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Predictive Analysis of Sugarcane Pathogens: A Machine Learning Approach

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Abstract : Sugarcane cultivation is vital for the global sugar industry, but it is threatened by various pathogens that can cause significant yield losses. Predictive analysis techniques, especially machine learning, offer a promising approach to mitigating the impact of these pathogens on sugarcane production. In this study, we propose a machine learning-based predictive analysis framework for identifying and predicting the occurrence of sugarcane pathogens. The framework involves collecting and analyzing large datasets of environmental variables, disease incidence rates, and other relevant factors to develop accurate predictive models. Various machine learning algorithms are employed to train these models and predict the likelihood of pathogen outbreaks. Through the integration of advanced analytics techniques, such as feature selection and ensemble learning, our framework aims to improve the accuracy and reliability of predictions. The results demonstrate the potential of machine learning in enhancing the management of sugarcane pathogens, enabling timely interventions and increasing the overall resilience of sugarcane crops to disease outbreaks. This research contributes to the growing body of knowledge on precision agriculture and demonstrates the capability of machine learning in addressing complex agricultural challenge.

***IndexTerms* - Sugarcane, Cultivation, Detection, Analysis, Machine Learning.**

I. Introduction

Agriculture in India is shaped by a multitude of factors such as geography, climate, history, institutions, politics, biological development, and socio-economic conditions. The production of agriculture is primarily influenced by environmental factors. Over millions of years, agriculture has served as a crucial natural food source for both humans and animals. In the present day, agriculture not only plays a vital role in food supply but also contributes significantly to a country's economic development by providing employment opportunities. Agriculture is the foundation of the Indian economy, with more than 50% of the workforce engaged in this sector, contributing around 17-18% to the country's GDP. However, the extensive commercialization of farming has had adverse effects on the current situation. India, known as the birthplace of sugarcane and sugar production, is the second largest producer of sugar globally, following Brazil. Sugarcane, a key commercial crop in the country, is planted annually from January to March and serves as a major cost driver for sugar production. India leads in sugarcane cultivation globally in terms of area (3.93 million hectares) and ranks second in production (167 million metric tons). Sugarcane is a crucial cash crop in India, playing a significant role in both the agricultural and industrial sectors of the tropical and subtropical regions of the country. The chart below illustrates the regions and states in India where sugarcane is produced.

Table 1. Cultivation of Sugarcane in Indian States

REGION	STATES
Subtropical	Uttar Pradesh, Bihar, Haryana
Tropical	Maharashtra, Gujarat, Tamil Nadu, Andhra Pradesh, Karnataka

Sugar production is categorized into three classes based on capacity across various states in India. Maharashtra and Uttar Pradesh are classified as high sugar producing states. Andhra Pradesh, Gujarat, Tamil Nadu, Haryana, and Karnataka fall under the medium sugar producing category. The remaining states, such as Bihar, Assam, and others like Andaman and Nicobar Islands, Chhattisgarh, Himachal Pradesh, and Jammu and Kashmir, have minimal sugar production. Machine learning, specifically deep learning, is a technique that focuses on learning multiple representation layers simultaneously. It has been utilized in some studies to classify and diagnose plant diseases, using algorithms like Filter and SVM. Machine learning can help farmers in various ways such as identifying areas of contamination, optimizing irrigation plans, and determining the best crops to plant based on market demand and environmental factors. By analyzing historical market data and weather patterns, machine learning models can predict crop demand and suggest optimal planting strategies. Application of AI in agriculture provides real-time insights to farmers, helping them make informed decisions regarding irrigation, fertilization, and pest control. Innovation in farming practices, like vertical agriculture, aims to increase food production while minimizing resource use. The growing global population, expected to reach 10 billion by 2050, puts pressure on the agricultural sector to enhance crop production. AI technology in farming can lead to precision agriculture, maximizing yields with minimal resources. As the agricultural landscape evolves to address challenges such as limited land, labor shortages, and environmental issues, modern technologies like AI and machine learning play a crucial role in improving farming efficiency. Intellias, with over 20 years of experience in the agricultural sector, focuses on developing innovative solutions for quality control and compliance. This narrative supports the utilization of machine learning for detecting sugarcane diseases, demonstrating how such technology can help farmers in various aspects of improving crop health and soil quality.

