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A Literature Survey on Precision Crop Prediction Using Soil and Environmental Analysis

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Abstract: *With the increasing global demand for agricultural efficiency, the importance of accurate and well-informed crop planning is highlighted. The objective of the research project, titled "Precision Crop Prediction using Soil and Environmental Analysis," is to develop a system that utilizes machine learning algorithms and extensive datasets to forecast the most suitable crop for a particular region. This system incorporates essential input parameters such as soil NPK values, pH levels, temperature, humidity, and rainfall data. It provides users with valuable insights, including recommended crops for cultivation, anticipated yield per acre, and estimated market prices for the yield. By offering a comprehensive and data-driven solution, farmers can make more informed decisions, optimize resource allocation, and enhance overall agricultural productivity.*

Keywords: Precision Crop Prediction, Machine Learning Algorithms, NPK Values, Soil PH

I. INTRODUCTION

The changing landscape of agriculture, influenced by advancements in technology and data-centric approaches, is entering a transformative phase commonly referred to as precision farming. This literature survey delves into the integration of machine learning, environmental analysis, and soil assessment at the heart of this transformation. Faced with the challenges of feeding a growing global population amid uncertainties in climate change, conventional farming practices are making room for data-driven decision-making. The survey explores various soil analysis techniques, underscoring the importance of Nitrogen, Phosphorus, and Potassium levels, alongside environmental factors like temperature and rainfall. Within this context, machine learning applications play a pivotal role, particularly in crop prediction models utilizing diverse algorithms. In alignment with these principles, the survey aligns with the objectives of our project, "Precision Crop Prediction using Soil and Environmental Analysis." This initiative aims to equip farmers with an intelligent system that leverages machine learning and extensive datasets for accurate crop predictions, incorporating NPK values, soil pH, and environmental parameters. As we delve into existing literature, we unravel the historical progression and innovative interventions in agriculture, laying the groundwork for the distinctive approach of the project at hand.

II. LITERATURE REVIEW

[1] The proposed solution addresses challenges associated with traditional soil testing processes by introducing an automatic soil testing system. The primary concern identified is the time-consuming nature of soil testing in government laboratories, which may lead to extended waiting periods and potential sample loss. The system aims to assess soil fertility by analyzing key characteristics and nutrient levels, including nitrogen (N), phosphorus (P), and potassium (K). It involves a portable pH meter, an Arduino board, ESP8266, and a MySQL server device. The pH meter measures soil pH, with the data transmitted to the Arduino board and then relayed to the server. Machine learning classification methods are employed to convert pH values into NPK values, categorizing soil fertility into three classes (LOW, MEDIUM, and HIGH). Based on the fertility class, the system recommends suitable crops and fertilizer quantities. The conclusion underscores the efficiency and real-time capabilities of the proposed method, presenting it as a superior alternative to manual soil testing despite any drawbacks.

[2] This research tackles crop outcome prediction, utilizing 15 varied machine learning algorithms on a rich dataset encompassing 2200 entries and 22 crop categories. Highlighting the significance of farm-based IoT data acquisition, it considers factors like temperature, humidity, rainfall, soil chemistry, and nitrogen content. The approach leverages diverse classifiers like Random Forest, Multilayer Neural Network, and Naïve Bayes, adhering to established data analysis steps like modeling, feature reduction, and augmentation techniques. The authors emphasize the criticality of meticulous data collection and preprocessing for optimal performance. Results demonstrate the efficacy of classification algorithms in recommending suitable crops, with Naïve Bayes, Hoeffding Tree, and Random Forest exhibiting noteworthy accuracy. The study champions the integration of IoT and machine learning in agriculture, showcasing promising accuracy achievements and potential yield increase alongside waste minimization. In conclusion, it offers valuable insights into the symbiotic relationship between machine learning and agriculture, emphasizing the importance of feature selection and suggesting potential applications in contemporary farming practices. To bolster global food security, the study advocates for intensified research and development in seamlessly integrating machine learning within the agricultural domain.

[3] T. Saraswat's research on crop prediction through the utilization of machine learning and artificial neural networks follows a structured approach consisting of five key phases: data preprocessing, data visualization, training, testing, and model evaluation. The dataset, sourced from Kaggle, is sufficiently extensive to ensure credible performance metrics and encompasses seven vital components influencing crop forecasting. Emphasizing the significance of meticulous data preprocessing, including the handling of missing values, the author employs visual aids like heatmaps and histograms to enhance understanding. Various classifiers, including Random Forest and Artificial Neural Networks, are applied for both model training and testing, implementing an 80:20 train-test split. The paper's conclusion underscores the effectiveness of the algorithms in predicting crops across multiple locations in India, emphasizing the role of soil and atmospheric variables.

