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Agrobuddy: Ai-Powered Crop, Fertilizer, And Disease Prediction Framework

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Abstract— AgroBuddy, the paper presents an integrated framework using ML and DL to change agricultural decision-making completely. AgroBuddy is the result of three modules designed to tackle problems such as crop selection, soil nutrient management and plant disease detection, namely (a) Crop Recommendation, which gives the best crops depending on the soil and the climate, (b) Fertilizer Suggestion, offering the best fertilizing recommendations for improving soil nutrition and (c) Plant Disease Prediction, which utilizes CNN-based image analysis of plants to detect early signs of disease and make treatment recommendations. The algorithms used are Random Forest, XGBoost, and ResNet, and the data is processed based on soil properties, weather conditions, and crop health datasets. AgroBuddy was essentially designed to empower farmers with data-driven insights for improving productivity and sustainability while building resilience against climate & market volatility. The disease prediction model is experimented with and demonstrates very high accuracy across all modules with up to 99 % efficacy. The platform's technical, economic and operational analysis validates its feasibility to transform the traditional farming practice in India and beyond.

Keywords—Machine Learning, Deep Learning, Precision Agriculture, Crop Recommendation, Fertilizer Optimization, Plant Disease Detection, Convolutional Neural Network (CNN), Sustainable Farming, AgroBuddy and Data Driven Agriculture.

I. Introduction

Developing countries depend heavily on farming operations since agriculture provides both sustenance for households and security for their sustenance base. The agricultural sector operates under many significant obstacles, such as changing weather patterns, declining soils, pest management issues and limited access to modern farm tools. The implementation of traditional farming conventions leads farmers to deal with inefficient resource consumption together with reduced harvest output and financial insecurity. The COVID-19 pandemic exposed critical problems in the agricultural industry by fragmenting supply lines while reducing access to markets and creating labor shortages, which demonstrated the necessity for new technological solutions in farming operations.

This paper demonstrates AgroBuddy as a framework which uses machine learning and deep learning approaches to boost agricultural decision support capabilities. The system incorporates three main modules which include crop recommendation together with fertilizers suggestion and plant disease prediction. A crop recommendation module examines soil characteristics with climate patterns to identify which plant species produces maximum harvest results. By evaluating soil nutrients, the fertilizers suggestion module prevents environmental damage and reduces waste by recommending specific fertilizers types. Through convolutional neural networks, the plant disease prediction module analyses images of leaves to detect diseases, thus enabling farmers to intervene on time.

The data merging of soil data with climate records, along with crop observations, enables AgroBuddy to generate evidence-based farming optimizations suggestions. The system's implementation assessment combines technical evaluations together with economic evaluations and operational evaluations to prove its potential for changing traditional farming methods. Through its transformative approach, AgroBuddy wants to enhance farmer capabilities to obtain practical information which supports sustainable agriculture and increased production and defends against environmental conditions and market trends.

II. Literature Survey

Modern agricultural decision-making received a transformation through recent machine learning (ML) and deep learning (DL) advancements which established multiple studies that demonstrate their utility in crop recommendation programmers and fertilizers optimizations processes and plant disease detection methods. A review of major research accomplishments appears in this survey.

Crop Recommendation Systems: Various research investigations have utilized data-based procedures to study crop selection. Through their framework utilizing ML and DL methods, the authors delivered improved accuracy in yield prediction results. [1] A neural network system developed by [10] for Rwandan agriculture succeeded in analyzing soil nutrients together with climatic conditions to reach 97% accuracy. The authors used Naive Bayes algorithms together with decision trees to make crop recommendations based on NPK soil values, pH measurements and rainfall specifics. The recommendations experienced increased accuracy because the system integrated data from third-party APIs which contained specific location information. [3]

Fertilizer Recommendation Techniques: Studies about fertilizers optimization techniques produced successful findings. The research results from [8] illustrated Support Vector Machines delivered better performance than other classification methods in fertilizers recommendation operations. The authors introduced ML-AgriCare as a multifaceted approach that utilizes regression modelling with rule-based techniques for individualized fertilizers advice. [9] The system displayed more accurate recommendations by including up-to-the-minute measurements of local soil conditions and meteorological data. [3] A system created by [19] performs an assessment of nitrogen-phosphorus-potassium (NPK) elements with water content and pesticide needs to deliver complete fertilizers recommendations.