II. LITERATURE SURVEY

Sugarcane is a prominent crop grown in numerous tropical and subtropical regions worldwide, primarily for sugar production and with applications in biofuels and other products. Detection of sugarcane diseases involves the identification and diagnosis of illnesses that impact sugarcane crops. Given its importance in sugar and product production, diseases can significantly affect the industry economically. Early detection and control of these diseases are essential to reduce crop damage and losses. Amarasingam and et.al[1] introduced machine learning methods using UAV Multispectral Images to identify white leaf disease in sugarcane. They conducted a detailed evaluation of the classification performance of four machine learning methods (XGB, RF, DT, KNN) from various perspectives, assessing classification accuracies at both pixel scale and for identified infection areas. XGB and RF emerged as strong performers in classification. Their findings provide insights for sugarcane plantation management by enabling the precise identification of infected areas in the fields. Sathiamoorthy and et.al [2] introduced Data Mining techniques for detecting sugarcane diseases, analyzing the performance of machine learning techniques in predicting sugarcane disease based on time measures. Techniques such as Multilayer perceptron, J48 pruned trees, and the k-means clustering algorithm were utilized for predicting sugarcane leaf diseases using the Weka tool, demonstrating promising results. On the other hand, Militante and co-authors [3] introduced a Deep Learning approach for identifying sugarcane diseases. Deep learning employs an artificial neural network architecture with multiple layers, unlike traditional neural networks. In this study, researchers utilized Convolutional Neural Networks (CNNs) as the fundamental deep learning approach. The study aimed to apply deep learning to differentiate between diseased and healthy sugarcane leaves. Sammed et al.[4] implemented a simple convolutional neural network with four discrete classes to identify sugarcane diseases. The model was trained to classify sugarcane images into healthy and unhealthy categories based on leaf patterns and diseases. The system was developed as a web application. Arifa et al.[5] utilized an Image Processing method for disease detection in sugarcane leaves. They used a computer vision-based technique to detect leaf diseases in sugarcane plants, employing image processing and k-means classification to categorize the leaf dataset based on diseases. The authors compared the leaf image with a database to identify the specific disease in the plant. Rutuja et al.[6] explored image processing and machine learning techniques for accurate identification and diagnosis of sugarcane diseases. The authors analyzed the performance of various approaches including CNN, K-means clustering, SVM, Deep learning, and image processing techniques. Kishore et al.[7] discovered that the distribution of diseases in sugarcane crops was primarily impacted by factors such as weather conditions, cultivated genotypes, and the practice of ratooning. Dutta[8] conducted a survey program over a span of four years in Assam, finding that sugarcane diseases caused yield losses of approximately 10-15%. Evy et al.[9] conducted research on the detection and severity assessment of sugarcane leaf diseases using segmented spot images. Different research methods such as Disease Identification, Data Acquisition, Image Processing Techniques, and Classification Methods were employed. Prince et al.[10] developed a sugarcane disease detection model in 2021 utilizing image processing and Deep learning through Convolutional Neural Networks (CNN). Minbo et al.[11] discussed a wavelet-based method for recognizing sugarcane stem nodes to enhance pre-cut sugarcane planting technology for automated sugarcane seed production. Sammy et al.[12] mentioned the use of Adaptive Deep Learning models of CNN for detecting sugarcane diseases. Three deep learning models utilized in this research for the detection and identification of sugarcane leaf diseases are StriedNet, LeNet, and VGG. These models were implemented using the Keras and OpenCV frameworks for machine learning computation. The study's architecture involves a comparison of these three models to determine which one is most effective in categorizing and identifying sugarcane leaf diseases. This research serves as a valuable decision-making tool to aid farmers in recognizing and diagnosing various sugarcane diseases presented in the study. Manavalan[13] conducted a survey involving different image processing techniques for analyzing sugarcane, extracting essential features for disease classification, and supporting diagnostic decision-making. Another study by Sammy et al.[14] explored the application of five deep learning models, including StriedNet, AlexNet, LeNet, VGGNet, and GoogleNet Models, to detect and differentiate between six classes of sugarcane leaf diseases along with a healthy category. Their research offers insights into aiding farmers in identifying and distinguishing sugarcane diseases effectively. Similarly, Priscila and co authors[15] proposed a deep learning-based classification methodology for differentiating sugarcane varieties. By utilizing neural networks, they successfully classified four Brazilian sugarcane varieties using remote sensing data, enabling plant monitoring without physical interaction with the study subjects. This study sought to utilize deep neural networks to classify four different sugarcane varieties, and then compare these results with a traditional machine learning technique. Thangadurai[16] and colleagues developed an Internet of Things (IoT) based technique for detecting diseases in sugarcane plants. The accuracy of disease severity measurement depends on accurately segmenting images due to the varying