[4] This study delves into soil health data from 94 villages in Vellore, India, during the 2018-2019 academic year. Multivariate analysis techniques like correlation, regression, principal component analysis (PCA), and analysis of variance (ANOVA) are employed to understand the interconnectedness and influence of various soil factors on agricultural yield. Soil data encompasses pH, electrical conductivity, organic carbon, macronutrients (nitrogen, phosphorus, and potassium), and micronutrients (copper, iron, manganese, zinc, sulfur, and boron). Leveraging SPSS software, the study aims to predict soil elements that optimize yield. Key findings suggest prioritizing crops suited for moderately alkaline soil pH for improved productivity. Regression analysis explores the impact of pH on electrical conductivity, organic carbon, and macronutrients, while correlation matrix analysis unveils relationships between various soil variables. ANOVA results confirm a linear association between soil pH and these aforementioned factors. The study further emphasizes the significance of pH in guiding crop selection, soil type identification, fertilizer application, and overall crop production. PCA identifies two major components: "Plant growth component" and "Crop nutrition component", explaining roughly 77% of the data's variance. These findings underscore the critical role of comprehending soil health for informed agricultural decisions and implementing sustainable crop management practices.

[5] The research explores the application of machine learning techniques in crop recommendation, specifically focusing on the K-Nearest Neighbor (KNN), Decision Tree Classifier, and Random Forest Classifier methods. The objective of the project is to develop a model capable of suggesting suitable crops based on environmental parameters. The KNN method is chosen for its user-friendly nature and effectiveness in classifying new cases. The Random Forest Classifier enhances overall performance by employing an ensemble of decision trees, while the Decision Tree Classifier uses entropy and the Gini Index to partition datasets. The process involves data collection, preparation, model training, and evaluation using metrics like classification reports, accuracy, and confusion matrix. The results underscore the predictive capabilities of the KNN and Decision Tree classifiers, emphasizing the critical role of accuracy in crop recommendations. The conclusion summarizes the findings and underscores the practicality of the employed machine learning algorithms in agricultural decision-making.

[6] The proposed approach advocates for a holistic strategy utilizing machine learning algorithms to predict the most suitable crop for a specific piece of land, considering both weather and soil conditions. The framework comprises key phases, starting with the collection of data from various sources like VC Form Mandya, government websites, and

APMC websites to establish a comprehensive dataset. Subsequently, redundant attributes are removed and the dataset is split into training and test sets during the data preprocessing phase. For crop prediction, Decision Trees are employed, while Support Vector Machines (SVM) are utilized for rainfall prediction within the supervised machine learning component. Factoring in expected rainfall, soil composition, and meteorological conditions, the system offers crop recommendations and details on required fertilizers, seeds, market costs, and estimated yields. By leveraging machine learning and predictive analytics, this approach empowers farmers to make informed decisions in resource management and crop selection. The system's accuracy and practical utility necessitate further evaluation through additional validation and experimental results, especially in the dynamically evolving fields of precision farming and smart agriculture.

[7] The research titled "Crop Prediction Based on Characteristics of Agricultural Environment" explores a comprehensive approach that considers various agricultural and environmental factors to determine optimal crops for cultivation. The study utilizes a substantial dataset sourced from diverse outlets, including government datasets and Kaggle, covering crucial aspects like soil nutrients, pH levels, and weather conditions. The preprocessing phase addresses dataset imbalances and enhances prediction performance through techniques like ROSE, SMOTE, and MWMOTE. The research evaluates three feature selection methods—Boruta, Recursive Feature Elimination (RFE), and Modified RFE—and their contributions to identifying relevant features for accurate predictions. Multiple classification methods, including Naïve Bayes, Decision Trees, Support Vector Machine (SVM), K-Nearest Neighbor (KNN), Bagging, and Random Forest, are investigated for crop prediction. The authors emphasize the application of these strategies in addressing issues like feature selection, crop yield prediction, and imbalanced datasets. The study particularly scrutinizes the Random Forest method due to its effectiveness in ensemble learning, exploring its applications in predicting pest attacks and optimizing agricultural water usage. In summary, the research provides a comprehensive analysis of approaches for crop prediction based on agricultural environmental features, highlighting the benefits and applications of various machine learning strategies in agriculture.

