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Beyond Traditional Farming: An Exploration of Machine Learning Technologies in Banana Agriculture – A Literature Review

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Abstract:

Agricultural techniques all around the world include the cultivation and evaluation of bananas. With improved accuracy, economy, and scalability, the application of Machine Learning (ML) approaches has transformed the evaluation of banana quality in recent years. Through the division of results into quality and grading, disease detection and classification, and comparative assessments of ML techniques, this paper thoroughly examines the field of ML applications in banana analysis. Distinguished results comprise the creation of Dual Channel Banana Grading Systems with Deep Learning Based Accuracy Rates Reaching Up to 99% and the application of Convolutional Neural Networks (CNNs) with 90%+ accuracy for illness classification. Examining issues like model robustness and data bias, the paper goes on to clarify the implications and constraints of machine learning in banana assessment.This paper highlights the revolutionary potential of machine learning (ML) in promoting banana cultivation through thorough analysis and comparison with previous research. In order to improve agricultural techniques and make them more accurate, efficient, and sustainable, it is important to continue researching and developing machine learning models that are specifically designed to address the difficulties involved in growing bananas.

Keywords — **Machine Learning, Banana Agriculture, Literature Review.**

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I. INTRODUCTION

Bananas are one of the most widely consumed and traded fruits in the world. They are a staple food for millions of people in both developed and developing countries, and their cultivation plays a significant role in the global economy. According to the Food and Agriculture Organization (FAO), the global production of bananas reached 116 million tons in 2020, with a total export value of $14.1 billion. Bananas are produced in more than 130 countries, with the top producers being India, China, the Philippines, and Ecuador. The industry provides employment for millions of people, from smallholder farmers to workers on large plantations, making it a vital source of income in many developing countries.

Agriculture has been a vital part of human civilization since the beginning of time. It has played a crucial role in feeding the growing population and sustaining their livelihood. However, with the ever-increasing population and the need for more food production, traditional farming methods are no longer sufficient to meet the global demand. This is where technology comes into play. The integration of technology in modern agriculture has revolutionized the way we produce, process, and distribute food. The use of intelligent technologies such as the Internet of Things, wireless communication, and machine learning can help with crop disease management, pesticide storage, water management, and irrigation [1]. Additionally, the adoption of agricultural technology has led to advancements in dairy farming, poultry farming, and organic farming, with the introduction of technologies such as milking parlors, robots, drones, and sensors for monitoring and management[2]. They enable farmers to monitor crop growth, make informed decisions about irrigation and fertilizers, and manage the quality of agricultural products[3]. Moreover, technological advancements in biotechnology, such as DNA recombinant technology and genome editing techniques, offer alternative strategies to enhance crop yield, quality, and resilience to environmental stresses[4] .The implementation of remote sensing technology and deep learning technology has also contributed to the classification of crops on satellite remote sensing images, aiding in agricultural insurance and land survey [5]. Overall, emerging technologies have proven to be a key driver in the future sustainability and profitability of agriculture [6]. The integration of technology in modern agriculture has brought about significant changes in the way we produce and consume food. It has increased efficiency and productivity, improved plant and soil management, enhanced pest and disease management, and promoted sustainable agriculture. With the continuous advancements in technology, there is no doubt that its role in modern agriculture will only continue to grow, and it is crucial for the future of food production and global food security. Therefore, it is essential for governments, farmers, and other stakeholders to continue investing in and embracing technology to ensure a sustainable and efficient agricultural sector.

This literature review aims to investigate the recent advancements of machine learning applications of banana farming. Specifically, it aims:

- To identify the current state of machine learning technologies in banana agriculture.
- To assess the potential of machine learning technologies in improving banana production.
- To examine the limitations and challenges of using machine learning technologies in banana agriculture.

