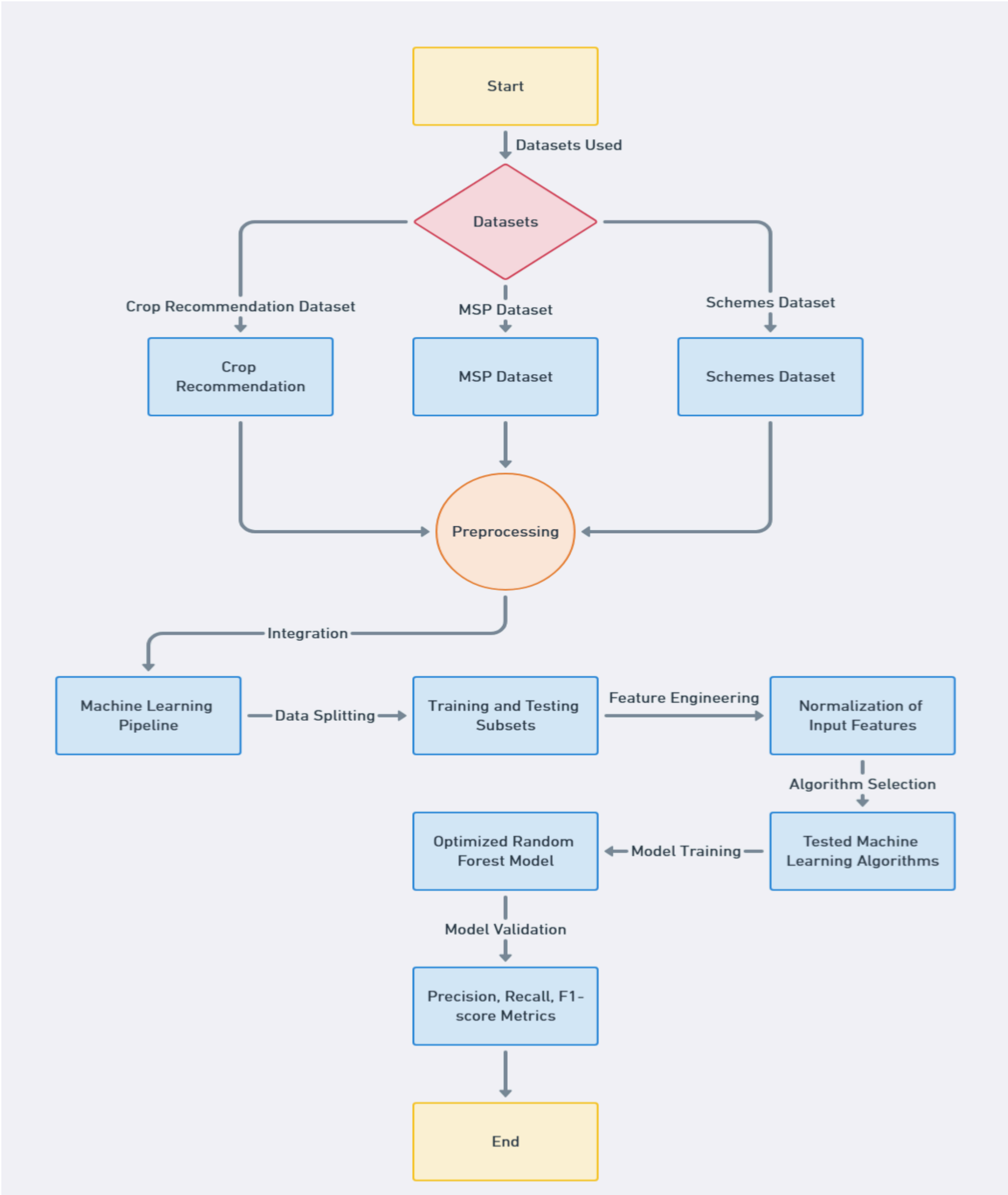


**Figure 3.1** The step-by-step flow of the machine learning pipeline

The machine learning pipeline ensures that the system is equipped with the computational strength to provide accurate and reliable recommendations across diverse agricultural scenarios.

### 3.3 Proposed Methodology

The proposed methodology integrates the machine learning model into a comprehensive platform designed for accessibility and usability. The system functions as a web application, combining backend logic, a user-friendly frontend, and seamless data integration.

1. **Input Parameters**: Users can provide soil and climatic details, such as nitrogen, phosphorus, potassium, temperature, humidity, pH, and rainfall. The system also supports automated input retrieval through GPS and weather APIs, streamlining the data collection process.
2. **Crop Recommendation**: The Random Forest model predicts crops most suited to the provided conditions. Recommendations are displayed with an accuracy score and supporting data.
3. **Fertilizer Guidance**: For a selected crop, the system analyzes soil data and suggests fertilizers optimized for nutrient deficiencies. This ensures cost-effective and environmentally conscious fertilizer use.
4. **Data Visualization**: Interactive graphs and regional data visualizations enhance user understanding. For instance, farmers can view nutrient distributions or crop suitability on a map grouped by region.
5. **MSP and Scheme Integration**: Recommendations are augmented with MSP values and relevant government schemes. Farmers can access these benefits directly through the platform, adding economic and policy perspectives to their decisions.

