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A Survey Paper on Smart-Farm: Machine Learning and IoT-based Agriculture Decision Support Portal

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***Abstract*— Smart Farm, an innovative agricultural platform, is at the forefront of revolutionizing traditional farming practices by integrating machine learning, deep learning algorithms, and IoT technologies seamlessly. This trailblazing technology goes above and beyond traditional approaches by properly estimating crop yields and analyzing seed quality, giving farmers critical insights for optimal agricultural planning. Smart-Farm, by leveraging the power of machine learning algorithms, becomes a trustworthy ally for farmers, providing precise and fast information critical for agricultural decision-making. The addition of IoT technology expands its capabilities even further, allowing for real-time soil quality evaluations via strategically positioned sensors in the soil. These sensors monitor crucial characteristics like as moisture levels, nutrient content, and pH levels, allowing farmers to perform targeted soil management using a data-driven approach. This not only optimizes crop farming practices but also increases overall productivity tremendously. The Agriculture Portal, a key component of Smart-Farm, exemplifies agricultural empowerment by empowering farmers to make well-informed decisions that result in better outcomes, thereby creating a more sustainable and efficient approach to contemporary farming.**

***Index Terms*— Soil Quality, Crop Yield Prediction, Seed Quality, Convolutional Neural Networks, Internet of Things.**

I. INTRODUCTION

In the fast-changing agricultural landscape, accurate forecasting of soil conditions, seed quality, and crop yield has emerged as a critical component for guaranteeing global food security and supporting sustainable farming practices. Soil quality, a pillar of agricultural success, has an impact on nutrient availability, plant development, and total output. The combination of modern technology such as remote sensing and machine learning algorithms is revolutionizing soil quality prediction. These models act as navigational aids, highlighting locations requiring specific interventions by integrating data on nutritional content, pH levels, and organic matter. The outcome extends beyond optimized resource utilization; it extends to the cultivation of sustainable soil management practices meticulously tailored to the unique needs of each agricultural plot.

Simultaneously, seed quality prediction has emerged as a pillar for successful crop production, influencing critical aspects such as germination rates, genetic purity, and disease resistance. To analyze and forecast seed quality, the modern predictive modelling landscape employs genetic tests, imaging technology, and machine learning

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algorithms. These models enable farmers to make wise judgments when picking seeds that are most suited to their conditions, promoting improved crop establishment and, as a result, increasing total output. As a result, the framework for efficient and sustainable agricultural practices is strengthened, expressing a revolutionary approach to seed selection.

In the field of agricultural production prediction, precise foresight is critical for successful farm management and the orchestration of global food supply chain planning. The complexities of elements impacting agricultural output, ranging from weather patterns to soil conditions and seed quality, need the use of advanced prediction modeling. These models provide detailed information to farmers, allowing them to make educated decisions about planting dates, irrigation, and fertilizer application. The total result is an increase in production efficiency, which contributes significantly to the broader objective of global food security.

Finally, in the face of rising agricultural needs, the predictive capability incorporated in soil quality, seed quality, and crop yield models serves as a beacon of development. This confluence of cutting-edge technology and data-driven approaches is more than just a collection of tools for individual farmers; it is an essential component of the worldwide effort toward sustainable agriculture. By providing actionable information, these models enable stakeholders to make wise decisions, fostering a future in which food production is not only efficient but also environmentally friendly. Soil quality, seed quality, and crop yield prediction constitute a transformational force moving agriculture into an era defined by resilience, efficiency, and sustainability.

II. RELATED WORK

A) Seed Quality Analysis

Ravikumar Hodikehosalli Chennegowda, Santosh Kumar Jankatti, Meenakshi, and Raghavendra Srinivasaiah [1] Aim to make a prediction model using machine learning approaches, notably convolutional neural networks (CNN), to properly predict seed quality and enhance agricultural productivity and harvest quality. Because it does not have a validation mechanism, the current seed prediction analysis is not useful for predicting the quality of seeds. The method proposed in the paper makes use of CNN architectures to identify individual seeds with extraordinary precision and to distinguish between various types of seeds with high accuracy. When compared to standard and manual procedures, the proposed strategy can speed up the seed health prediction system while reducing error rates and improving performance for larger experimental data sets. The model achieves over 97% accuracy in training and 64% accuracy in predictions for the testing dataset.

