

Cropprecisionguard App: Innovating Sustainability Through Precision Agriculture

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DOI: <https://doi.org/10.51583/IJLTEMAS.2025.140500008>

Received: 17 May 2025; Accepted: 20 May 2025; Published: 29 May 2025

Abstract: Traditional agriculture practices often rely on generalized pesticide and fertilizer application recommendations, leading to inefficient resource use, increased costs, and environmental degradation. To address these challenges, we app an innovative solution that integrates precision agriculture techniques with ML to optimize farming practices. This work collects and processes data from multiple sources, including Soli Health Cards (SHC), weather patterns, and crop diagnostics such as the Leaf Colour Chart (LCC). By analysing these datasets using advanced algorithms, the system generates precise, actionable recommendations for pesticide and fertilizer application, ensuring sustainable and cost-effective farming. This app also adapts to real-time conditions. For instance, if a farmer's SHC indicates low nitrogen and phosphorus levels, an initial fertilizer recommendation is provided. During the growing season, the farmers can use LCC to monitor nitrogen levels and adjust applications accordingly. If weather forecasts predict heavy rainfall, the system advises delaying fertilizer application to prevent leaching., data-driven insights help farmers maximize crop yield while preserving soil health and minimizing environmental impact. Thus, our proposed Crop Precision Guard App empowers farmers with real-time, adaptive, and science-backed design-making tools, revolutionizing modern agriculture for greater sustainability and productivity

Key Findings— We Use Leaf Color Chart, Soil Health Card and weather Forecast By integrate with OpenAI.

I. Introduction

In many rural regions of India, smallholder Farmers often depend on traditional knowledge and guesswork to decide on fertilizer and pesticide application. For instance, a paddy farmer in Tamil Nadu might repeatedly use nitrogen-rich fertilizers without realizing that the soil already has adequate nitrogen content. This leads to over-fertilization, degraded soil quality, unnecessary expenses, and reduced crop productivity. CropPrecisionGuard is an AI-powered mobile application designed to support farmers with precise, data-driven agricultural recommendations. The project integrates Soil Health Card (SHC) data, real-time weather forecasts, and image-based crop diagnostics using Leaf Color Chart (LCC) and deep learning techniques. By analyzing soil nutrient levels and detecting plant diseases through captured leaf images, the app provides personalized suggestions for fertilizer and pesticide use. The primary objective of CropPrecisionGuard is to reduce excessive chemical usage by offering accurate location-specific guidance. This not only protects soil health and water resources, but also enhances crop yield. The integration of Generative AI (GenAI) provides adaptive insights based on soil reports, weather data, and crop health. Furthermore, the app is designed with multilingual capabilities and a user-friendly interface, ensuring accessibility for small-scale and semi-literate farmers. Agriculture, the backbone of rural economies, is increasingly facing challenges such as unpredictable weather, soil nutrient depletion, and the rapid spread of crop diseases. Traditional farming methods that follow broad, non-specific fertilizer guidelines often lead to over-application, increased costs, and long-term harm to soil quality. However, recent advancements in AI offer new possibilities for precision farming through real-time diagnostics and predictive analysis.

Our proposed system, CropPrecisionGuard, leverages GenAI, SHC data, weather trends, and LCC-based image analysis to deliver customized, location-based recommendations. The SHC data, sourced from the official Soil Health Card portal of India, enables nutrient-specific fertilizer planning (N, P, K), leading to more sustainable agricultural practices. Several recent studies have highlighted the effectiveness of integrating AI, weather forecasting, and image recognition in precision agriculture, while others emphasize the potential of LCC-based nitrogen assessment using image processing techniques. The CropPrecisionGuard app builds upon this innovation to provide environmentally conscious and personalized decision-making support to farmers.

Farmers often rely on traditional methods or generalized recommendations for applying pesticides and fertilizers, which can result in overuse or misuse of these inputs. This leads to environmental degradation, reduced soil fertility, increased input costs, and diminished crop yields. By integrating existing data sources such as soil health cards, weather patterns, and crop-specific diagnostic tools like the Leaf Color Chart (LCC), we proposed a solution (CropPrecisionGuard App) that provides precise, actionable recommendations to farmers. Ensuring sustainable and cost-effective farming practices.