The methodology is designed to provide end-to-end agricultural solutions, empowering farmers with tools to enhance productivity, reduce costs, and maximize benefits. By unifying multiple functionalities into a cohesive system, the methodology addresses both short-term and long-term challenges in farming.

# CHAPTER 4
# IMPLEMENTATION

## 4.1 System Architecture

The system architecture of the *Intelligent Crop and Fertilizer Recommendation System* is designed to ensure efficient communication between its various components, enabling accurate predictions, seamless user interaction, and data-driven decision-making. The architecture follows a three-tier structure: **frontend**, **backend**, and **database**, integrated with a **machine learning model**. Figure 4.1 illustrates the system architecture via a flowchart. Figure 4.2 shows the primary technologies used in the development of the *Intelligent Crop and Fertilizer Recommendation System*

**Frontend**:
The frontend, developed using React.js, serves as the user-facing interface. It allows users to input soil and climatic parameters or use location-based automation to fetch data. The interface also presents crop recommendations, fertilizer suggestions, and visualized outputs, making complex data easy to interpret.

**Backend**:
The backend, implemented with Node.js and Express.js, acts as the bridge between the frontend, the database, and the machine learning model. It processes user inputs, fetches real-time MSP and government scheme data, and routes requests to the model for crop and fertilizer recommendations. It also ensures secure and efficient API communication.

**Database**:
The system employs MongoDB to store datasets, including MSP data, government schemes, and user logs. The database design focuses on fast retrieval of information and scalability.

**Machine Learning Model**:
The trained Random Forest model is hosted within the backend to predict optimal crops and fertilizers based on user-provided or fetched parameters.

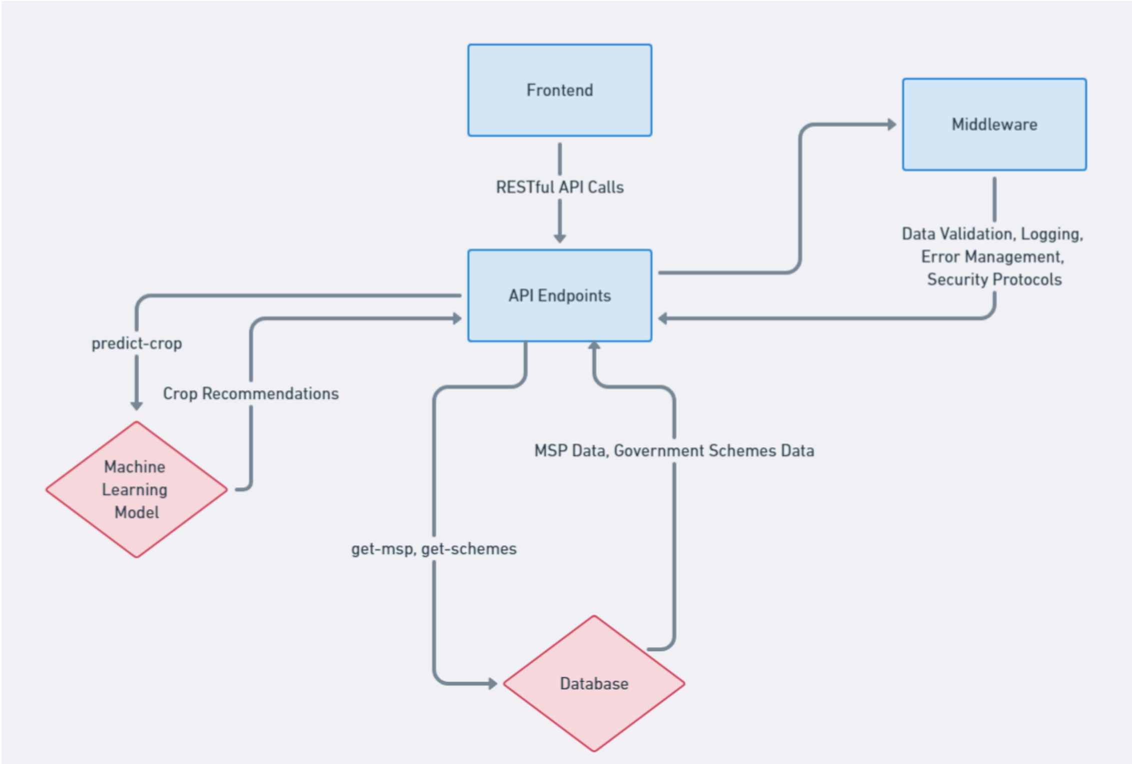


**Figure 4.1** System architecture


**Figure 4.2** Tech Stack

## 4.2 Frontend Development

The frontend of the *Intelligent Crop and Fertilizer Recommendation System* serves as the primary interface between the users and the system. Designed to be highly intuitive and user-friendly, it ensures that farmers, regardless of their technical proficiency, can interact seamlessly with the platform. The frontend is built using **React.js**, a powerful and flexible JavaScript library that allows for the creation of responsive, dynamic, and engaging web applications.