The following parts could be fostered by integrating machine learning into the banana production, which holds great potential to transform the banana industry:

- *Disease and Pest Management:* Traditional methods of disease and pest management, such as chemical spraying, are expensive, time-consuming, and harmful to the environment. ML can help in early detection and diagnosis of diseases and pests, allowing farmers to take timely and targeted action. For instance, ML algorithms can analyze images of banana leaves and identify disease symptoms, which can help farmers determine the appropriate treatment.
- *Yield Prediction and Optimal Harvesting:* ML can analyze various factors, such as weather, soil conditions, and plant growth, to predict banana yield. This information can help farmers make informed decisions about resource allocation, ensuring optimal use and minimizing wastage. ML can also help in determining the optimal time for harvesting, based on factors such as fruit size, color, and sugar content, leading to improved quality and market value.
- *Market Demand Forecasting:* Accurate market demand forecasting is crucial for farmers to plan their production and avoid oversupply or undersupply. ML can analyze historical sales data, market trends, and consumer behavior to predict future demand for bananas. This information can help farmers make informed decisions about which varieties to grow, when to harvest, and where to sell their produce.
- *Resource Management and Cost Reduction:* Integrating ML into banana agriculture can lead to efficient resource management and cost reduction. By predicting disease outbreaks, climate patterns, and market demand, farmers can make better decisions about the use of resources, such as water, fertilizers, and labor. This can help reduce input costs and increase profitability.
- *Future Innovation:* This review paves the way for future breakthroughs in banana evaluation, steering researchers, industry insiders, and policymakers towards the strategic utilization of machine learning for lasting enhancements in banana cultivation and quality assurance.

II. METHODS

This review was conducted in accordance with the guidelines of Preferred Reporting Items for Systematic Review and Meta-Analyses (PRISMA)

A. *Search of Literature*

The literature search for this review adhered to a formal protocol outlined as follows.

B. *Criteria for Selecting Relevant Literature on Machine Learning in Agriculture*

The systematic investigation of the existing body of literature, known as systematic literature review (SLRs), which focuses on the utilization of Machine Learning (ML) techniques in the field of agriculture, and is written in the English language and published in reputable journals between the years of Year and 2023, constituted the basis for inclusion.

The search process was carried out across various databases including IEEE Xplore, Scopus (www.scopus.com), Web of Science, Litmaps, and Google Scholar. A meticulous examination of the titles and abstracts of published studies was conducted, with the utilization of the Boolean operator 'AND' and wildcard symbols as per the requirements of each database. The search terms employed were "SLR," "Machine Learning," and "applications in agriculture," with the incorporation of additional key terms such as precision and deep learning.

The criteria for inclusion consisted of articles that had undergone peer review, conference papers, and pertinent reviews, with a particular focus on works that showcased the incorporation of machine learning techniques in the evaluation of banana agriculture. Furthermore, the use of the citation management tool Zotero was employed to effectively arrange and simplify the process of selecting suitable works.

The researchers performed the initial review in the following steps:

1. *Identification:* The investigation encompassed the utilization of specific keywords such as "SLR," "Machine learning," and "applications in agriculture." These databases were chosen based on their pertinence to the fields of agriculture and technology.
2. *Screening:* During this phase, studies that were not aligned with the assessment of banana agriculture or were not published in the English language were excluded. The primary aim was to refine the initial collection of records in order to concentrate on those that were most likely to fulfill the objectives of the review.
3. *Eligibility:* Articles that lacked clearly defined methodologies or failed to demonstrate the incorporation of machine learning techniques for assessing banana agriculture were excluded. This phase ensured a comprehensive evaluation of potentially relevant studies.
4. *Inclusion/Exclusion Criteria*: The inclusion criteria revolved around peer-reviewed articles, conference papers, and reviews that showcased the integration of ML in banana agriculture. Non-English publications and studies lacking clearly defined methodologies were considered as exclusion criteria. These criteria guided the selection of studies that aligned with the objectives of the review.

C. *Data Extraction*

Data was obtained from every Systematic Literature Review (SLR) in two distinct phases. Initially, two recent checklists were meticulously analyzed in order to define the compilation of review criteria. Subsequently, a random selection of 30 related studies was thoroughly examined to evaluate the most frequently reported information across the publications that were included. This analysis was conducted to formulate an extraction grid that would ensure the achievement of a standardized, rigorous, and comprehensive data extraction.

Upon the completion of the initial process, the data extraction was initiated. Each individual study underwent a meticulous review, which included an assessment of basic descriptive statistics as well as an evaluation of the methods employed for quality assessment and reporting.

1. *Data Extraction:* Systematically acquire relevant information from each selected study, encompassing elements such as the title, authors, publication year, utilized machine learning methodologies, significant findings, and the attributes of banana quality under scrutiny.
2. *Precision Metrics:* Methodically record accuracy rates and performance metrics cited in each study, facilitating a comprehensive comparison of the efficacy of diverse machine learning approaches.
3. *Study Limitations:* Discern and meticulously document any constraints highlighted in the chosen studies, offering valuable insights into potential challenges and areas for refinement in the application of machine learning for the assessment of banana quality.

