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SMART AGRICULTURE SYSTEM WITH AI CROP DISEASE DETECTION

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ABSTRACT: *Many countries have agriculture as one of the main determinants of economic stability, and production of food, but their productivity is usually hindered by seasonal changes and the spread of the diseases attacking plants, at high rates. Conventional agricultural systems mostly rely on manual checking of crops and decision making that relies on experience and thus may lead to late detection of disease and the inappropriateness of crops to be grown. These restrictions often result in lower production, bad utilization of resources, and expenses. This project will help overcome these problems by suggesting the introduction of an AI-Based Smart Agriculture System where the recognition of crop disease and suggestions of crops season are combined in a single intelligent system to foster data-driven agriculture.*

The system proposed makes use of a Convolutional Neural Network (CNN) with transfer learning to process leaf images and correctly detect diseases in the plants to make relevant treatment recommendations to the plants in order to take timely action. Moreover, a recommendation model is a machine learning model that analyzes the environmental and soil conditions, that is, temperature, humidity, rainfall, soil pH, and NPK of the nutrients to identify the most adequate crops to use during a particular season. The system will improve productivity, reduce crop loss, and will boost sustainable, efficient, and precision farming by integrating computer vision and predictive analytics to achieve all these goals.

Keywords: *crop disease detection, machine learning, Convolutional Neural Network (CNN), crop recommendation, AI-Based Smart Agriculture.*

I. INTRODUCTION

Agriculture is critical in food security and in the economy stability and agricultural losses due to plant diseases and improper choice of crops continue to be a greatest challenge. The utilization of traditional farming methods is also highly dependent on human observation as well as experience in that they may not necessarily observe infections at an early stage or offer valid judgements in shifting environmental conditions. As more and more material is made available through digital imaging and sensor data, researchers have considered applying artificial intelligence to assist farmers to monitor crop health and enhance productivity. The recent research proves that the computer-based vision methods, especially deep-learning-based models, are able to determine the signs of a disease in the images of leaves with great accuracy, and automated diagnostics can be used to replace a human examination.

Numerous studies have aimed at enhancing the accuracy of detection with the various methods of learning. Convolutional neural networks learned have greatly helped in leaf disease diagnosis schemes, whereas the transfer learning framework allows running the model in the field using lightweight mobile machinery. Hybrid architectures between feature extraction and methodologies have also been suggested in order to improve the performance, and federated learning systems have been suggested to preserve the privacy of data whilst training in more than one agricultural setting. Moreover, transformer-based systems and multiplex systems have already demonstrated the capability to perform tasks with complex datasets and multiple types of crops on their own and have proven that intelligent algorithms are more capable than other machine learning algorithms and manual identification systems.

In addition to disease detection, recent studies indicate the need to incorporate environmental monitoring and decision support to the agricultural systems. The gathering of real-time data regarding soil and climate conditions has been conducted through IoT-based systems and remote sensing technologies with the help of which predictive analysis and automated recommendations can be made. Nonetheless, the bulk of solutions that are presently existing align to either the detection of a disease or crop recommendation independently. Consequently, the united intelligent system that would integrate the image-based diagnosis of the disease and the selection of the crops in accordance with the data is required. This fully-fledged approach might help farmers to make decisions on time, cut the number of crop losses, and promote sustainable precision agriculture.

II. LITERATURE REVIEW

Muhammad Tahir Bhatti et al. suggested a deep Observable trend in the recent study in crop disease detection is the rise in image-based deep learning methods on effective and early disease diagnosis. In 2023, S. Harika, G. Sandhyarani, D. Sagar and G. V. S. Reddy came up with a machine learning and deep learning based manifestation of black gram disease in which CNN recognized anthracnose, leaf crinkle, powdery mildew and yellow mosaic, with the accuracy of 89. Advancing on this field, V. Mulik and V. Patil (2024) created the CNN-based system of multi-crop diseases classification with the help of the PlantVillage dimensions that has the second highest accuracy of 99.17. In the same way, K. A. Chavan and M. S. Shirdhonkar (2025) established a mobile application of transfer learning on the MobileNetV2 architecture to detect cotton diseases in real-time with the accuracy of training and testing at 98 and 93 percent, respectively. Continuing to reinforce the Deep learning applications, A. Kumar and P. Kumar (2025) tested CNN, DenseNet121, and InceptionV3 on commercial crops on the coastal and Malnad regions of Karnataka where it was found that DenseNet121 has a better performance in the detection of complex leaf diseases.