**Key Features of the Frontend**:

1. **User-Centric Design**: The frontend interface focuses on simplicity and accessibility. It provides intuitive forms for data entry, such as soil parameters (NPK values, pH) and environmental conditions (temperature, rainfall). Visual aids like icons, tooltips, and user prompts guide farmers through the process, ensuring ease of use. The layout emphasizes clear typography, logical navigation, and visually distinct sections, making the platform suitable even for users with minimal technical exposure.
2. **Responsive and Adaptive Framework**: Built with responsiveness in mind, the interface adapts seamlessly to devices of varying screen sizes and resolutions, including desktops, tablets, and smartphones. By leveraging **React.js** and **Bootstrap**, the frontend ensures consistency across all devices, making it accessible to farmers both in the field and at home.
3. **Real-Time Data Interaction**: The frontend connects with the backend via **RESTful APIs**, enabling real-time updates. Farmers receive instant recommendations on crops and fertilizers based on their inputs. Features like automatic data refresh ensure that any changes in MSP or government schemes are reflected promptly without requiring manual page reloads.
4. **Interactive Data Visualization**: A significant aspect of the frontend is its ability to present complex data through visual tools. Using libraries like **Chart.js** and **D3.js**, the platform displays crop suitability, soil parameter trends, and regional data insights through bar graphs, line charts, and heat maps. This approach

simplifies data interpretation, making it easier for farmers to understand and act on recommendations.

5. **Automation and Efficiency**: The frontend incorporates location-based data automation using GPS and APIs. Environmental parameters like temperature, humidity, and rainfall are automatically fetched and pre-filled, reducing the manual effort for users. This feature enhances both accuracy and efficiency.

**Technologies Used in Frontend Development**:

- **React.js**: The core framework used for building modular and reusable components.
- **Material-UI and Bootstrap**: These libraries provide pre-designed components and styling options, ensuring a polished and modern interface.
- **Axios**: A promise-based HTTP client utilized for API interactions between the frontend and backend.
- **Chart.js and D3.js**: Libraries for creating dynamic and visually appealing charts and graphs.

The frontend has been rigorously tested to handle various edge cases, such as missing or invalid data, ensuring smooth performance. It bridges the gap between the technical capabilities of the system and the practical requirements of its users, empowering farmers to make informed agricultural decisions.

## 4.3 Backend Development

The backend of the *Intelligent Crop and Fertilizer Recommendation System* serves as the system's operational backbone, processing user inputs, executing machine learning models, and providing critical data to the frontend. This robust architecture, built using **Node.js** and **Express.js**, prioritizes scalability, performance, and seamless communication with the database and external APIs. Its modular and efficient design enables the integration of various functionalities while maintaining security and reliability.

**Core Responsibilities of the Backend**

The backend architecture is divided into key modules, each handling specific responsibilities to ensure the system can manage multiple user queries efficiently and deliver timely responses.

1. **User Input Management**:
   The backend receives parameters such as nitrogen (N), phosphorus (P), potassium (K) levels, soil pH, temperature, humidity, and rainfall from the frontend interface. This data is processed to ensure correctness and consistency before being passed to the machine learning model.
   - Input data is validated against predefined ranges to avoid errors.
   - Invalid or incomplete inputs trigger appropriate error responses, ensuring user-friendly feedback.
2. **Machine Learning Model Integration**:
   The backend integrates a pre-trained Random Forest machine learning model to provide accurate crop recommendations.
   - Soil and climatic parameters are sent as input to the model, which predicts the most suitable crops in real-time.
   - Fertilizer recommendations are generated based on the selected crop and the input parameters.
   - The backend processes the model output, ensuring that predictions are presented clearly to users.
3. **Data Retrieval and Enrichment**:
   The backend queries the MSP database for minimum support price information related to the recommended crops. It also retrieves relevant government schemes mapped to the predicted crops. This contextual data enhances the recommendation system's utility, providing users with actionable insights.
4. **Visualization Preparation**:
   The backend generates datasets for visualization, supporting graphical representations of parameter-specific trends and geographic data points. This ensures farmers and policymakers can easily interpret critical information through intuitive charts and maps.

**APIs and Middleware Integration**

- RESTful APIs form the backbone of the backend's communication capabilities, allowing seamless interaction between the frontend, machine learning models, and external systems. Table 4.1 summarises the primary API endpoints of the backend.

**Table 4.1: API Endpoints**

| API Endpoint | Description |
|---|---|
| /predict-crop | Processes user inputs and provides crop recommendations. |
| /get-msp | Fetches minimum support price data for crops. |
| /get-schemes | Retrieves government schemes applicable to recommended crops. |

- Middleware layers handle data validation, logging, and error management. These layers ensure that incoming requests are secure, formatted correctly, and logged for debugging or analytics purposes. Security protocols include authentication mechanisms to protect sensitive user data.