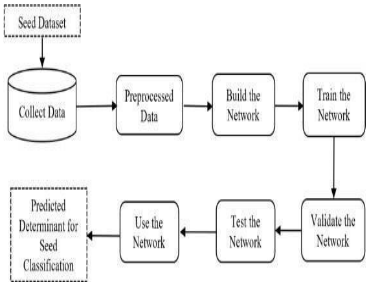

Figure 1. Block diagram for forecasting the quality of seeds [1]

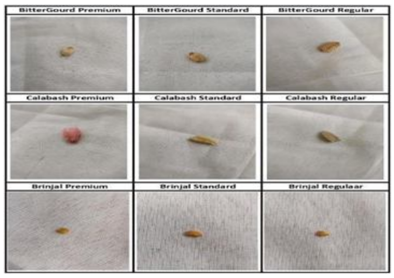

Figure 2. Dataset preview [1]

Dr. A. P. Rao, Miss Shivpriya Desai, [2] The study underlines the limits of traditional, often costly, and time-consuming methods for seed quality assessment, emphasizing the crucial necessity of high-quality seeds in rice production due to their direct impact on yield, disease susceptibility, and overall crop strength. The proposed methodology provides an efficient and cost-effective alternative by leveraging digital image processing to extract essential geometric features such as major axis length, minor axis length, area, eccentricity, and perimeter from rice seeds, allowing rice grains to be classified into grades 1, 2, and 3 based on specific length characteristics with an impressive accuracy of approximately 98%, especially when dealing with minimal grain overlap. The addition of an LCD and voice messages improves system use by providing an automated and dependable solution for rice quality assessment and resolving market concerns from both consumers and sellers. In conclusion, the paper highlights the potential of digital image processing and ANN-based technologies in agricultural quality control, providing an innovative and practical solution for quality assessment and paving the way for future advances in automated quality control across various food products, ultimately promoting food safety and consumer satisfaction in today's quality-conscious market.

TABLE I. RICE TESTING RESULTS FOR QUALITY ANALYSIS AND GRADING [2]

Rice Grade	Number of samples	Classification Result	Accuracy (%)
Grade 1	20	18 are classified as grade 1	98
Grade 2	20	19 are classified as grade 2	99
Grade 3	20	19 are classified as grade 3	99

Santosh Shrestha, Birte Boelt and Zahra Salimi [3]. Investigating novel methods of evaluating seed quality, this study promotes multispectral imagery as a flexible instrument. It can identify fungus, determine the maturity of sugar beetroot seeds, determine varieties, and measure insect damage with ease. Its reliability is established by a close connection with reference approaches. The study indicates that multispectral imaging shows substantial potential in addressing the requirements for surface structure, chemical formula, seed color, morphology, and size. It emphasizes the necessity for quick, non-destructive approaches.

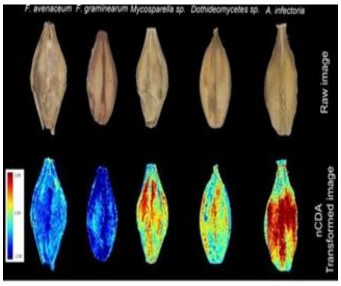

Figure 3. Raw photos of barley seeds and the associated modified image produced by the USDA model.

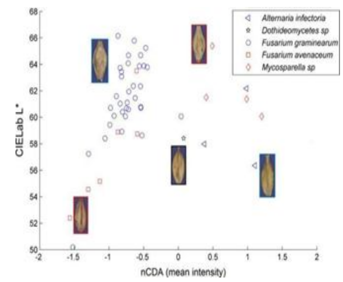

Figure 4: The nCDA scores plot depicts the grouping of the barley seeds infected by the five distinct fungus species.