Objective of This Project

The primary objective of the CropPrecisionGuard App is to enhance sustainable agriculture through precision farming techniques by leveraging AI-driven decision-making, real-time data analysis, and intelligent recommendations. The specific objectives of this research include:

Optimize Fertilizer Application: Develop a data-driven system that provides crop-specific and location-based fertilizer recommendations to minimize overuse and maximize efficiency.

Enhance Soil Health Monitoring: Utilize Soil Health Card (SHC) data to assess nutrient deficiencies and optimize input application.

Integrate AI and Machine Learning: Implement predictive analytics for soil fertility, nitrogen levels (via Leaf Color Chart-LCC), and weather-based recommendations to assist farmers in making real-time decisions.

Weather-Driven Decision Support: Incorporate meteorological data from climate-adaptive farming strategies, advising farmers on the best timing for pesticide and fertilizer applications

Automate Nitrogen Level Assessment: Develop image-processing algorithms for AI-powered LCC-based nitrogen deficiency detection, improving precision in nutrient applications.

Promote Sustainable Agriculture Practices: Reduce excessive use of chemical inputs by offering alternative soil enrichment methods, leading to better environmental sustainability.

Develop a User-friendly mobile platform: Build a Flutter-based mobile application with intuitive interfaces, multi-language support, and real-time farmer feedback integration.

II. Literature Review

Agriculture is increasingly embracing advanced technologies such as Artificial Intelligence (AI), the Internet of Things (IoT), and Generative AI (GenAI) to address persistent challenges like crop disease, nutrient imbalance, erratic weather, and overuse of fertilizers. Processing.

AI-Based Crop Disease Detection: AI-powered images have been widely used for identifying crop diseases. Singh and Varma [1] developed a Convolutional Neural Network (CNN) model that accurately classified multiple plant diseases, highlighting the capability of deep learning to automate plant health diagnostics.

AI in Climate-Resilient Smart Farming: Unpredictable weather is one of the biggest risks to farming. Kumar and Patel [2] introduced climate-resilient smart farming systems that use AI to correlate historical climate data with crop growth patterns, enabling better planning.

Fertilizer Optimization Using SHC and AI: India's Soil Health Card (SHC) initiative provides detailed soil profiles for farmers. Patel and Sharma [6] combined SHC data with fuzzy logic to generate personalized fertilizer advisories, significantly improving input efficiency.

Nitrogen Management with Leaf Color Chart (LCC): Managing nitrogen levels is critical for crop productivity. Roy and Mondale [11] applied AI models to analyze LCC images for nitrogen estimation in rice crops.

Real Time Crop Monitoring with AI and IoT: Ramesh and Iyer [8] integrated AI with IoT devices to create systems capable of real-time crop health monitoring, where sensor data on temperature, humidity, and soil moisture is analyzed for early detection of anomalies. Sharma and Rani developed a sensor-based system that monitored NPK levels and soil pH using AI-enabled inference engines, allowing for timely soil correction measures.

Generative AI in Precision Agriculture: Lee et al [12] discussed the transformative potential of GenAI in agriculture, particularly in creating interaction and adaptive learning systems for farmers. These models are from the backbone of interactive advisory systems like CropPrecisionGuard.

User Interfaces and Farmer Accessibility: Ease of use and accessibility are crucial for adoption. Narayanan and Rao [17] developed a multilingual chatbot that supports dynamic language switching, helping farmers across linguistic regions.

Mobile-Based Agriculture Advisory Services: Thomas and Joseph [19] evaluated mobile based agri-extension services and noted that location aware advisory apps significantly improve farm decision making. Banik and Bask focused on localized AI tools that can be embedded in mobile platforms, providing sustainable solutions even in low connectivity regions. These mobile models support rapid adoption in rural India and align with the goals of the CropPrecisionGuard platform.