**Database Interaction**

The backend employs **MongoDB** as its database solution, designed for flexibility and high performance. The NoSQL schema efficiently manages diverse data types, including crop recommendations, MSP details, and government schemes.

- Data is stored in a structured format, facilitating rapid retrieval.
- Updates to MSP or scheme information are reflected immediately across the system, ensuring that users always access the most recent data.

This comprehensive architecture ensures a smooth flow of operations from data input to result delivery.

## 4.4 Integration of Machine Learning Models

Integration of machine learning models into the system's architecture is a critical aspect of the *Intelligent Crop and Fertilizer Recommendation System*. This process involves seamlessly connecting the trained machine learning models with the backend to provide accurate, real-time recommendations to users. The integration is designed to ensure high performance, low latency, and scalability while maintaining ease of use for end-users.

**Process of Model Integration**

1. **Backend Model Integration**: The backend, built using **Node.js**, acts as the intermediary between the frontend and the machine learning models. Flask-based APIs were developed for the models to facilitate communication with the Node.js backend. When a user submits input parameters, the backend sends these to the Flask service, which loads the relevant serialized model, processes the input, and returns predictions.
2. **Real-Time Prediction Flow**: The system is designed for low-latency predictions. Inputs received from the frontend are preprocessed in real time to match the format required by the model. For instance, categorical variables are encoded, and numerical values are normalized. This ensures that the input data aligns perfectly with the format the model was trained on, maintaining prediction accuracy.
3. **Error Handling and Validation**: Robust error-handling mechanisms were implemented to account for scenarios like missing input fields or incorrect data formats. The backend validates all incoming data before processing, ensuring the model receives clean and accurate information.
4. **Continuous Model Monitoring**: A logging mechanism was integrated to monitor model performance and identify anomalies. Metrics such as response time, prediction accuracy, and model drift are tracked regularly to ensure the system remains reliable and effective.