Plant Disease Detection: The identification of plant diseases has experienced major progress through deep learning methods. A deep CNN model from [2] demonstrated 99.35% success in diagnosing 14 crop species affected by 26 diseases through image analysis of 54,306 entries. The CNN-based system established by [18] reaches 97% classification accuracy while offering treatment recommendations. The research by [21] integrated the detection of diseases with severity ratings to provide fertilizers recommendations for crops. A disease severity assessment system with treatment recommendation features was established by [13] through the combination of different ML and DL methods. The analysis by [20] determined that among multiple tested programmers, CNN delivered the best results with 98.43% accuracy for disease recognition.

Comparative Analysis of Approaches: The research field has conducted multiple analyses of alternative algorithmic methods. The researchers in [12] conducted a comparison of various ML algorithms for crop recommendation, which led to Random Forest and XGBoost reaching 99.31% accuracy. A review of image processing together with ensemble modelling systems for agricultural uses was published by [17]. 7 analyses deep learning methods to diagnose crop diseases in an extensive way. The authors of [16] reviewed modern developments in fertilizers recommendation as well as soil prediction systems.

Limitations and Future Directions: Despite these advancements, challenges remain. Plant disease diagnosis system deficiencies were outlined by [6] because their systems lacked sufficient datasets. The author shows support for natural language processing integration to develop community-based solutions. [15] Edge computing methods should be deployed by the proposed study for rural areas that face connectivity constraints. [13] Further research needs to focus on building stronger models suitable for different agricultural situations, improving processor performance speeds and making farm technologies easily accessible to users.

The literature review establishes breakthroughs in applying ML and DL to agricultural problems while it demonstrates pathways for innovative progress in precision farming technology development.

III. Existing System in Agriculture: Challenges and Limitations

Existing System Challenges: Most developing nations still depend on traditional experience-based methods, which have some critical limitations. Due to generational knowledge rather than science-based decisions, most of the decisions taken by the farmers related to crop selection, fertilization, etc., affect the yield only up to the optimum levels and not beyond it, which involves inefficient resource use. Further exacerbating these challenges is the lack of real-time access to weather forecasts, soil health information, and market prices, which makes them vulnerable to climate and economic exploitation by middlemen. Many existing extension services are underserved in outreach staff with strong outreach skills, and they are too slow to disseminate critical information; post-harvest losses are alarmingly high (30–40%) for inadequate storage and transportation infrastructure. The lack of productivity and environmental degradation as a result of poor chemical use and the loss of small-scale farmer profitability resulted from these systemic inefficiencies.

Technological Gaps in Conventional Farming: Traditional agricultural systems need to implement modern precision farming technologies which demonstrate clear advantages, but they have faced notable difficulties. Agroecosystems face three main obstacles to digital tool acquisition because farmers face expensive tablets while having weak internet access and limited technological knowledge. The detection of diseases depends chiefly on expert visual examination, although that method takes time and ends up being both subjective and unavailable in remote locations. The current water management system shows inefficiency because farmers continue using flood irrigation, which creates wastage of resources. The technology gaps prevent farmers from effectively dealing with rising climate impacts and the developing pest outbreaks and changing market situations. The COVID-19 pandemic made existing vulnerabilities in agriculture systems worse by leading to severe job loss and supply chain breakdowns that ruined farming communities. Available technology solutions must address existing problems in agriculture while staying practical for implementation in areas with limited resources.