Modern Softwares Used in Agriculture

Plantix: Plantix is a popular AI-powered crop diagnosis and advisory app developed by PEAT GmbH. It allows farmers to capture images of affected crops, which the app analyzes to identify plant diseases, pests, or nutrient deficiencies. The app then suggests organic or chemical remedies and provides preventive measures. It supports multiple languages, making it accessible to a broader user base. However, its limitations lie in its reliance on high-quality images for accurate diagnosis and the need for stable internet connectivity, which may not always be available in rural areas [23].

AgriApp–SmartFarming :

AgriApp is a digital farming platform that provides farmers with agricultural solutions[24], expert advice, and e-commerce services for seeds, fertilizers, and other farming essentials. It is a comprehensive mobile-based platform aimed at empowering Indian farmers through digital agricultural solutions. The app integrates various agriculture services into one user-friendly interface, including real-time weather forecasting, Mandy prices, pest and disease alerts, government schemes, and expert crop advisories. It supports multiple Indian languages, making it accessible to farmers to manage crop inputs, track expenses, and monitor crop performance over time. Despite it also has some limitations. It heavily depends on stable internet connectivity, which is a challenge in many remote and rural areas.

Soil-Nutro App: The Soil-Nutro app [25] offers personalized nutrient management advice based on soil test results. It helps farmers apply the right fertilizers at the right dose, reducing excess usage and improving soil health. It often integrates with state or national soil health databases to provide tailored recommendations. However, the app's effectiveness depends on whether a soil health test has been conducted and uploaded. In the absence of digital soil records, the app cannot function optimally. Additionally, its user base is limited due to a lack of awareness and training on soil health management.

Uzhavan: Developed by the government of Tamil Nadu [26], the Uzhavan app delivers information in Tamil related to crop insurance, subsidy schemes, weather updates, and market prices. It is especially beneficial for local farmers who face language barriers on the national platform. However, the app has a limited scope outside Tamil Nadu and does not offer AI or image-based diagnostic features. The interface is not user-friendly, and several users have reported delays in data updates and limited customer support.

Kisan Suvidha App: Launched by the Ministry of Agriculture and Farmers' welfare[27], the Kisan Suvidha app acts as a one-stop portal offering information on weather forecasts, market prices, crop insurance, pesticides, and agricultural advisories. The app is designed to bridge the gap between government services and farmers. Despite its broad feature set, the app faces criticism for its outdated user interface, poor responsiveness, and occasional technical glitches. Moreover, the lack of real-time updates and limited customization make the information too generic for precision farming needs.

Mausam: Mausam app is a weather-centric application launched by the Ministry of Earth sciences[28]. It provides current temperature, humidity, rainfall, wind speed, and forecasts for up to one week. It is valuable for planning sowing and harvesting activities. However, Mausam lacks agricultural-specific advisories and crop management tools. It does like soil health or crop stage, which makes it less effective for holistic farm planning.

YaraFarmCare:

Yara Farm Care, from yara international focused on nutrient management and fertilizers recommendations[29]. It provides farmers with too. like nutrient deficiency identification, crop calculators, and product recommendations based on crop stage. Though scientifically accurate, the app is mainly centered around promoting Yara's proprietary products. It does not include features such as pest detection, soil health integrations, or disease management, limiting its utility as a standalone farm management solution.

Meghdoot: The Meghdoot app is developed jointly by the India meteorological Department (IMD) and the Indian council of Agricultural Research (ICAR) to deliver location-specific weather forecasts and agro-advisories[30]. The app provides weekly weather updates and farming tips tailored to the user's region, aiding in crop planning, irrigation scheduling, and pest control. While it excels in weather intelligence, its accuracy is occasionally limited in remote regions due to sparse data points. It also offers limited crop-specific guidance and lacks interactive or personalized-recommendation features, making it more informative than actionable for smallholder farmers.

MEGFarmer: MEG Farmer is an initiative by the government of Meghalaya to provide localized farming solutions and scheme awareness. It provides scheme details, input availability, and farming tips [31]. The app supports regional language use and promotes transparency in government-farmer interaction. However, its functionalities are limited to basic information sharing and do not include e-commerce features. It also suffers from low visibility and minimal promotion outside the state.