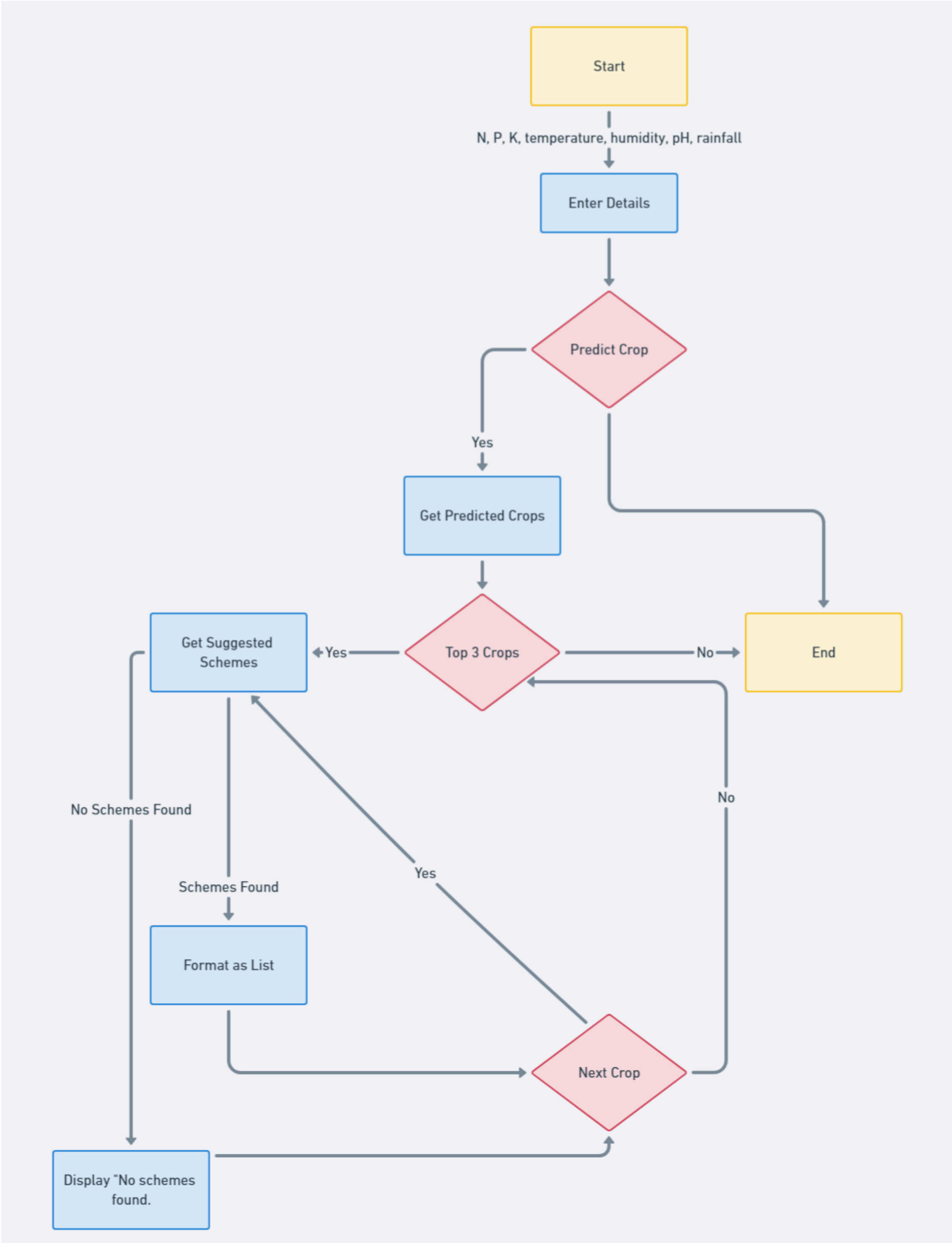


**Figure 4.3:** Crop Recommendation model Workflow

Figure 4.3 illustrates the workflow of the crop recommendation module. As the flowchart in the figure shows, the model outputs its top three suitable crops and these are presented along with the respective MSP and Government Scheme information. This approach enables the farmers to make better informed decisions.

# CHAPTER 5
# RESULTS

This chapter presents the outcomes of the *Intelligent Crop and Fertilizer Recommendation System*, including model performance metrics, the effectiveness of the system's functionalities, and data visualization capabilities. Each subchapter provides a comprehensive analysis of the results achieved during the development and testing phases.

## 5.1 Machine Learning Model Performance

The heart of the system lies in its machine learning-based crop recommendation engine. Multiple machine learning algorithms were evaluated to ensure optimal performance. The comparison of models was conducted based on accuracy, precision, recall, and F1 score. Table 5.1 and Figure 5.1 below summarize the results:

**Table 5.1: Comparison of Machine Learning Models**

| Algorithm | Accuracy (%) | Precision (%) | Recall (%) | F1 Score (%) |
|---|---|---|---|---|
| Logistic Regression | 96.36 | 96.44 | 96.36 | 96.35 |
| Decision Tree | 98.18 | 98.23 | 98.18 | 98.18 |
| Random Forest | 99.32 | 99.37 | 99.32 | 99.32 |
| Support Vector Machine (SVM) | 96.82 | 97.15 | 96.82 | 96.80 |
| K-Nearest Neighbors (KNN) | 95.68 | 96.29 | 95.68 | 95.67 |

From the analysis, the Random Forest algorithm emerged as the most effective model, achieving the highest accuracy of 99.32%. This superior performance is attributed to Random Forest's ability to handle high-dimensional data and avoid overfitting.

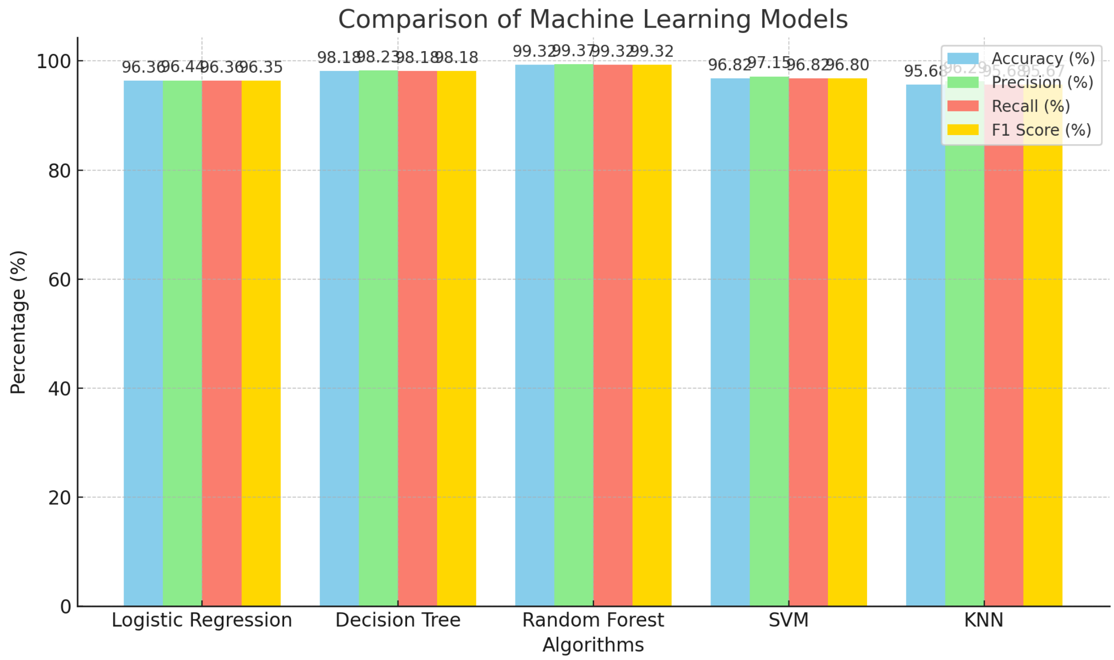


**Figure 5.1:** Comparison of Machine Learning Models

## 5.2 Crop Recommendation Results

The crop recommendation system uses soil and climatic parameters—such as nitrogen (N), phosphorus (P), potassium (K), temperature, humidity, pH, and rainfall—to predict the best-suited crops for a given region. The model effectively processes this input and produces a ranked list of crops based on suitability scores. During testing, the recommendations aligned well with expected outcomes, showcasing the system's reliability.