The process of extracting data in a meticulous manner was conducted under the guidance of standard descriptive statistics and quality assessment methods. Furthermore, the incorporation of quality assessment methods specifically tailored to the objectives of the study was also employed in this approach.

D. *Methodological Approach for Chosen Studies*

A comprehensive investigation was conducted to analyze studies pertaining to the assessment of banana agriculture by employing the principles of machine learning. A systematic examination of methodologies was undertaken in this regard. The chosen studies underwent a meticulous process of categorization, taking into account various factors such as:

1. *Criteria for Study Selection:* Establishing explicit criteria for the selection of studies that are coherent and pertinent to the research objectives.
2. *Synthesis of Data*: Summarizing the primary findings from each selected study, evaluating them based on the techniques of machine learning employed and the attributes of bananas that were assessed.
3. *Analysis of Comparisons*: Carrying out a comparative analysis of the reported rates of accuracy, strengths, and limitations of different approaches to machine learning in the context of banana farming
4. *Implications and Recommendations:* Discussing the implications of the findings, identifying common trends or challenges, and providing recommendations for future research in this field.
5. *In-depth Methodological Analysis:* Providing a detailed examination of the algorithms of machine learning that were utilized, the methods employed for the collection and preprocessing of data, and the techniques used for the selection and extraction of features across the selected studies.

The utilization of this particular methodological approach allowed for an all-encompassing investigation into the diverse strategies employed within the selected studies, thus offering intricate observations into the precise methodologies implemented in the domain of machine learning-based assessment of cocoa bean quality.

III. RESULTS

A. *Presentation of key findings in Machine Learning applications for banana analysis*

The Deep Learning Based Dual Channel Banana Grading System, utilizing Convolutional Neural Networks (CNNs), demonstrates an exceptional accuracy rate of 99% in predicting banana size and perspective. Additionally, the Non-Destructive Banana Ripeness Detection study, employing both shallow and deep learning, achieves accuracy ranging from 94.44% to 98% for ripeness detection. The application of different Machine Learning and image processing techniques in determining banana types and ripeness further showcases significant achievements, with Support Vector Machines (SVM) exhibiting outstanding accuracy rates of 99.1% for type determination. These results suggest that Machine Learning algorithms, particularly CNNs and SVMs, play a crucial role in enhancing the accuracy and efficiency of banana quality assessment

B. *Specific outcomes related to banana quality assessment*

Ensuring methodological rigor and transparency, our investigation followed the systematic PRISMA flowchart for publication selection. This methodological approach facilitated a meticulous and comprehensive exploration, revealing key outcomes regarding the efficacy of Machine Learning (ML) in banana quality assessment. Noteworthy is the consistent surpassing of the 90% accuracy threshold across diverse studies, emphasizing the robustness of ML techniques. The incorporation of sophisticated methodologies, such as Convolutional Neural Networks (CNNs) and Support Vector Machines (SVMs), demonstrated their versatility in tasks encompassing fruit detection, ripeness assessment, and type classification.