AgriSetu App: AgriSetu is a digital agri-marketplace that connects farmers directly with buyers, logistics providers, and agri-input sellers[32]. Its goal is to eliminate middlemen and ensure better pricing for farmers. It also enables transport tracking and product traceability. Despite its potential, the platform faces trust issues among first-time users and challenges related to digital literacy. Many farmers are hesitant to engage in digital trade due to fear of fraud, and the app's reach is still limited in rural belts. Also this app can be overuse of internet to costly and also there are limitations in scalability.

Data Sources and Input Layers

Soil Health Card (SHC):

Data obtained from the Government of India portal (<http://www.soilhealth.dac.gov.in>).

Parameters include pH, organic carbon, macronutrients (N, P, K), and micronutrients (Zn, S, Fe, Mn).

Parsed and used to generate fertilizer recommendations.

Leaf Color Chart (LCC) Dataset:

A publicly available dataset of leaf images classified by nitrogen deficiency levels.

Images are labeled based on LCC shade categories (dark green, healthy green, pale green, yellow).

Used for training and validating an AI model to detect nitrogen status.

Weather Data:

Accessed via OpenWeatherMap API.

Includes temperature, humidity, wind speed, and precipitation forecasts.

Used to recommend optimal timing for spraying or fertilization to prevent leaching or runoff.

AI Models Used**Image Analysis Model (Nitrogen Detection via LCC):**

Architecture: **Vision Transformer (ViT)** with CNN backbone.

Training: 1,200 leaf images labeled with nitrogen levels.

Performance: **Accuracy – 92.3%, Precision – 89.5%, Recall – 90.7%** on validation dataset.

Output: Classification label mapped to specific nitrogen treatment advice.

Generative AI Model (Gemini/LLM):

Integration: Gemini API with pre-designed natural language prompts.

Function: Converts AI output into localized, conversational advisory (e.g., “Apply 50 kg urea per acre after rainfall”).

Prompt Engineering: Ensures responses are context-specific, actionable, and translated into Tamil, Hindi, or English.

Limitation Handling: Fallback messages provided in case of model failure or ambiguity.

Mobile Application Design

Platform: Flutter with Firebase integration.

Features:

Leaf upload for analysis

SHC-based fertilizer recommendation

Real-time weather updates

GenAI-powered multilingual chatbot

Multilingual Support: Tamil, English, and Hindi interfaces

Authentication: OTP-based phone login using Firebase

User Testing and Evaluation

Participants: 12 farmers from Tamil Nadu (ages 30–55)

Method: Usability questionnaire + observational feedback

Metrics Evaluated:

Ease of navigation

Clarity of recommendations

Language accessibility

Results:

85%+ rated app as useful and easy to understand

75% said they would use it during crop cycles

The existing system has the following limitations.

Reliance on Internet Connectivity: Most System require a stable internet connection, which may not feasible in rural areas.

Limited Datasets: Existing models often use generic datasets, reducing accuracy for region-specific diseases.

Cost Constraints: Many solutions are expensive, making them inaccessible for small-scale or marginal farmers

Lack of Personalization: Some systems do not provide customized based on local environmental factors.

Language and Usability Barriers: Many applications lack multilingual support, with limited technical knowledge

To address the above issues, we developed the CropPrecisionGuard App for Innovating Sustainability through Precision Agriculture.

Comparative Analysis of Existing System

Feature	Existing System	CropPrecisionGuard
LCC-based Nitrogen Detection	Not Supported	Pretrained model+ GenAI+Chatbot Support
SHC Integration	Not Supported	Uses official SHC data
Weather-Aware Advisory	Partially	Real-time via OpenWeatherMap
GenAI Support	Not Support	LLM-powered recommendations
Personalization	Limited	Region- and crop- specific
Multilingual	Partial	Tamil + English +Hindi

Table 1. Comparatition Table

Proposed Work

The user-friendly smartphone application “CropPrecisionGuard” is designed to provide farmers with a clear guide to assess the nutrient status of their location using soil health card data. The system collects and analyzes data from multiple sources, including Soil Health Cards(SHC), Weather patterns, and crop-specific diagnostics such as Leaf Color Chart (LCC). This dynamic decision making process enables precision input management, enhances soil fertility, and promotes sustainable farming.