[8] In the context of agriculture in Maharashtra, the author discusses the development and implementation of a system designed for predicting crops and analyzing soil. The authors emphasize the diverse soil types in the region and the importance of assessing soil fertility based on concentrations of hydrogen ions (H+), nitrogen (N), phosphorus (P), and potassium (K). Dissatisfied with traditional crop prediction methods, the authors propose an automated soil testing system that predicts crops by analyzing soil samples. The publication reviews a study encompassing soil nutrient analysis, soil classification algorithms, and the monitoring of environmental parameters like temperature, humidity, and moisture. The suggested system involves continuous monitoring and analysis of soil conditions using sensors, cloud computing, and the Internet of Things. It features a user-friendly application interfacing with the Internet of Things cloud to provide precise data on moisture and temperature. The authors conducted tests using temperature and soil moisture sensors, employing various algorithms, including Logistic, NaiveBayes, and C4.5, to assess the findings. The C4.5 algorithm demonstrated notable accuracy. Additionally, the paper explores the impact of rainfall on crop prediction using a dataset from the Thane district. The conclusion highlights the accuracy and efficiency of the proposed system in enhancing agricultural productivity and optimizing resource allocation.

[9] The study outlines a comprehensive approach to crop prediction through the integration of artificial neural networks and machine learning, utilizing three distinct datasets: yield, crop, and soil datasets. The Soil Dataset incorporates 15 attributes, including pH, EC, OC, N, P, K, and others, to facilitate the classification of soil fertility using machine learning models. The Crop Dataset, comprising features like temperature, humidity, pH, and rainfall, is employed for predicting crop types using various classification algorithms. Additionally, the Yield Dataset, containing attributes such as pH, temperature, organic carbon, nitrogen, phosphorus, potassium, and pH, is utilized for yield prediction through regression approaches. For each prediction task, the authors provide a flow diagram illustrating the application of machine learning methods, including regression models, Support Vector Machines, Naïve Bayes, and Random Forest. The research underscores the importance of achieving high accuracy in both crop type prediction and soil fertility categorization, with Random Forest identified as the recommended model. Furthermore, the authors explore the application of artificial neural networks (ANN) in predicting soil fertility, achieving a notable 98% accuracy rate. In summary, the study offers a systematic and detailed method for leveraging machine learning and neural networks to generate comprehensive agricultural predictions, emphasizing their dependence on soil and environmental data.

[10] The author introduces IoTSNA-CR, an IoT-enabled precision agriculture model for soil nutrient classification and crop recommendations. The model encompasses processes such as data collection through sensors, cloud storage, crop recommendation, and MSVM-based classification with FFO-based parameter optimization. Data is gathered from fields using an ESP8266 Wi-Fi module, an Arduino micro-controller, and various sensors including moisture, temperature, GPS, LDR soil color, and pH. Nutrient assessment involves analyzing data that includes soil parameters, pH readings, and RGB color values. The MSVM model is optimized using the FFO algorithm for precise soil characterization and crop recommendations. Emphasizing the importance of real-time data collection from diverse crop fields and geographic regions, the study employs cloud services for efficient data storage and retrieval. The paper addresses challenges related to data storage, crop prediction, and the necessity for regular data cleansing. The third stage of data pre-processing involves preparing the collected data for machine learning model training through cleaning, transforming, and normalizing. The dataset is used to train the MSVM-DAG-FFO classifier, and real-time monitoring is established to continuously analyze soil nutrient data. The paper concludes by discussing the integration of cloud services, challenges faced, and the application of machine learning models for crop recommendation and soil nutrient analysis. The main focus of the article is on the integration of cloud services, machine learning algorithms, and IoT technologies in precision agriculture. The strategy involves using various sensors for data collection, employing cloud storage for effective data management, and utilizing the MSVM-DAG-FFO classifier for accurate soil nutrient classification and crop recommendations. The paper also addresses challenges related to real-time data collection, storage, and accurate predictions.