M. Rudra Kumar, G. Ramesh, and K. Sreenivasulu [4] Introduced the Pivot Based Seed Germination Evaluation (PBSGA) pattern is a methodology based on machine learning for classifying seed germination that makes use of an evaluation tool based on a statistical method. The PBSGA model is shown to be effective in determining the relevant model category and conceptualizing consecutive improvements using a rice seed quality assessment using machine learning (RSGA) using a variety of baskets from the KAGGLE dataset. The results of the experimental research point to the PBSGA model's potential and imply that multi-class labeling in seed germination analysis will be investigated in later research. Each seed selected for the study is dynamically evaluated by the statistical method-based assessment tool, PBSGA, enabling a more precise and accurate examination of germination quality. Flexibility in use, as PBSGA shows promise for analyzing diverse seed types as it is successfully applied to many baskets from the KAGGLE dataset and used to evaluate rice seed quality (RSGA).

Jamel Nebhen, Bhavya Tiwari, Bhavesh Gedam, Michal Dobrovolny, Abhishek Kumar, and Puneet Singh Thakur [5] propose a deep transfer learning (TL) photonics sensory effective in automatically identifying and classifying high-quality seeds. One backscattered picture of a seed sample may be captured by the sensor and examined by DL models like convolution neural network (CNN) and TL models like VGG16, VGG19, InceptionV3, and ResNet50. With an accuracy of as much as 98.31%, InceptionV3 outperformed the other DL models. Moreover, the proposed sensor could track seed quality (GP) by calculating common quality parameters like radicle length, germination percentage, and percentage imbibition (PI). The sensor can be used for real-time applications due to its simple experimentation and DL-based automatic classification.

B) Soil Quality Analysis

Anirudh Sandur, Gowda B G Dharshan, Shivashankar, and Dileep Reddy Bolla,[6]. The goal of the paper is to provide a solution that can be used globally to control soil parameters, such as pH, nutrient, and moisture content, in agricultural land. IoT technology, embedded systems, cameras, and microcontrollers are used in the study to remotely monitor and collect real-time environmental data. Moisture content and the pH of the soil are determined using image processing techniques, which can give instantaneous information about soil nutrients and suitable crops. All things considered, the study advances the creation of a dependable and expandable method for soil quality monitoring through the use of the Internet of Things and image processing.

Kaoutar Doumali, Yassine Al Masmoudi, Lahcen Hssaini, Khalid Ibno Namr and Yassine Bouslihim,[7] To perform predictive analyses on soil fertility elements within Moroccan soil, the researchers in this study utilized a range of algorithms, including multiple linear regression (MLR), random forest (RF) and support vector machine (SVM) to leverage the power of machine learning. The model produced encouraging results when it came to the prediction of organic matter (OM), as demonstrated by its high R2 values and noticeably low RMSE values, which indicate its effectiveness in this area. When it came to phosphorus (P2O5) and potassium (K2O) prediction, on the other hand, the models' performance levels followed a different path, showing poor performance indicated by smaller RMSE values and low R2 values. Through this investigation, they were able to pinpoint the crucial variables—soil texture, carbonates, and cation exchange capacity—that were essential to the OM, P2O5, and K2O predictions. The work cited above emphasizes how machine learning can completely transform the field of digital soil fertility mapping and evaluation. It provides a financially feasible substitute for labor-intensive and time-consuming traditional methods.

Abhishek More, Ashishkumar Mouria, Namrata Panchal, and Kavita Bathe [8] This research presents a novel approach for quick evaluation of rice crop levels of nutrients (N, P, and K) using the TCS3200 color sensor. The technique greatly speeds up the analysis in comparison to conventional approaches, producing speedier findings. The system includes a user-friendly online application that makes it simple to see and get data on the fertility of the soil. Most notably, it offers suggestions for organic fertilizers, which are essential for maintaining soil fertility and raising crop yields. The study successfully illustrates the possible revolutionary influence of this technology on soil analysis, promising more fruitful and efficient agricultural operations, even though the exact result is kept a secret.

V. Sathiyavathi, K. Selvakumar, T. Sindhu, and R. Reshma[9] The suggested IoT system deals with crop yield prediction and soil content analysis and offers a promising direction for the development of smart agriculture. The system produces extensive data by using a variety of sensors to measure important soil parameters like temperature, pH, humidity, moisture, and nutrient content. After that, the data is sent to a cloud server for comprehensive analysis, which is essential for farming strategy optimization. Using SVM and Decision Tree algorithms to determine crop suitability has the potential to significantly increase crop growth through more efficient farming methods. It is imperative to recognize the limitations present in the paper, though, such as the need for a more thorough examination of the methodology's limitations, validation using actual data, scalability issues, and the inclusion of extraneous variables like pests and weather. Even more reliable and useful solutions for precision agriculture may come from more research in these areas.