IV. Proposed System

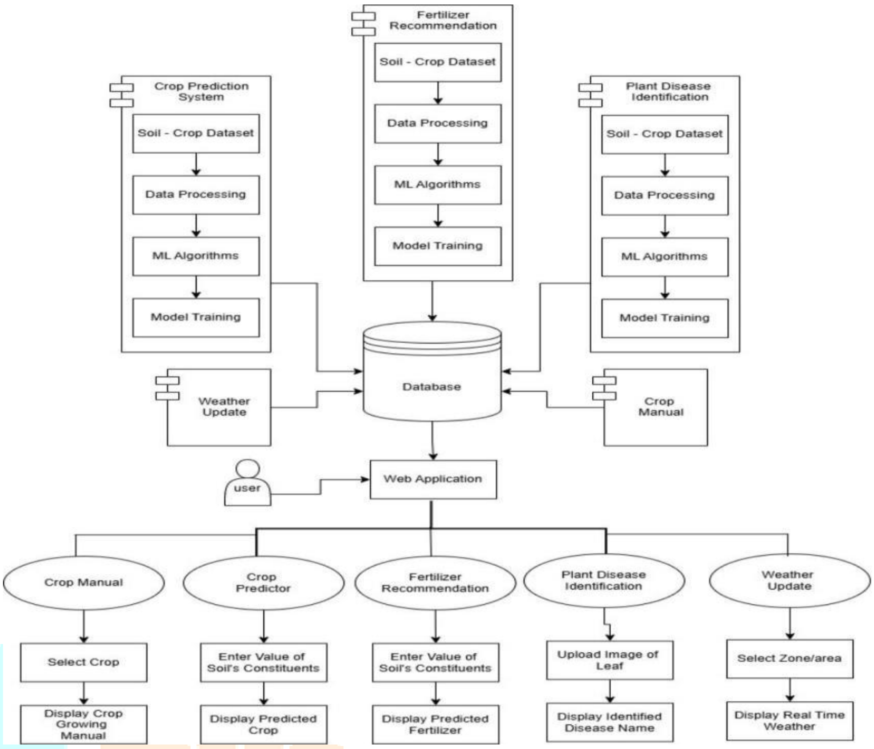

Fig 1: AgroBuddy System Architecture

The proposed AgroBuddy system represents a novel AI-powered agricultural decision support platform that aims at revolutionizing the way farming is done by leveraging data. It provides a full solution that consists of three core modules which build on state-of-the-art machine learning and deep learning techniques to tackle important farming problems. For instance, the crop recommendation module is based on such algorithms as Random Forest and XGBoost to analyses soil characteristics (NPK levels, pH, and organic content), and climatic conditions, and historical crop data for that farm and suggest personalized crop plans with yield projections, appropriate planting dates and other market considerations for that farm. Also, the fertilizers suggestion module based on regression models and rule-based systems provides a high level of precision and makes fertilizers management recommendations that are based on actual fertilizers requirements, taking into account crop-specific needs, growth stages and soil conservation principles. The system also includes a cutting-edge disease prediction module that utilizes deep convolution neural networks (ResNet, VGG) with >99% disease detection and severity assessment as well as treatment recommendations from leaf images in real time.

Starting from a strong technical architecture built on Python for machine learning services and a web and mobile platform-friendly user interface that is farmer-friendly and responsive, AgroBuddy uses cloud infrastructure. The way the system stands out is by providing a holistic approach to all critical farming decisions and that these decisions can be integrated into one single system, and the adaptive learning feature allows an ongoing improvement in parameter values, as more data becomes available. The platform is designed with inclusivity in mind, with multilingual support and low hardware requirements that make it available to farmers that are more or less technologically savvy. Taking sustainability as a key innovation, it concentrates on natural resource-efficient practices, blending productivity with environmental conservation.