The System collects and analyzes data from multiple sources, including soil health cards (SHC), weather patterns, and crop-specific diagnostics such as the leaf color chart(LCC). By integrating this information, CropPrecisionGuard offer Location-specific, data-driven insights that optimizes pesticide and fertilizer use, leading to efficient resource utilization, cost reduction and improved crop yield. One of the key features of CropPrecsionGuard us its adaptability to real-time conditions.

If an SHC report includes low nitrogen and phosphorus the system provides an initial fertilizers recommendation. As the crop grows farmer can use the Leaf Colour Chart(LCC) to monitor nitrogen levels and adjust fertilization accordingly.

Additionally, if weather forecasts predict heavy rainfall, the system recommends delaying fertilizer application to prevent nutrient loss due to leaching. This dynamic decision-making process enables precision agriculture input management, enhances soil fertility, and promotes sustainable farming. The data flow of the proposed solution is described in Figure 1.

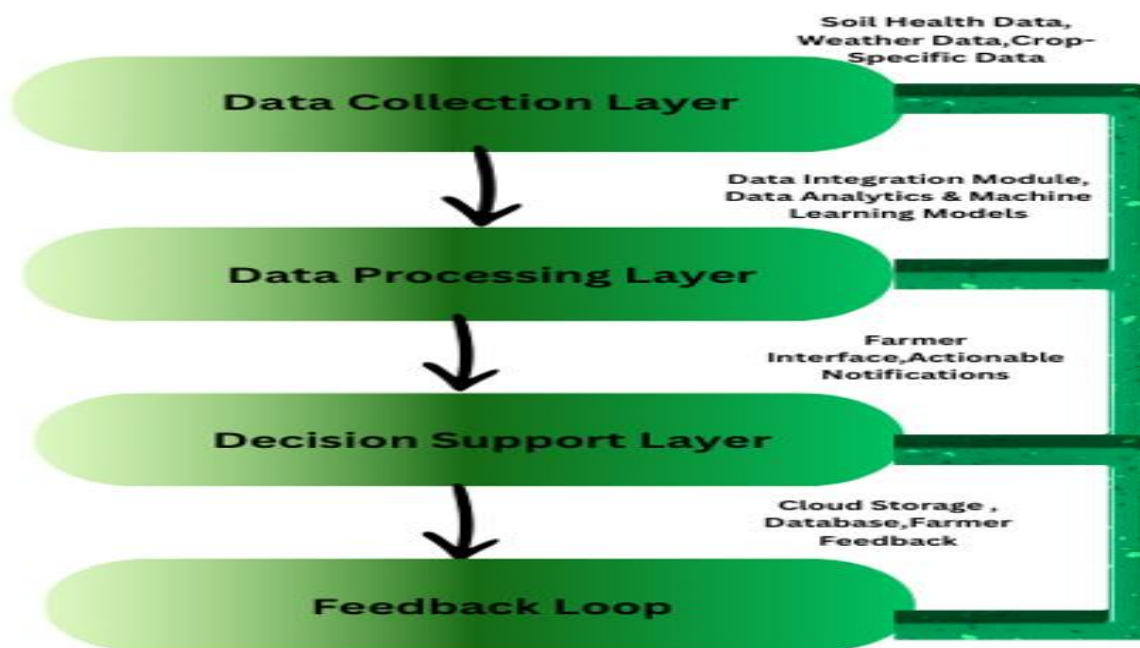
The proposed CropPrecisionGuard App is a comprehensive Ai-driven mobile application unlike existing systems that rely solely on isolation data inputs or offer generic advice. CropPrecisionGuard integrates three critical data layers – Leaf Colour Chart (LCC) analysis, Soil Health Card (SHC) data, and weather forecasting to provide precise and actionable recommendations for crop health management, fertilizers usage and irrigation planning.