An example test case involved parameters with high pH and moderate nitrogen content. The system correctly recommended crops such as wheat and barley, which thrive under such conditions.

The integration of MSP (Minimum Support Price) data with the recommendations adds significant value. Farmers can assess the economic feasibility of cultivating specific crops, enabling informed decision-making. This feature ensures that farmers are not only guided on agricultural suitability but also economic viability. Figure 5.2 below shows a sample run of the crop recommendation pipeline along with MSP and Government Scheme suggestions.

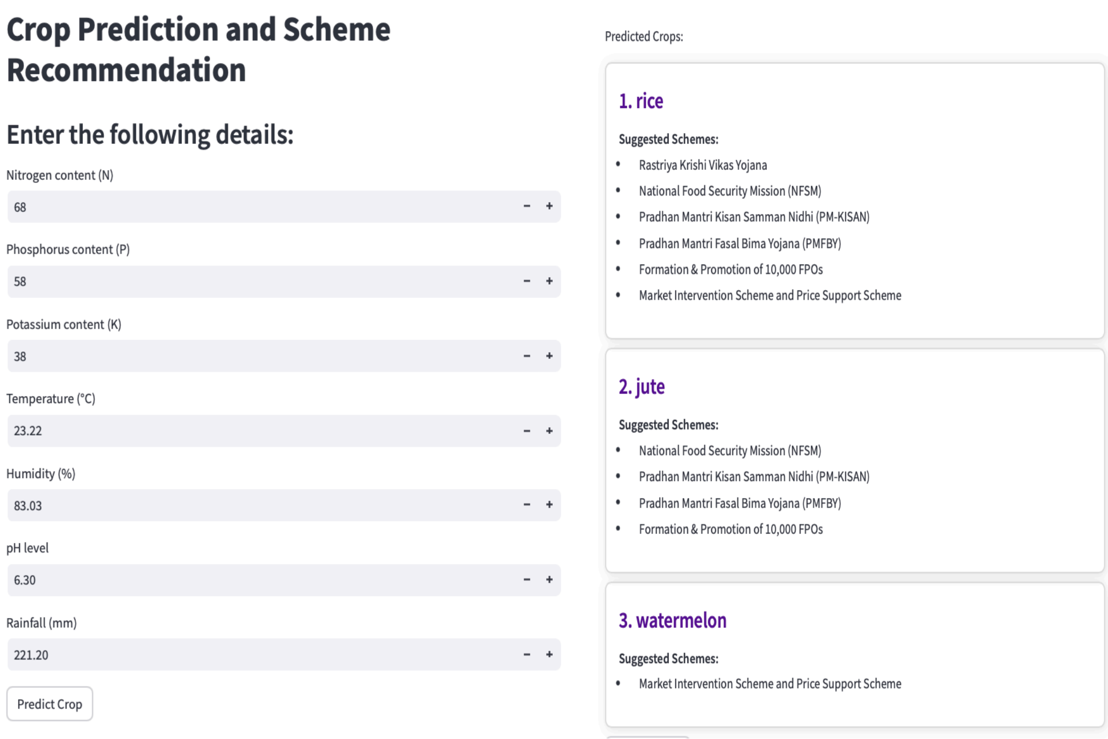


**Figure 5.2:** Crop Recommendation with MSP and Government Schemes Demonstration

## 5.3 Fertilizer Recommendation Results

The fertilizer recommendation module provides targeted suggestions based on the selected crop and soil conditions. For instance, if a farmer inputs low potassium levels with a target crop of rice, the system recommends potassium-rich fertilizers. This functionality is particularly useful in addressing nutrient deficiencies, thus optimizing crop yield.

Feedback from test scenarios demonstrated the system's precision in aligning fertilizer recommendations with soil deficiencies and crop requirements. As an example, for a test case with a nitrogen-deficient soil profile and a target crop of maize, the system suggested nitrogen-heavy fertilizers such as urea, enhancing the soil's fertility profile.

## 5.4 Data Visualization Results

The system's data visualization capabilities provide users with graphical insights into agricultural data. Features include:

1. **Parameter Trends**: Graphs illustrating temporal trends for soil properties such as pH and NPK levels.
2. **Regional Crop Suitability Maps**: Choropleth maps showing the most suitable crops for various regions.