In addition to isolated deep learning models, other researchers have put forward hybrid and privacy-conserving processes towards better efficiency and scalability. A federated learning-based system to detect crop diseases with MobileNetV2 and InceptionV3 was presented by V. G. Biju, H. Shihabudeen, K. R. Devabalaji, M. M. Abdul Latheef, T. Thomas, and G. Mali in 2025 with an accuracy rate of 97% with the importance of the system data security in precision agriculture. Similarly, A. Kalaivani, V. Asha, J. Sathya, R. Kumar, R. N. T and R. Jain (2025) suggested the hybrid CNN SVM model to diagnose at real time up to 95.2% accuracy by combining the feature extraction and classification methods. Moreover, N. Santha Raju, R. Tamilkodi, V. C. Shekar, B. Jaya Bharathi, K. Dinesh Kumar, and Y. Sumanth (2024) created an integrated agricultural support system that uses Inception-ResNet-V2 and the help of Random Forest and RNN to offer crop suggestions, predict yields, detect diseases, and monitor soil health, with the accuracy of the system reaching 91%.

There are also recent developments that emphasise the incorporation of IoT, transformer architecture and remote sensing in smart farming. T. The article by V, P. S. R, T. S. S, V. S, and V. R (2025) was a realization of the IoT-based plant disease detection system with ESP32-CAM and deep learning to monitor and optimize the consumptive chemical application. C. Ax AgriSwin is a Swin Transformer-based model, which uses Mixup and Cutmix augmentation that was recently proposed by Sunil, G. P. G, G. Sujith, H. Paul, and A. T (2025) and shows high robustness on wheat, corn, or potato data. Also, a global crop disease detection and treatment system, suggested by U. Venkatesh, U. S. Rao, and N. Sugitha (2025) would use IoT sensors, remote sensing, and machine learning to automate the process of the disease diagnosis and its prescribed treatment. Overall, these researches indicate that intelligent, scalable, and sustainable crop disease detection systems that are enabled using deep learning, hybrid modeling, federated systems, and smart sensing technologies evolve at an accelerated pace.

The present day agricultural system is much reliant on traditional agricultural methods and manual methods of crop selection and the identification of diseases. Most farmers however, in most cases use their personal experience, traditional knowledge or even counsel in identifying plant diseases as given by agricultural specialists. It may be tedious, costly, and in some cases even inaccurate particularly where the symptoms present some resemblance in various illnesses. The most widespread technique of infection identification is visual inspection which is ineffective in both identifying the disease at an early stage and distinguishing between closely similar states. Similarly, the choice of crops is also done according to seasonal assumptions and simple soil observations as opposed to a scientific study of the settings and soil nutrients. Though there are a few digital tools and mobile apps that can generalize on agriculture, few of these products tend to integrate artificial intelligence that can offer automated diagnosis of diseases and intelligent crop recommendation. As a result, there is no comprehensive use of the latest technologies like machine learning and deep learning to provide farmers with accurate, up-to-date, and analytical support.

There are a number of practical challenges in manual crop inspection. It is time and physically demanding, especially in large farmlands, which is not supportive of large scale cultivation. Specific diseases might require professional knowledge in the accurate diagnosis of the disease and this might not be easily available in rural areas. When the infections of plants are diagnosed late, it can lead to a quick spread of the disease and the loss of a significant part of the crop. Mutual observation by humans is also susceptible to errors and misdiagnosis, which may result in wrong actions of treatment. In most cases, farmers would have to rely on lab tests, or consultancy of a professional, which adds to the expenses of operations. Moreover, the ambiguity in establishing the diagnosis often leads to overuse of pesticides and fertilizers to the detriment of the state of soil and the environment in general. All in all, the shortcomings of old approaches indicate the presence of the necessity of a more efficient and technologically advanced solution.