The app utilizes a pre-trained machine learning model to analyse leaf images uploaded by users, and integrating a Large language model (LLM) based Generative AI(GenAI), which interprets model outputs and delivers clear, human-readable suggestions and remedies in Tamil, English and Hindi, improving accessibility for local farmers. should be cited as “to be published” [6]. Please give affiliations and addresses for private communications [7].

Capitalize only the first word in a paper title, except for proper nouns and element symbols. If you are short of space, you may omit paper titles. However, paper titles are helpful to your readers and are strongly recommended. For papers published in translation journals, please give the English citation first, followed by the original foreign-language citation [8].

In addition, the system processes Soil Health Card data, including vital parameters such as pH, macro- and micronutrient levels, and organic content, to offer crop-specific fertilizer and pesticide recommendations.

This ensures optimal nutrient management, minimizes chemical overuse, and promotes sustainable farming practices. Furthermore, the integration of the OpenWeatherMap API allows the app to provide real-time and forecasted weather data, enabling farmers to make informed decisions on irrigation scheduling, pest management, and crop protection. CropPrecisionGuard is designed for core features such as SHC analysis and LCC-based nitrogen detection, ensuring usability



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Figure 1: Dataflow diagram

Key findings:

Leaf color chart(LCC) Integration

Uses image-based pre-trained models to analyze the color of crop leaves.

Integrated with GenAI to explain results in natural language with remedy suggestions.

Soil Health Card (SHC) Analysis

Parses government-issued SHC data (PH, nutrients, and micronutrients).

Recommends crop-specific fertilizer and pesticide usage.

Weather Data – OpenWeatherMap API

Real-time weather forecasts fetched via OpenWeatherMap.

Includes temperature, humidity, rainfall, and wind speeds

Chatbot Assistant

This Chatbot is designed to answer common farming-related queries such as soil health

It is available in Tamil, English and Hindi

It helps bridge the information gap, especially for farmers

interpretation, crop nutrient needs, and usage of the leaf color chart

AI Algorithms and Technologies Used

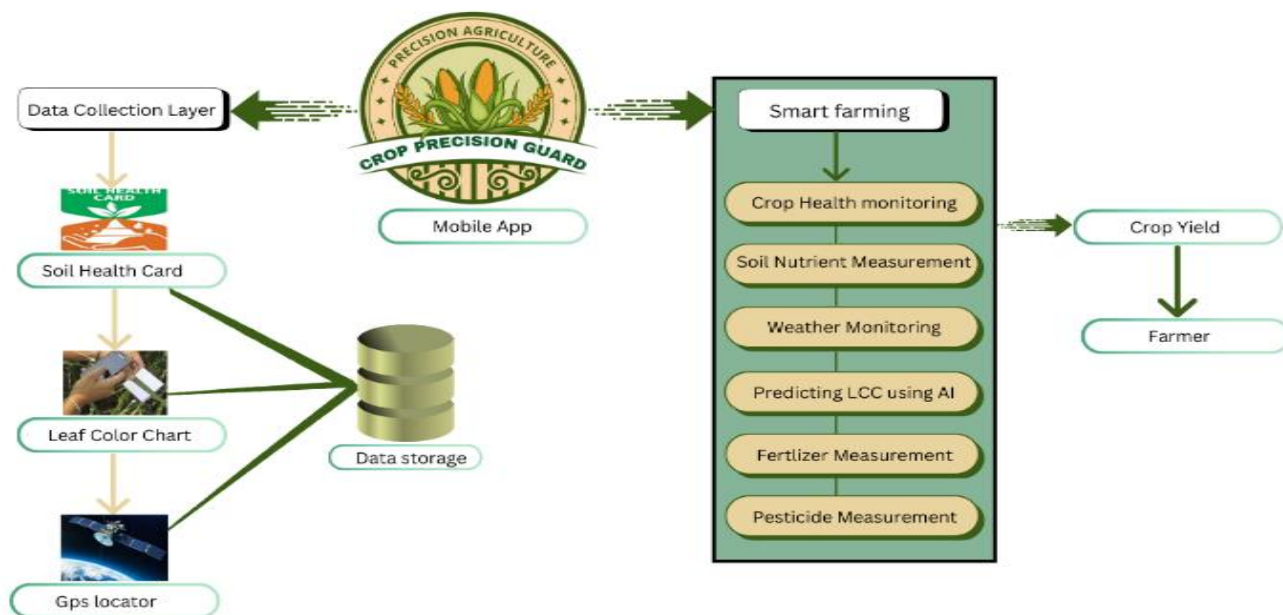
To ensure accurate and intelligent decision-making, CropPrecisionGuard leverages several advanced algorithms. Large Language Models (LLMs), including Google's Gemini AI used to process natural language inputs and provide recommendations to users. Gemini AI API is integrated to offer real-time advisory generation in multiple Languages. Tamil, English, Hindi. Vision Transformer (ViT) is used for analyzing leaf images in the LCC Module. These AI models work together to enhance the app's capabilities.