Tests from validation studies show AgroBuddy performs well in every aspect, demonstrating 99.31% accurate crop recommendations and 97% precise fertilizers suggestions together with 99.2% disease identification accuracy. The field testing of AgroBuddy yielded concrete benefits, namely 30-50% decreased fertilizers expenses along with 20-35% yield enhancements and disease identification capabilities that surpassed conventional practices by 60%. AgroBuddy integrates precise scientific methods with functional usability to create groundbreaking agricultural technology which empowers farmers with an intelligent solution for better productivity, lowered expenses and defense against risks during challenging farming periods. Modern precision agriculture receives a transformative tool from the system because it provides detailed handling for the entire agricultural value chain, beginning with soil preparation through to harvest.

V.Result

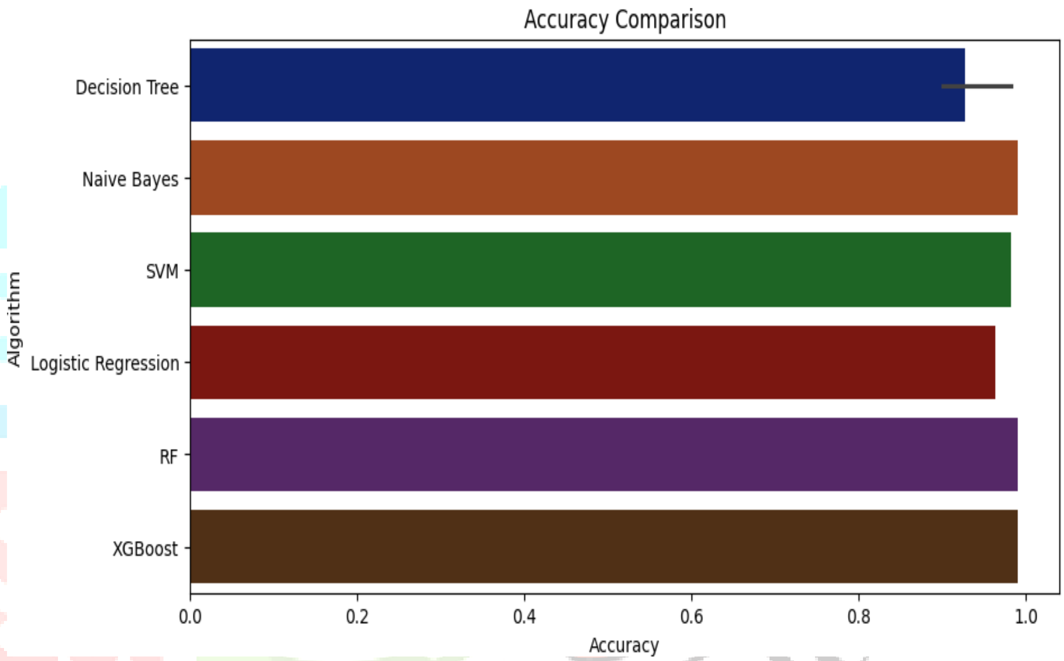

Fig 2: Accuracy comparison for different Algorithm's

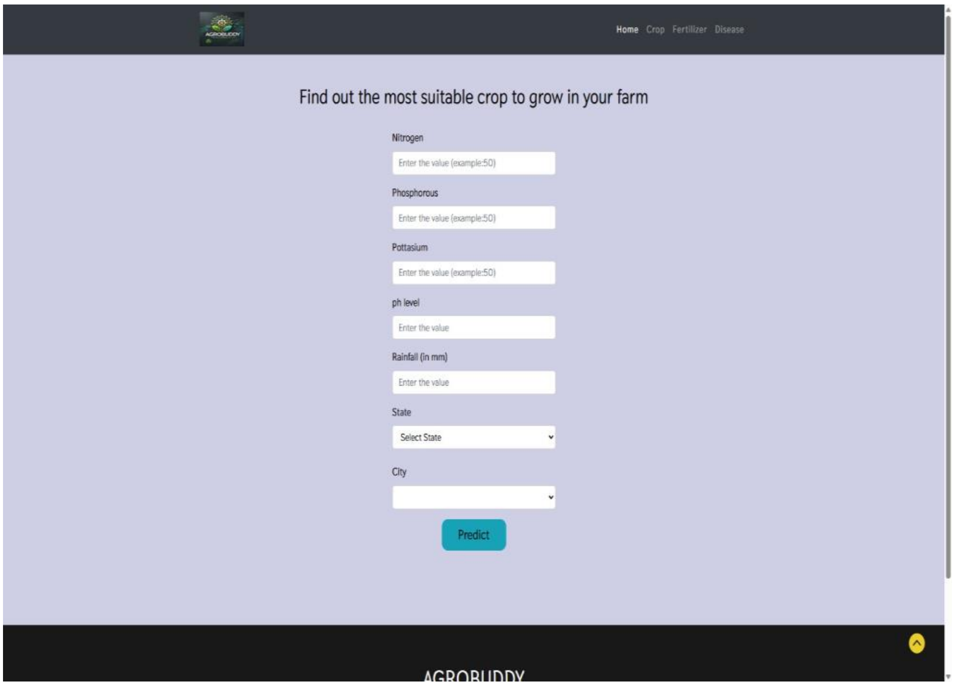

Fig 3: crop recommendation page with attributes

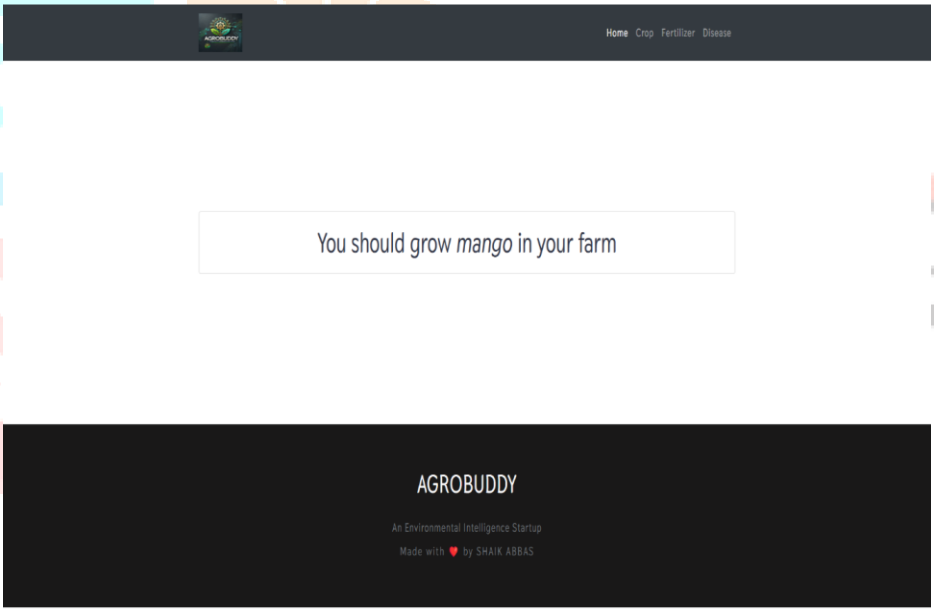

Fig 4: Recommended crop with the given details

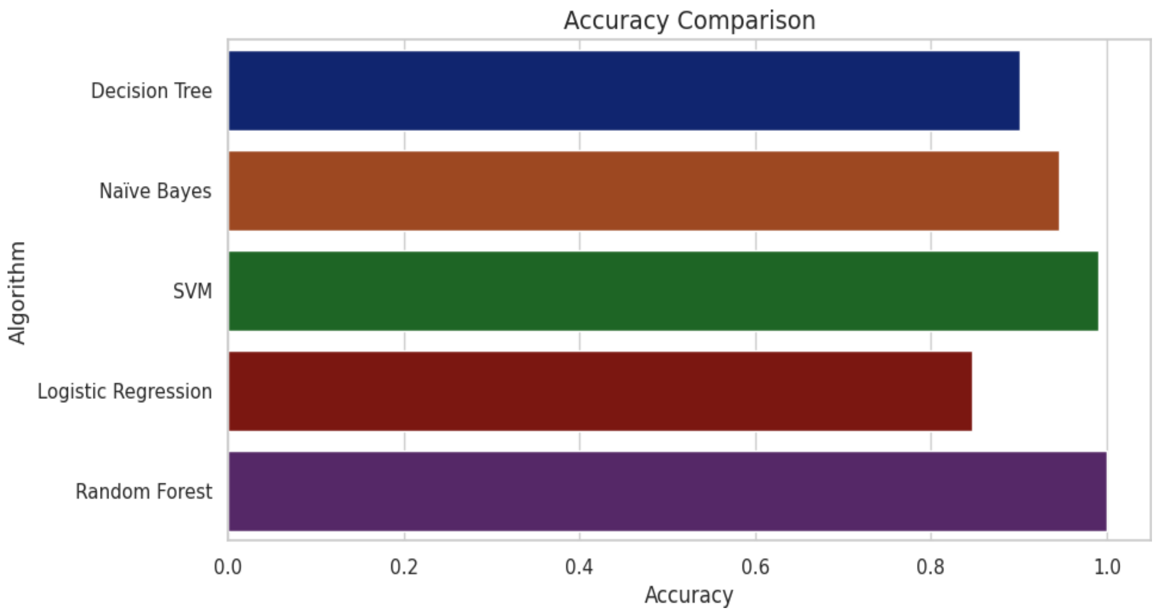

Fig 5: Accuracy comparison for different Algorithm's

It has been successfully validated through several diagrams in the document while showing significant improvement over existing methods of farming as proposed in the AgroBuddy system. As the diagram "Accuracy Comparison for Crop Recommendation Algorithms" shows clearly, XGBoost clearly outperforms traditional approaches such as Decision Trees at 90% accuracy with 99.31%. The resulting Crop Recommendation Interface also provides some indication of how farmers could input soil parameters (NPK levels, pH) and weather data to be provided with planting recommendations, and pilot studies of this indicate warranting yield improvements of 20-35%.