symptoms of the plant at different disease stages. This research could provide valuable insights for researchers seeking new solutions in agriculture, as well as for agricultural industries aiming to enhance automation processes for better outcomes. Thilagavathi[17] and team employed image processing techniques for disease detection in sugarcane, developing surveillance methods to identify and classify diseases using leaf images. Their work offers an overview of sugarcane diseases, causes, and symptoms, along with a web application designed to assist farmers in implementing the system effectively. ANIL KUMAR[18] introduced an innovative approach to identify various sugarcane leaf spot diseases, including rust spot, yellow spot, ring spot, and emerging diseases like whitefly. Their research also involves effective pesticide spraying mechanisms using embedded systems and IoT technology, successfully detecting diseases such as Whitefly, Mosaic disease (Yellow spot), and Eyespot. Additionally, they designed an automated irrigation system leveraging OpenCV for sugarcane plant disease identification. Additionally, they offer the monitoring of environmental factors such as temperature and humidity, allowing users to adjust pesticide application by activating or deactivating the motor as needed. Swapnil and et.al [19] proposed various methods and datasets, comparing different plant types such as Strawberry, Mango, Citrus, and Apple. They utilized deep neural network variants tailored to each plant type, aiding farmers in minimizing losses and enhancing overall production quality. Johnmartin and team [20] presented the Symptoms and Assessment of sugarcane Pokkah Boeng disease, caused by the fungus fusarium sacchari, with potential additional pathogens. They outlined the disease progression in three phases: Chlorotic Phase, Top-Rot Phase, and Knife-Cut Phase, wherein the growing point is killed, leading to plant top mortality. Maheshgouda and Indira [21] employed a Deep Learning Method based on convolutional neural network architectures to identify various crop diseases, assisting farmers in diagnosing and preventing crop losses and offering solutions for affected crops. Deepak and Rama [22] researched major sugarcane diseases and integrated control approaches. Yogesh and Pardeshi [23] examined recent advancements in horticultural automation, focusing on autonomous weed control, field surveillance, and harvesting technologies. Shailendra and team [24] investigated smut disease in sugarcane caused by Sporisorium Scitamieum, also known as carbon disease. Sakshi and et al. [25] implemented a method for classifying and detecting sugarcane disease by utilizing image processing to extract plant features and determine if the plant is diseased. They utilized a novel deep learning approach and employed three different feature extractor models – VGG-16, VGG-19, and Inception V3. Adequate image acquisition and data collection are essential for the proper operation of any deep learning system. Muhammad and et al. [26] identified various factors influencing the cultivation of sugarcane and discussed the factors affecting sugarcane production in Pakistan, as well as strategies for disease and pest management. Their innovative pest management methods are aimed at enhancing crop protection. They also discussed government and non-government initiatives to educate people about sugarcane diseases and pest avoidance. Narmilan and et al. [27] developed an application of deep learning techniques in precision agriculture, particularly focusing on the identification of the White Leaf Disease (WLD) plant in sugarcane fields using UAV imagery. Their methodology provides technical guidelines for precise detection and treatment of WLD. Lastly, Suresh and et al. [28] provided insights into the current status of Yellow Leaf Disease (YLD) of sugarcane caused by the Sugarcane Yellow Leaf Virus (ScYLV) in Andhra Pradesh and Telangana in 2020. A survey was conducted over four planting seasons, annually from 2012 to 2016 to identify the occurrence, distribution, and severity of Yellow Leaf Disease (YLD) in popular commercial sugarcane varieties grown in various sugarcane-growing regions of Andhra Pradesh and Telangana states. The results, based on GIS mapping, clearly illustrate the disease distribution and progression in these regions. Sujeet and et al. [29] reviewed fifty-five sugarcane diseases caused by various microbes such as fungi, bacteria, viruses, phytoplasmas, and nematodes in India. They examined different materials and methods for managing sugarcane diseases in Uttar Pradesh, and discussed the climatic conditions affecting sugarcane from April 2019 to March 2020, including lesser-known diseases. Mumpy and et al. [30] explored how image processing techniques can aid in detecting crop diseases using methods like Image Segmentation, Feature Extraction, and Classification. Krishnamoorthy and et al. [31] conducted research on sugarcane production in India, distinguishing between Subtropical and Tropical regions. They found variations in sugarcane production, attributing low yields to unpredictable monsoon conditions and recommending improved irrigation management practices. Parminder and Kale [32] demonstrated the utility of Landsat-8 for crop identification and mapping through remote sensing images and Multispectral medium-resolution images. Snehal and Jyotismita [33] focused on disease detection by using techniques such as Hidden Markov Model, Anisotropic Diffusion Algorithm, and Convolutional Neural Network with both Static and Dynamic Approaches, offering prevention and treatment strategies. Hassan and Syed [34] explored sugarcane agriculture in Bangladesh, advocating for the use of NDVI from Landsat data and promoting the adoption of remote sensing technologies in the country's agricultural sector to boost productivity and ensure food security.