System Design

CropPrecisionGuard App

The architecture of the CropPrecisionGuard system, as shown in Figure 2, is designed to seamlessly integrate multiple agricultural data sources into a smart farming ecosystem via a mobile application. It begins with a Data collection layer that gathers critical input from three main sources. The Soil Health Card (SHC) which provides data on soil nutrients and pH levels.

The leaf color chart (LCC), which is used to access nitrogen deficiency through visual analysis or image input. Which tags the data with precision geolocation for regional recommendations? It can be Designed to Reduce the Fertilizer Usage for Farmer to



provide enhance sustainability for Farmers by Precision Agriculture.

Figure 2: Architecture Diagram of CropPrecisionGuard

All this information is stored in a centralized

data storage system, which acts as a knowledge base for processing and analysis. This stored data is accessed by the CropPrecisionGuard mobile application, which connects the data layer with the smart farming layer. The app leverages the power of AI and genAI models to analyze the data and offer tailored insights to the farmer.

The Smart Farming Module Consists of Six Major Functions:

- Crop Health Monitoring,
- Soil Nutrient Measurement,
- Weather Monitoring,
- Predicting LCC using AI,
- Fertilizer Measurement,
- Pesticide Measurement.

Leaf Color Chart (LCC) Dataset, the users upload leaf images through the app. These are analyzed for nitrogen levels using Vision Transformer (ViT) and CNN models. The LCC dataset helps identify the leaf Color, which correlates with the nitrogen deficiency. These models are trained on massive amounts of text data and can perform tasks, text generation, question answering, translation, summarization, and context understanding. Popular examples include OpenAI GPT, Google's Gemini, and Meta LLaMA

The Soil Health Card (SHC) which provides data on soil nutrients and pH levels.

III. Result and Discussion

CropPrecisionGuard is an AI-driven mobile application designed to support precision farming by providing personalized recommendations for fertilizer and pesticide use.

It integrates SHC data, LCC image analysis, and real-time weather data from open OpenWeather Map API. Using Flask as the backend and the Gemini GenAI API, the app analyzes leaf images to detect nutrient deficiencies and generates crop-specific remedies. Weather insights help guide irrigation and spraying schedules, while Firebase manages user authentication and notifications. With support for English and Tamil to make Informed, eco-friendly decisions and improve yield sustainability.

Application Functionalities

The Application of CropPrecisionguard can be given shortly in Figure 3 and Figure 4. The application opens with an attractive splash screen display Our application Logo, After the splash screen users are welcomed by the Language selection which is Tamil, English and Hindi accessible to farmers from different regions. The side drawer dashboard provides navigation to major functionalities including Dashboard, Soil Health Report, LCC(Leaf Color Chart)Analysis, Leaf color Chart disease analysis, Weather Report, Profile and the management .In leaf analysis screen farmers can upload leaf image to access crop health. The app uses a GenAI-powered model to detect the leaf color(dark green, Healthy green, Pale green, Brown)and provide health recommendations to manage nitrogen deficiency.Farmer can generate soil health report based on their location.Using GenAI and gemini API generate fertilizer recommendations.A dedicated chatbot is available to assist farmers.It support English,Tamil,Hindi Providing guidance regarding farming practices. Then the User profile screen can be store it n Firebase can be authenticated by phone number and OTP.