[11] This research delves into the importance of soil testing for customized fertilizer, focusing particularly on conventional soil NPK testing methods. Typically, these methods consist of three stages: soil sampling, sample pre-treatment, and chemical analysis. Soil sampling involves physically collecting representative soil samples at the appropriate depth in the field. Subsequently, chemical analysis is conducted using various technologies, including conductivity measurement, optical techniques, and electrochemical sensors. The author developed a sensor for NPK measurement based on multimode optical fibers. The sensor probe has a concentric configuration of seven fibers, with one receiving fiber in the center and six sending fibers around it. The sensor operates on a colorimetric approach, utilizing different colored LEDs to emit light with uniform intensity through a soil sample. The reflected light is collected by the receiving fiber, and the output is converted into an electrical signal. This electrical output is then calibrated in terms of deficient component values using a standard color chart. The experimental procedure involves creating aqueous solutions of soil samples with known NPK values, and the sensor is tested with various soil samples. Optimization of the distance between the sensor probe and reflector is conducted. The results show that the sensor output varies with different soil samples, and the data are compared with threshold values stored in a microcontroller.

[12] To enhance crop productivity, the paper introduces a comprehensive agricultural monitoring system designed to assess the nitrogen-phosphorus-potassium (NPK) ratio in the soil. This proposed system integrates soil image processing, communication, and sensor modules. Image processing methods, particularly the Gray-Level Co-occurrence Matrix (GLCM), are employed to analyze color, texture, and shape attributes for identifying soil conditions. Thirteen feature qualities are utilized to classify data through the Support Vector Machine (SVM) technique. The system effectively detects the NPK ratio and provides information on soil moisture, humidity, and pH levels. The results align with expectations, showcasing the system's ability to monitor and offer insights into variables influencing plant growth. Future enhancements include refining NPK ratio detection, developing a farmer-focused mobile app, and exploring wireless sensor networks (WSN) and solar energy concepts. The proposed system holds the potential to advance both conventional crop management techniques and precision agriculture.

[13] The proposed method in this study aims to predict the optimal crop for cultivation through a comprehensive approach that integrates weather parameters (temperature, humidity, rainfall, and pH) with soil characteristics. The methodology involves a systematic data collection process from diverse sources, including government datasets, Kaggle, and private data, encompassing crucial aspects like pH levels, climatic conditions, and soil nutrients (potassium, phosphorus, and nitrogen). Python libraries are employed to analyze the gathered data, enabling pattern and trend analysis crucial for model training. In the preprocessing phase, the dataset undergoes cleaning, missing value filling, and organization into separate tables. Feature scaling is applied to ensure uniform scales for different characteristics, thereby enhancing model accuracy. After exploring various machine learning algorithms such as KNN, Decision Tree, and Random Forest, the author opts for the Decision Tree approach for crop prediction due to its higher accuracy. Visualizations like pair plots, join plots, box plots, and heat maps are utilized in the findings and discussions section to illustrate the system's effectiveness and showcase the Decision Tree's capability to accurately predict crops based on important characteristics like temperature, humidity, and rainfall.

[14] The researcher explored the application of image processing in soil characterization, incorporating digital imaging for assessing texture and moisture while employing supervised learning algorithms to analyze soil composition. The inclusion of remote sensing data enhances the evaluation of soil properties, contributing to more accurate predictions of crop suitability. Additionally, the author developed customized machine learning models for crop prediction, considering both climate data and soil properties. The study delved into challenges such as data quality and model interpretability, discussing the potential and hurdles in implementing this technology. Overall, the case study illustrated the capability of these integrated techniques to empower farmers in making informed decisions for crop planning and yield improvement, offering valuable insights into the utilization of technology in agriculture.

[15] The research delves into the examination of soil data, employing regression and classification methods to predict soil properties for effective agricultural decision-making. Utilizing data sourced from soil testing facilities in Pune District, the authors underscore the necessity for automated systems in soil classification and propose Naive Bayes, J48, and JRip as viable options. They emphasize the critical importance of accurate soil categorization in guiding crop selection and recommending appropriate fertilizers based on fertility levels. In the pursuit of creating a fertilizer recommendation system for soil testing laboratories, the study explores regression approaches such as least median squares regression for forecasting soil properties. In essence, the research provides a comprehensive analysis of soil data analysis with implications for enhancing crop productivity and resource efficiency in precision agriculture applications.