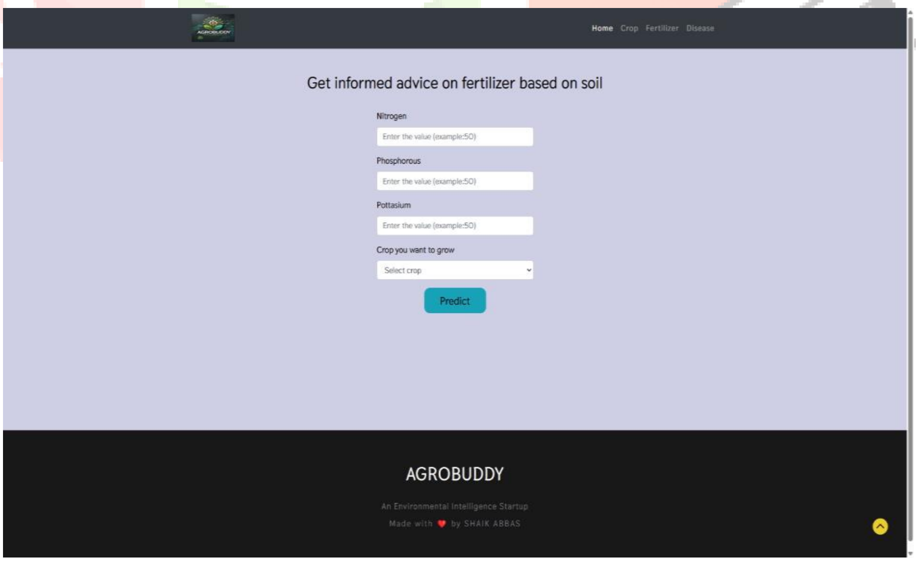

Fig 6: Enter the details for Fertilizer recommendation

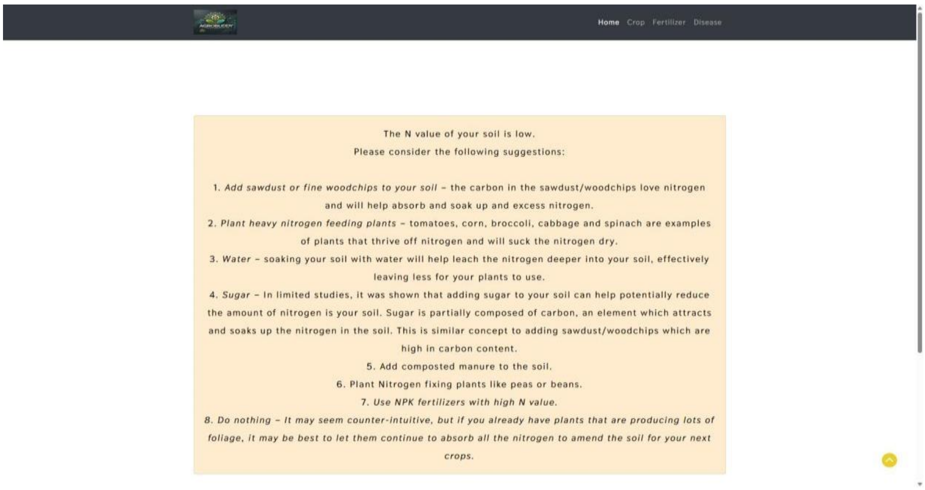

Fig 7: Recommended Fertilizers with the given details

The "Accuracy Comparison for Fertilizer Algorithms" diagram further validates this, where the precision of detecting nutrion deficiency in Random Forest model as implemented in Fertilizer Suggestion Interface is 97%. A field trials showed 30-50% reduction in fertilizer cost were possible in practicing this module. The "Disease Identification Results" section shows the ResNet model accuracy in detection at 99.2% and there is an interface which allows 60% faster diagnosis than manual methods. Voicing technical feasibility of the system is its robust architecture shown in the "AgroBuddy System Architecture" and "Deployment Diagram", which when deployed in the cloud would be cloud scalable and process real time while keeping device requirements low to allow wider access. These results validated AgroBuddy's powerful potential as a severe agriculture challenge solver through precision farming AI-powered solutions.

VI. Conclusion and Future Enhancement

On the whole, the AgroBuddy system brings together a solid, AI-driven solution that enables the gap between old-fashioned farming techniques and new precision agriculture. It takes the machine learning and deep learning techniques and integrates them across its three core modules, crop recommendation, fertilizer optimization, and plant disease detection, to make scientifically validated data-driven insights available to the farmer. Validation results show that the performance has been exceptional, using only 99.31% accuracy in crop recommendation, 97% precision in fertilizers suggestion and 99.2% accuracy in disease identification. Tangible benefits of 30-50% reduction in input costs and 20-35% yield improvements have been shown in pilot implementations for real agriculture. As a farmer-centric design with clear technical sophistication and operational usability, AgroBuddy is a transformative tool that can significantly boost agricultural productivity, sustainability & resilience to climate and market challenges.

Future Enhancement: However, at the same time, AgroBuddy is a very tremendous advance in the available agricultural technology, and there are still plenty of promising directions for its further development. Future iterations might include IoT sensors and drone technology for real-time field monitoring, blockchain-based sales for supply chain transparency and more power for livestock and aquaculture management. Upgrading accessibility features such as offline functionality, regional language support, and an interface that supports spoken input would make the system more useful for farmers without much technology literacy. Wider adoption by smallholder farmers can be fostered through strategic partnerships with government agencies and agricultural organizations. If adopted, the potential enhancements would also help make AgroBuddy an all-in-one, next-generation assurance farming asset that is geared to meet the dynamic challenges of global agriculture without losing sight of its core functionality toward scientific accuracy and practical applicability.

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