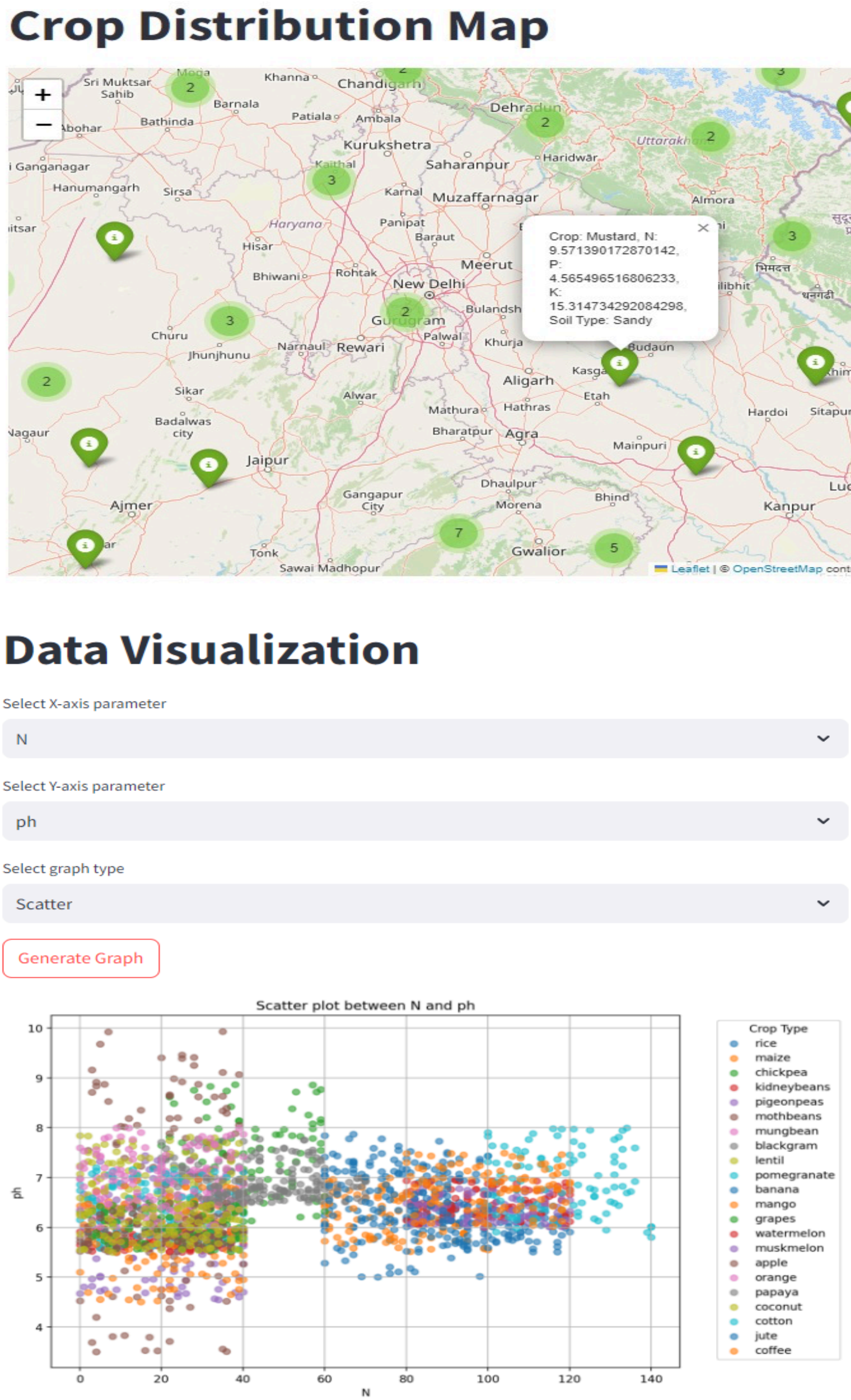


**Figure 5.3:** Data Visualisation Demonstration

Figure 5.3 shows some sample visualisations. Data visualization not only aids individual farmers but also serves policymakers in planning region-specific agricultural interventions.

## 5.5 Overall System Evaluation

The *Intelligent Crop and Fertilizer Recommendation System* was tested extensively for usability, performance, and accuracy. Key observations include:

1. **Ease of Use**: The web-based interface is intuitive, enabling users to navigate the system effortlessly.
2. **Performance Metrics**: Both the crop and fertilizer recommendation modules demonstrated high reliability during simulated and real-world testing scenarios.
3. **Integration**: The combination of machine learning, MSP data, and government schemes results in a holistic decision-making tool.

The system successfully bridges the gap between agricultural data and actionable insights, offering a comprehensive tool for modern farmers.

## CHAPTER 6
## CONCLUSION AND FUTURE SCOPE

### 6.1 Conclusion

The *Intelligent Crop and Fertilizer Recommendation System* has been developed to bridge the gap between traditional farming practices and modern technological advancements. By leveraging machine learning and data visualization techniques, the system empowers farmers to make informed decisions regarding crop selection, fertilizer usage, and financial planning. The inclusion of Minimum Support Price (MSP) data and government schemes further enriches the system, providing actionable insights that enhance agricultural productivity and sustainability.