III. LITERATURE SURVEY TABLE

Sl. No	Research Paper Title	Publication Year	Techniques/Algorithms used	Findings
1	Soil Analysis and Crop Fertility Prediction	2018	Using handheld device which is build using pH meter	Implementation of automated soil testing method using a handheld device which will determine the pH of that soil. Then on basis of pH, values of nutrients i.e. NPK present in soil are given
2	Crop Prediction Model Using Machine Learning Algorithms	2023	Random Forest, Multilayer Neural Network, Naïve Bayes	The dataset, incorporating features like temperature, humidity, pH, and precipitation, achieved a remarkable 97.05% accuracy with Bayes Net and a slightly higher 97.32% accuracy with Random Forest.
3	Crop Prediction Using Machine Learning and Artificial Neural Network	2023	Decision tree classifier, Naïve Bayes, Gradient Booster, Logistic Regression and ANN	The algorithms have a limitation – they require a dataset with a significantly large number of entries for optimal performance. A lack of sufficient data entries can lead to lower performance measures.
4	Prediction of soil reaction (ph) and soil nutrients using multivariate statistics techniques	2020	Data analysis, correlation analysis, Anova methods and regression analysis	The results demonstrate that the soil test data analysis method is effective in predicting suitable crops for specific fields.

5	Crop prediction using machine learning	2021	KNN, Decision tree algorithm, Random forest classifier	The Random Forest Classifier, using both Entropy and Gini Criterion, demonstrated the highest accuracy among the three models, reaching 99.32%.
6	Crop Prediction using Machine Learning Approaches	2020	SVM algorithm, Decision tree algorithm.	The system's recommendation of suitable crops, along with detailed information such as required seeds, market price, and approximate yield, suggests practical applications in agriculture for informed decision-making.
7	Crop Prediction Based on Characteristics of the Agricultural Environment	2022	Random Forest, KNN, SVM, Decision Tree, Naïve Bayes	Employing modern forecasting techniques in agriculture can lead to measurable financial benefits.
8	Soil Analysis and Crop Prediction	2020	Naïve Bayes, Logistic Regression	The project integrates Arduino and Cloud Computing for soil analysis, indicating a technological approach for enhancing agricultural practices.
9	Soil analysis and crop fertility prediction using machine learning	2021	Data analysis, SVC, Random Forest, Naïve Bayes, Logistic Regression	Among all classifiers, the Artificial Neural Network (ANN) demonstrated the highest accuracy in soil fertility prediction, crop prediction, and crop yield prediction.
10	IoT-Enabled Soil Nutrient Analysis and Crop Recommendation Model for Precision Agriculture	2023	IoT Sensory system, Data Pre-processing and analysis, MSVM-DAG-FFO	The proposed MSVM-DAG-FFO algorithm enables farmers to access and analyse pre-processed soil data, tuning the MSVM model through the selection of kernel functions.
11	Detection of NPK nutrients of soil using Fiber Optic Sensor	2015	NPK Sensors	The sensor operates based on colorimetric principle, where the absorption of light by a solution leads to variations in the sensor's output.
12	Detection of NPK Ratio Level Using SVM Algorithm And Smart Agro Sensor System	2017	SVM Algorithm, Image Processing, NPK Sensors	The images are classified using a support vector machine (SVM) classifier, indicating the use of machine learning for image classification.
13	Crop Prediction using Machine Learning	2023	KNN, Decision Tree and Random forest	The model is designed to learn from past data, utilizing machine learning algorithms to improve its predictive capabilities over time.
14	Soil Analysis for Suitable Crop Prediction using Machine Learning and Image Processing	2021	Convolutional neural network (CNN) Algorithm	The use of CNN and ANN algorithms indicates a sophisticated and data-driven approach to enhance the accuracy of the framework.

15	Soil classification and crop suggestion using machine learning	2020	Naive Bayes, J48, JRip algorithms	The primary focus of the paper is on the analysis of soil data using various algorithms and prediction techniques.The paper specifies the use of algorithms such as Linear Regression and Least Median Square Regression for the analysis.

IV. CONCLUSION

This literature survey navigated through soil analysis, environmental parameters, and machine learning applications in agriculture, leading to the exploration of the project "Precision Crop Prediction using Soil and Environmental Analysis." The project shows the transformative role of technology in revolutionizing farming practices, addressing traditional soil testing limitations and streamlining the testing process. Environmental factors emerged as crucial influencers, and the project aims toprovide comprehensive insights by incorporating them into predictive models. The survey reveals the exponential growth of machine learning in agriculture, with the project aligning with industry trends to empower farmers with sophisticated tools for informed decision-making. The proposed system not only predicts optimal crops but also estimates yield and market prices, enhancing overall farming efficiency. In conclusion, the survey highlighted the dynamic nature of current agricultural research, and the project stands as a testament to this evolution, promising a future of precision farming, sustainability, and increased global food security.

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