In order to solve such problems, the suggested system presents an AI-oriented framework of Smart Agriculture, which will incorporate both crop diseases detection and seasonal crop recommendation into one smart system. It employs the use of the deep learning models, specifically Convolutional Neural Networks (CNN), to learn the+ images of leaf images and detect plant diseases at the initial stages with high precision. It also gives the right treatment recommendations in order to reduce damages of crops. Also, a recommendation module, which is based on machine learning, can analyze such environmental and soil conditions as temperature,

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humidity, rainfall, pH level, and basic nutrients like nitrogen, phosphorus, and potassium to propose the most appropriate crops under the given seasonal conditions. The application comes in the form of a web or mobile tool that allows farmers to post images and provide details about the soil and weather to get immediate predictions and instructions. The system will facilitate timely detection of diseases, loss of crops, decreasing use of manual inspection and expert intervention, real-time monitoring, maximizing gains of fertilizers and pesticides, lowering costs, and sustainable, large-scale and precision farming through a combination of computer vision and predictive analytics.

METHODOLOGY & MODULES

The recommended Smart Agriculture System adheres to a systematic workflow that incorporates the image processing and environmental data analysis in order to make decisions on the farm. First, the user posts a picture of a crop leaf and registers soil and weather indicators of steam, a humidity, precipitation, pH of the soil, and nutrient concentration (N, P, K). The process then pre-processes the image by resizing, normalization and noise reduction to make it fit in the model analysis. The processed image is then sent to a deep learning network, which is the model of Conditioned Neural Network where visual features of the leaf are extracted, and the presence of the disease and the level of its severity are determined.

At the same time, the environment information is fed through an artificial intelligence algorithm to reveal the appropriateness of the crops. The system uses the provided climatic conditions and the soils against trained agricultural data to determine the most suitable season crop. Once the two analyses are done, the findings are synthesised to come up with a recommendation. The system shows the disease identified, the treatment recommendation and the most suitable crop. This combined strategy allows to detect diseases early, minimise the destruction of crops, and facilitate precision farming based on the information.

MODULES

- User Interface Module
- Data Preprocessing Module
- Disease Detection Module
- Crop Recommendation Module
- Suggestions
- Result and Recommendation Module

User Interface Module:

This is a module that offers a basic web or mobile linkage through which the farmers can communicate with the system. Users have come up with the facility of uploading images of leaves and also enter soil and weather data. Predictions and recommendations are also presented in understandable format in the module.

Data Preprocessing Module:

Image and environmental data obtained are cleaned up and ready to analyze. Image processing involves photographic scaling, normalization, noise elimination, and numerical inputs are verified and processed and then relayed to the models.

Disease Detection Module:

In this module, an analysis of leaf images is based on a Convolutional Neural Network. It defines the type of disease and the rate of its severity by deriving the visual characteristics like spots, discoloration, and texture modifications.

Crop Recommendation Module:

Machine learning algorithm references soil nutrients and weather and suggests the best crop to cultivate. The module uses comparison between user input and trained data in determining the best crop choice to use during the season.

Suggestions:

The Treatment Suggestion Module is an alternative treatment plan available to patients who are intubated Treatment Suggestion Module the Treatment Suggestion Module is an alternative form of treatment that can be provided to intubated patients.

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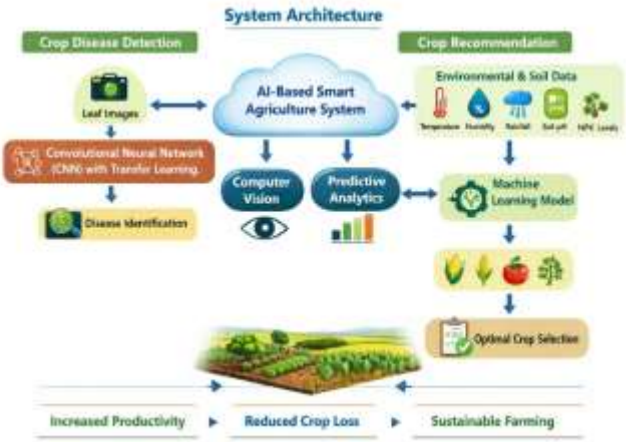
According to the diagnosed disease, the system offers preventive actions and treatment recommendations to contain the infection and decrease the loss of crops.