III. PERFORMANCE ANALYSIS

Figure 1 gives the performance analysis of the three major algorithms used in the literature survey. The table compares the models against 5 epoch values and it has been evident that SVM outperforms the remaining models.

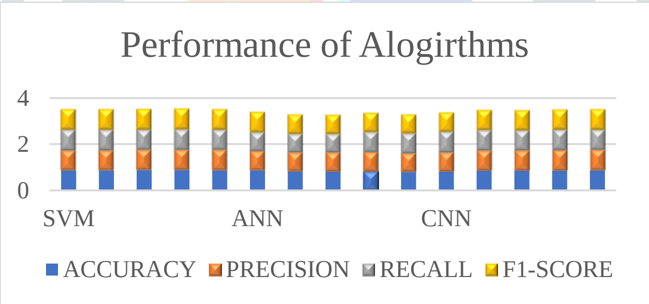

Figure 1. Performance analysis of Algorithms Reviewed

The following table shows the metric values of accuracy, precision, recall and f1-score for ANN, SVM and CNN for epoch values ranging from 10 to 50.

Table 2. Performance Metrics of ANN, SVM and CNN

MODEL	EPOCH	ACCURACY	PRECISION	RECALL	F1-SCORE
SVM	10	0.87	0.85	0.9	0.87
	20	0.87	0.86	0.89	0.87
	30	0.88	0.87	0.88	0.88
	40	0.88	0.88	0.88	0.88
	50	0.87	0.89	0.87	0.87
ANN	10	0.87	0.83	0.82	0.87
	20	0.83	0.82	0.8	0.83
	30	0.82	0.82	0.8	0.82
	40	0.82	0.84	0.87	0.82
	50	0.8	0.8	0.87	0.8
CNN	10	0.82	0.83	0.89	0.82
	20	0.86	0.86	0.89	0.86
	30	0.85	0.87	0.88	0.85
	40	0.86	0.88	0.88	0.86
	50	0.87	0.89	0.87	0.87

IV. CONCLUSION

In conclusion, the utilization of machine learning in predictive analysis for sugarcane pathogen identification and forecasting presents a promising solution to mitigate the threats posed by pathogens to global sugar industry. By leveraging advanced analytics techniques and large datasets, this framework aims to enhance the accuracy of predicting pathogen outbreaks, enabling proactive interventions and bolstering the resilience of sugarcane crops. This research not only contributes to the advancement of precision agriculture but also underscores the potential of machine learning in addressing complex agricultural challenges for sustainable sugarcane cultivation. There is much more scope of development of ML or DL models for predicting the sugarcane diseases.

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