Rajat Kumar Dwivedi, V Vanitha, Aby Varghese Thomas, and Kiran Venugopal [10] This study highlights how the Internet of Things (IoT) has revolutionized Indian agriculture, especially when it comes to measuring soil moisture. Implementing IoT brings benefits including more efficient farming, real-time environmental monitoring, and improved decision-making. IoT lets farmers make wise and effective decisions by offering useful data regarding factors like wind, humidity, temperature, water availability, and soil fertility. Comprehensive farm management and crop development monitoring are made easier by features like weed detection and online cultivation tracking. By enabling farmers to keep informed about current agricultural circumstances, remote connectivity can further enhance their ability to reduce expenses, increase precision, and ultimately improve productivity and resource management in conventional farming.

C) Crop yield prediction

Prof. Shraddha Shirsath, Shubam Khude, Vishal Malaye, Saurabh Mhase [11]. Developed a machine learning model that forecasts crop yield by taking into account variables like crop type, weather, and soil quality. Finding the most accurate and dependable model requires analyzing and contrasting numerous algorithms in machine learning, such as random forest, neural networks, and linear regression. Making educated decisions about crop management and resource allocation can help farmers by using the final model to predict crop yield for specific environmental conditions. demonstrating the accuracy with which machine learning algorithms can forecast crop yields in the presence of high-quality meteorological, soil, and crop type data. demonstrating how the neural network model outperforms the random forest model in accurately predicting rice yield and maize yield. illustrating the potency of the support vector machine model in accurately predicting wheat yield and cotton yield. Identifying the need for more accurate and reliable data, as well as further research on transfer learning and ensemble learning techniques.

Cagatay Catal, Ayalew Kassahun, and Thomas van Klompenburg [12] Outline a technique for predicting crop yield that makes use of a linear regression model and historical growing parameters to forecast a target crop's yield. Geographic environment variables are incorporated into the method as input parameters to gain prediction accuracy. The method provides a basis for site selection by using the intercept and coefficient obtained from the linear regression model to calculate the predicted yield of a target-selected site. The method provides a basis for making educated decisions about agricultural planning, making it possible to choose the best sites for planting.

Careful site selection is necessary to avoid undesirable consequences that arise from careless choice of location, such as low crop production. This method is very flexible, cost-effective, and not limited to any one crop.
Fatma M. Talaat [13] presents a novel method for agricultural production prediction that focuses on accurate Internet of Things (IoT) integration approaches in the farming area. The proposed Crop Yield Prediction Algorithm (CYPA) forecasts annual crop yields by using many data sources, including climate, weather, agricultural productivity, and chemical data. With the help of this all-encompassing strategy, farmers and politicians should be able to make well-informed decisions at the national level. The study uses five machine learning models, each trained and validated with ideal hyperparameter values, to support the efficacy of CYPA. With values of 0.9814, 0.9903, and 0.9933 in that order, the Decision Tree Regressor, Random Forest Regressor, and Extra Tree Regressor models, in particular, showed notable accuracy.

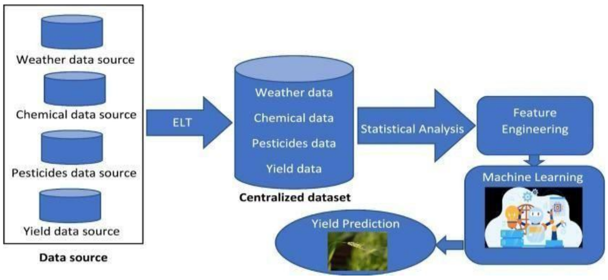

Figure 5: An overview of the crop yield prediction pipeline

S. Kiruthika, D. Karthika [14] highlights the importance of effective crop protection and raising yield. It recognizes the difficulties brought about by pests, evolving farming methods, and climate variability. The paper presents the idea of revolutionizing crop yield forecasting and recommendations through the use of machine learning techniques (MLTs) and the Internet of Things (IoT).The IDCSO-WLSTM technique is presented in the paper to improve prediction accuracy while cutting down on processing time. Crop prediction, pre-processing, and attribute selection are all improved by the suggested system, which also outperforms its predecessors in terms of recall, accuracy, and execution time. The work paves the way for additional research in the field, with potential improvements including support for bigger datasets, handling different weed species, and enhancing feature selection and deep learning models.