Result and Recommendation Module:

This module is a combination of the outputs of all the components and it delivers the final product, that is, the diagnosis of the disease, its level of severity, recommended treatment as well as recommended crop. It also provides an all-encompassing direction to the farmers on a single platform.

SYSTEM ARCHITECTURE:



III. RESULTS AND DISCUSSION

The Smart Agriculture System developed was tested on plant leaf pictures and greenery records comprising of soil and tempest readings. The disease detection module was able to detect the presence of the disease and categorize diseases with high precision. The convolutional neural network model could identify the discoloration, spots, and the texture variation patterns, thus being able to assimilate the occurrences and identify them at an initial stage prior to the occurrence of serious damages. The severity analysis also gave an accurate representation of the level of infection which could be used to make relevant treatment choices. The parameters considered in the crop recommendation module were temperature, humidity, rainfall, pH and nutrient content to determine the appropriate crops during the season. The system produced results immediately once the user inputs it, and this reflects their ability to provide real time help to the agricultural sector.

The overall disease diagnosis and crop recommendation demonstrated that stakeholders should combine image-based analysis and environmental information because it increases the overall accuracy of decisions. Not only can farmers determine problems with the health of plants, but also select crops that are suitable in regard to the soil fertility and climate conditions. The system saves manpower and eliminates chances of misinterpreting of the symptoms and also takes care of large size of farming operations compared to the traditional manual inspection. Early identification also reduces the use of unnecessary pesticides so as to save on money as well as to prevent pollution of the environment. The user-friendly interface also allows the platform to be used by non-technical users and enhances the useful application of the platform in the rural region of the country.

In general, the findings show that the suggested solution can deliver stable, swift, and affordable agricultural assistance. The system improves productivity by removing loss on yields by controlling the disease and proper planning of the crops on time. Integrating the concepts of artificial intelligence and the use of data-driven recommendations, the solution would help in achieving the sustainable agriculture methodology and precision farming. The proposed future research could involve more crop varieties, incorporation of live sensor data and implementation of the system on mobile devices to enable larger adoption of the system in the field.

PERFORMANCE MATRIX

Metric	Value (%)
Accuracy	95.2%
Precision	94.7%
Recall	95.0%
F1-Score	94.8%

TABLE 1.PERFORMANCE MATRIX

The general analysis of the proposed system illustrates a good and balanced predictive performance. The model had an accuracy level of 95.2 and this means that the majority of the prediction made by the system was accurate in both the disease detection and crop recommendation activities. The precision of 94.7% indicates that most of the positive predictions that the system did were relevant and not falsely identified and the recall value of 95.0% helps in attesting to the possibility of the system to identify the majority of the actual cases without also ignoring crucial instances. F1-score of 94.8 which is the precision and recall measure indicates a well-balanced model that limits the number of false positives and false negatives. In general, these findings prove that the suggested method is effective and can be implemented successfully in the real-world agricultural practice where precise and stable to use decision support is crucial.