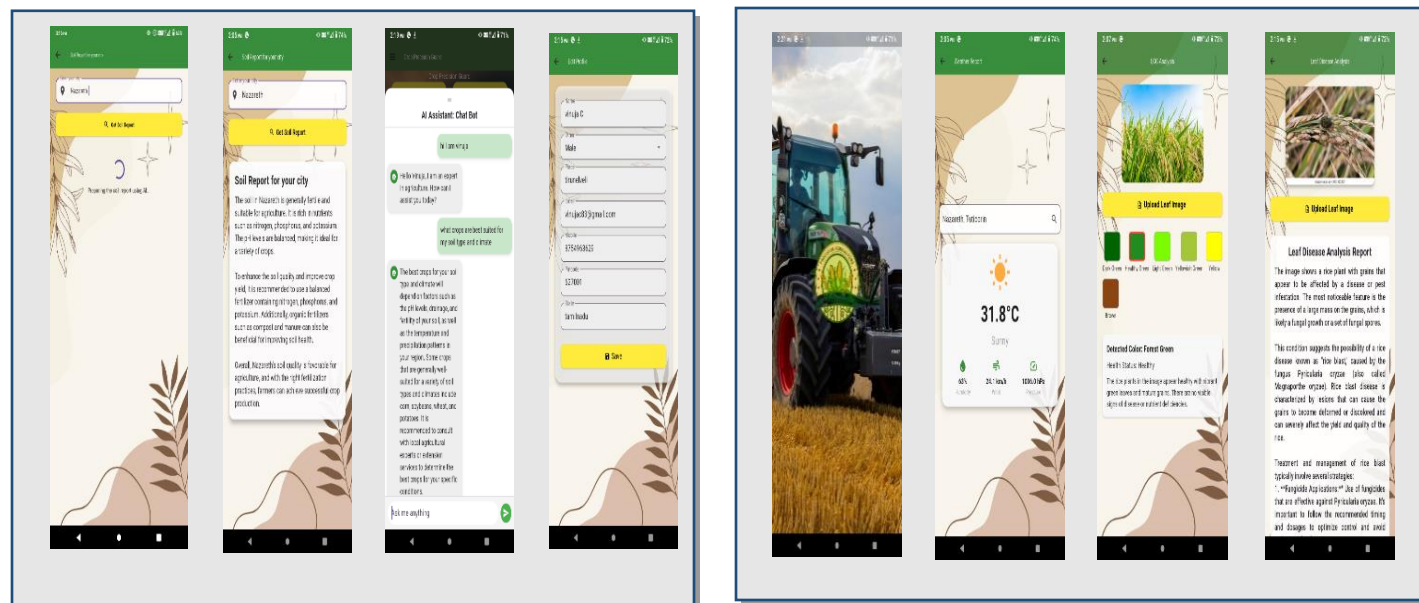


Figure 3. User Interface and output

Benefits

Precision agriculture techniques maximize crop growth.

Enhances user engagement and provide real-time assistance with AI-Powered Chatbot Assistant.

Reduces waste and conserves water, fertilizer, and pesticides.

Enables timely interventions and reduces crop losses.

Promotes environmentally friendly farming practices.

Enhance crop quality and quantity, leading to higher profits.

Easy to use farmers and agricultural professionals.

Provides actionable data for informed decision making

Challenges

Implementing the app and required technology can be costly.

Requires knowledge of precision agriculture and app functionality.

protecting sensitive farm data is crucial.

Requires stable Internet connectivity firm optimal performance.

Requires ongoing training and support for users

IV. Conclusion

The CropPrecisionGuard App is an AI- driven agricultural solution that empowers farmers with real-time, location, based insights for sustainable and precise farming. By allowing farmers to manually input their location, the app retrieves relevant soil health data and provides personalized fertilizer dosage recommendations based on machine learning data analysis techniques. Additional, the app displaces real-time temperature and moisture levels using interactive grapes and numerical indicators, enabling farmers to make informed decisions for crop Planning, irrigation, and fertilization. This digital intervention significantly reduces uncertainty in agricultural decision-making and promotes efficient farm management, ultimately contributing to increase crop yield and sustainability.

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