III. Major Trends And Key Findings

Seed Quality Analysis

A considerable revolution is taking place in the expanding landscape of seed quality analysis, defined by a noticeable trend toward sophisticated techniques. A prevalent development in this arena is the use of machine learning, specifically convolutional neural networks (CNNs), to not only forecast seed quality but also increase agricultural production. These approaches are closely linked to complete frameworks, as demonstrated by a notable five-stage architecture that includes CNN construction, data preparation, image processing, training, and analysis.The generation of high-quality datasets is a critical component of these approaches. One outstanding work meticulously classified three seed kinds into nine groups, highlighting the critical relevance of robust data in training efficient machine learning models.

Crop Yield

In the pursuit of accurate crop yield prediction, it is critical to investigate various machine-learning techniques. Specifically, the effectiveness of Decision Tree Regressor, Random Forest Regressor, and Extra Tree Regressor models in forecasting agricultural productivity has been examined. A comprehensive approach to yield prediction is produced by carefully configuring these models with characteristics that include climate, weather, past agricultural yield history, and chemical data. A comprehensive understanding of the intricate interactions between environmental variables and crop results is ensured by the inclusion of these many elements.
When it comes to accurate crop yield prediction, it is critical to investigate various machine-learning techniques. Specifically, the effectiveness of Decision Tree Regressor, Random Forest Regressor, and Extra Tree Regressor models in forecasting agricultural productivity has been examined. A comprehensive approach to yield prediction is produced by carefully configuring these models with characteristics that include climate, weather, past agricultural yield history, and chemical data. A comprehensive understanding of the intricate interactions between

environmental variables and crop results is ensured by the inclusion of these many elements helps to further the continuous development of precision agriculture techniques.

Soil Quality

The present landscape of soil quality prediction using IoT sensors demonstrates dynamic changes influencing precision agriculture. Advanced sensor technologies have proliferated, enabling real-time monitoring of critical soil characteristics like moisture, temperature, and nutrient concentrations. These sensors, linked by wireless protocols such as LoRaWAN, build enormous networks that provide farmers with full insights over broad agricultural areas. Machine learning methods, particularly linear regression, random forest, and neural networks, use historical and real-time sensor data to estimate crop yields exactly.

User-friendly interfaces enable farmers to successfully evaluate and act on soil quality data, whilst precision agriculture algorithms optimize resource consumption through targeted interventions. Cloud and edge computing solutions are critical in processing the massive datasets IoT sensors produce, providing scalability and real-time decision-making. Furthermore, research into blockchain technology improves data security and integrity, increasing confidence in precision agriculture systems. These developments are driving the growth of soil quality prediction, which promotes sustainability and efficiency in modern agriculture.

IV. Conclusion

Advanced technologies are altering approaches to soil quality, seed quality, and crop yield prediction in agriculture's dynamic terrain, heralding a future of precision agriculture powered by data-driven insights and cutting-edge technologies. The implementation of IoT devices is a dynamic trend in soil quality prediction. Farmers get insights into soil dynamics by using advanced sensors that provide real-time data on moisture content, temperature, and nutrient concentrations. LoRaWAN and NB-IoT wireless communication techniques enable smooth data transfer over huge agricultural fields. Machine learning algorithms evaluate massive IoT sensor information, allowing for precise soil quality forecasts that are further enhanced by including geographic characteristics. Machine learning, namely convolutional neural networks (CNNs), sophisticated frameworks, and high-quality datasets are used to forecast seed quality.

The increasing trend of multispectral imaging represents a paradigm shift towards data-driven, non-destructive approaches applicable to a wide range of crops. The convergence of IoT devices and machine learning promotes a paradigm shift towards data-driven and automated agriculture, optimizing resource consumption using precision agricultural algorithms. Finally, the incorporation of sophisticated technology reshapes agriculture towards precision, sustainability, and efficiency, allowing farmers to make more informed decisions.

Acknowledgment

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