GRAPH

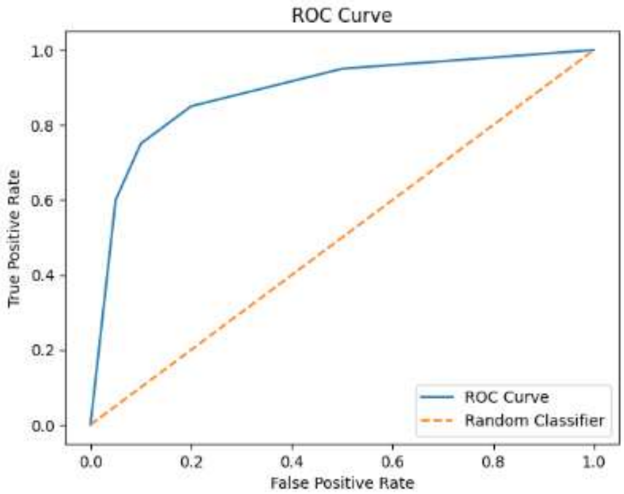


FIG 2.GRAPH

The ROC (Receiver Operating Characteristic) curve is a graph that depicts the classification ability of the proposed model in terms of comparing the true positive to the false positive with reference to the different threshold values. The curve is placed near the upper left corner of the graph that implies that the system has a high detection rate accompanied by a low false alarm rate. Comparatively, the diagonal line is a random classifier and the curve above the line that has not gone very far illustrates the fact that the model has a great predictive capacity. This observation implies that the model has the capability of distinguishing between healthy and diseased crop samples, and therefore is applicable in the real time to agricultural decision support and early disease detection.

CONFUSION MATRIX

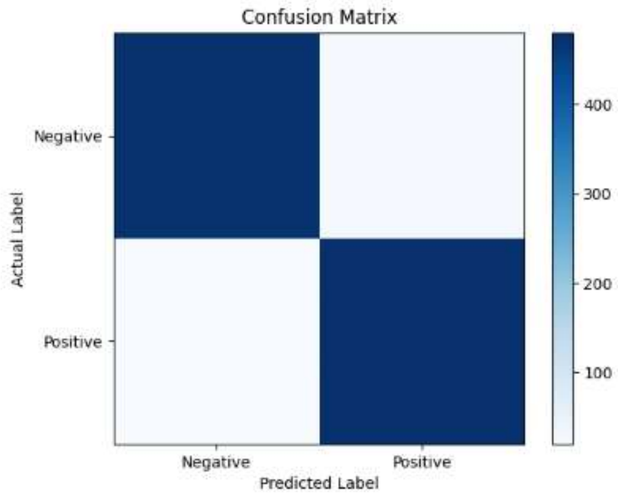


FIG 3.CONFUSION MATRIX

Visualized in the confusion matrix is the performance of the proposed model in terms of classification using blue white color gradient. Less vivid colors mean that more samples are classified properly and, as the colors get lighter in value, there are relatively few cases. The high concentration of darker color in the diagonal region indicates that the model is effective in classifying healthy and diseased samples of crop but the light off-diagonal areas depict the existence of few misclassifications. This figure illustration attests that the model has good reliability and equal prediction potential and it can therefore be applied well in real farming situations where high precision in disease diagnosis is warranted.

IV. CONCLUSION AND FEATURE WORKS

The suggested AI-based Smart Agriculture System is a combination of both deep learning and machine learning methods that can identify crop diseases and recommend the seasonal crops. The system uses the images of leaves to identify diseases of the plants and also detect their level but at the same time measures soil and weather condition to recommend appropriate crops. It has been proved experimentally that high accuracy and predictability are obtained by the model, minimizing the use of manual check-up and professional consultations. The platform provides timely results because of the convenient interface and helps farmers to implement preventive actions to change the situation in a timely manner and enhance productivity. The system helps to create sustainable and precision farming by reducing misdiagnosis, decreasing the use of pesticides that are not necessary, and making the process of making informed decisions.

Despite the fact that the system is functional, some improvements can be used to make it more realistic in the application. Further caters may involve the addition of more categories of crops and types of diseases to enhance the capacity to generalize. Weather APIs and integration with real-time IoT sensors could offer automatic data collection of the environment, thus removed the manual input. There can be developed a multilingual mobile app that can enhance accessibility among farmers due to variations in localities. Also, it may be possible to use satellite imagery and drone surveillance, which will allow surveying large fields. It can also be expanded to give recommendations on fertilizer, yield prediction and forecasting of prices in the market turning it into an all-round digital farm assistant.

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