The project's multi-faceted approach combines data analysis with user-friendly design, ensuring accessibility for farmers and policymakers alike. The machine learning pipeline's high accuracy, validated through extensive testing, underscores the robustness of the system. The integration of datasets sourced from credible platforms like Kaggle and government repositories ensures the reliability of recommendations.

While the project has achieved its objectives, it also sheds light on the broader potential of technological interventions in agriculture. The work demonstrates that with accurate data and powerful algorithms, modern farming can transition towards a more sustainable, data-driven future.

### 6.2 Limitations

Despite its strengths, the system has certain limitations:

1. **Dependence on Data Quality**: The system's accuracy is contingent on the quality and comprehensiveness of the datasets. In regions with limited or outdated data, recommendations may be suboptimal.
2. **Scalability**: While the current implementation works for a defined set of crops and conditions, scaling to a global level requires addressing region-specific variations in soil and climate.
3. **Access Barriers**: Small-scale farmers with limited access to technology may face challenges in utilizing the system effectively.
4. **Limited Scope of Recommendations**: The system currently focuses on crop and fertilizer recommendations but does not address pest and disease management or post-harvest logistics.

These limitations highlight areas for refinement and expansion in future iterations of the system.

### 6.3 Future Scope

The project opens avenues for significant enhancements and additions:

1. **Dataset Expansion**: Incorporating datasets for additional regions, crops, and soil types will improve the system's versatility and effectiveness.
2. **Real-time Data Integration**: Utilizing IoT devices and live weather feeds can enable dynamic, real-time recommendations tailored to immediate conditions.
3. **Multilingual Support**: Adding support for multiple regional languages can make the system accessible to a broader demographic, particularly small-scale farmers.
4. **Mobile Application Development**: A mobile app would provide easier access to recommendations and visualizations, making the system more convenient for on-the-go usage.
5. **Pest and Disease Management**: Extending the system to include modules for predicting and mitigating pest and disease outbreaks can significantly enhance its utility.
6. **Advanced AI Models**: Customizing AI models to optimize recommendations for specific regions can boost accuracy and reliability further.
7. **Enhanced Visualizations**: Providing more interactive data visualizations, such as GIS maps with crop viability overlays, would enrich user experience and aid decision-making.
8. **Integration with Farmer Feedback**: Incorporating direct feedback from users could refine the system and ensure it evolves to meet real-world needs.

In alignment with the planned future scope, the following additional features will be prioritized:

- **Farmer Feedback Data**: Collecting and analyzing user feedback to improve model performance and usability.
- **Pest and Disease Prediction**: Using additional datasets to address pest control and plant disease challenges.
- **Mobile Application and Notification System**: Providing farmers with personalized alerts and recommendations through mobile notifications.

The *Intelligent Crop and Fertilizer Recommendation System* represents a significant step toward modernizing agricultural practices. Its potential for scalability and innovation positions it as a cornerstone for future advancements in smart farming.

## REFERENCES

[1] IBM. (2019). IBM Watson Decision Platform for Agriculture. Retrieved from https://newsroom.ibm.com/IBM-watson?item=30660

[2] IBM. (2019). AI and Cloud Technology Helps Agriculture Industry Improve the World's Food and Crop Supply. Retrieved from https://spacewatch.global/2019/06/ibm-ai-and-cloud-technology-helps-agriculture-industry-improve-the-worlds-food-and-crop-supply/

[3] Krishi Jagran. (2024). Napanta Smart Farming Platform. Retrieved from https://krishijagran.com/agriculture-apps/napanta-smart-farming-platform/

[4] Attri, I., Awasthi, L.K., & Sharma, T.P. (2024). Machine learning in agriculture: A review of crop management applications. Multimedia Tools and Applications, 83(1), 12875–12915. https://doi.org/10.1007/s11042-023-16105-2

[5] Kaggle. (2020). Crop Recommendation Dataset. Retrieved from https://www.kaggle.com/datasets/atharvaingle/crop-recommendation-dataset

[6] Government of India. (2023). Notification for Kharif MSP 2023-24. Retrieved from https://desagri.gov.in/wp-content/uploads/2023/06/English-notification-for-website-.pdf

[7] Government of India. (2024). Kharif MSP Notification for 2024-25. Retrieved from https://desagri.gov.in/wp-content/uploads/2024/06/22-Kharif-MSP-Notification-2024-25English.pdf

[8] Press Information Bureau, Government of India. (2020). Press Release on Agricultural Initiatives. Retrieved from https://pib.gov.in/PressReleaseIframePage.aspx?PRID=2002012

[9] Ministry of Agriculture and Farmers' Welfare, Government of India. (n.d.). Central Schemes for Farmers' Welfare. Retrieved from https://www.manage.gov.in/fpoacademy/CGSchemes/central-schemes.asp