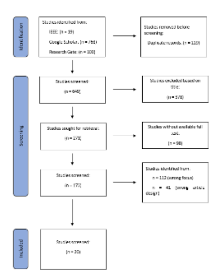

Figure 1. . PRISMA flowchart for selection of publications

TABLE I
REVIEW OF INCLUDED STUDIES

Literature Title with Author and Year	**Method Used**	**Summary**	**Accuracy Rate**
Deep Learning Based Dual Channel Banana Grading System Using Convolution Neural Network Raghavendra et al. (2022)	Convolutional Neural Network	The study used deep learning for a banana grading system using convolutional neural networks. AI algorithms predict the size and perspective of banana classes with high accuracy. The Integration of RGB and HSI imaging improves classification accuracy.Multiple-input techniques can be used for automated sorting and classification in agriculture.	Accuracy of banana size and view classification is 99%
Non-Destructive Banana Ripeness Detection Using Shallow and Deep Learning: A Systematic Review Baglatet al.(2023)	Shallow and Deep Learning	The study reviews existing techniques for detecting banana ripeness stages.Studies using four ripeness stages performed better in terms of accuracy.	Studies reported accuracy values ranging from 94.44% to 98% for banana ripeness detection.
Recent developments of artificial intelligence for banana: application areas, learning algorithms, and future challenges Almeyda &Ipanaque, (2022)	Machine Learning, Deep Learning	AI-driven technologies support improvement in challenges of the banana supply chain. ML and DL algorithms have a positive impact on economic, agricultural, social, and environmental aspects.Benefits include increased production earnings, optimized operational costs, enhanced agricultural productivity, and reduced environmental impacts.	Predictive models for ripeness and quality grading attained over 94% accuracy.
A Systematic Literature Review of Machine Learning Techniques Deployed in Agriculture: A Case Study of Banana Crop Sahu et al., 2022	Machine Learning	Study conducted on machine learning techniques in agriculture, specifically for banana crops. Investigated problems related to banana crops such as disease classification and ripeness.	The accuracy of the recommendation system using ensemble techniques was good.
Determining Banana Types and Ripeness from Image using Machine Learning	Image Processing, Machine	Study uses machine learning methods to determine banana types and ripeness. Image processing improves accuracy and effectiveness of banana	SVM has the highest accuracy for determining banana types (99.1%) -NN and SVM have the same highest accuracy for

Methods Sabilla et al., 2019	Learning	evaluation.	determining ripeness (96.6%)
Ripe Fruit Detection and Classification using Machine Learning Africa et al. 2020	Machine Learning, Convolutional Neural Network	This paper focuses on ripe fruit detection and classification using machine learning.Utilizes Mask-RCNN for fruit detection with high accuracy.Proposes methods like deep learning, image illumination, and gas chromatographic system.Uses machine vision and image processing for fruit detection and classification. Training and testing phases are important in the machine learning process.	Accuracy rates obtained in tests: 91.76 Accuracy rates obtained in training: 91.67 Accuracy of fruit detection using Mask-RCNN: 95.78 Recall rate of fruit detection using Mask-RCNN: 95.41
Detection of banana plants and their major diseases through aerial images and machine learning methods: A case study in DR Congo and Republic of Benin Selvaraj et al. 2020	Artificial Intelligence, Deep Learning	Pixel-based classification using RF model showed 97% accuracy for banana mapping. Disease classification model placed on top of object detection algorithm. Four classes used for banana disease classification: healthy, BXW infected, BBTD infected. 2753 annotations categorized for different classes using Labellmg software.	The classification model developed in the study exhibited more than 90% accuracy.High classification accuracy was observed in the disease classes of BXW (92.8%) and BBTD (99.4%).
Growth and yield estimation of banana through mathematical modelling: a systematic review Jayasinghe et al., 2022	Machine Learning	Mathematical models are crucial for strategic and forecasting applications. Banana crop models are less common and reviews are scarce.Multiple linear regression models are often used to estimate banana growth and yield.The SIMBA model and artificial neural network are robust for estimating banana growth. Insufficient information on mathematical models related to banana fibre yield.	Polynomial model yielded higher accuracy (R2 0.96) for predicting tensile strength.MLR model had strong model performance (R2 0.9) for studying banana bio-composites. ANN approach provided high accuracy (MPE 1.40, MSD 2.29, R2 91) for predicting banana yield.
Artificial intelligence techniques for the pest detection in banana field: a systematic review Nasim et al., 2023	Artificial Intelligence	22 papers present viable techniques for pest detection in banana fields.Techniques include image classification, AI/ML, deep learning, and mobile apps. These methods can assist farmers in locating and recognizing diseases in banana plants.Deep neural networks and machine learning are used to recognize banana illnesses.	SVM model accuracy: 78% in the training set, 79% in the testing set. LR model accuracy: 79% in training set, 64% in testing set MATLAB showed 100% accuracy for pest detection.

Plant diseases recognition on images using convolutional neural networks: A systematic review Abade et al. 2021	Convolutional Neural Network	The systematic review analyzed 121 papers on plant disease recognition. The review identified the use of convolutional neural networks (CNN) in disease identification. The review highlighted trends and gaps in the use of CNNs for plant disease detection. The review used selection criteria to filter the most relevant papers. The review aimed to provide an overview of the state of the art in plant disease recognition.	Not stated
Banana Plant Disease Classification Using Hybrid Convolutional Neural Network Narayanan et al., 2022	Hybrid Convolutional Neural Network	Proposed hybrid CNN for banana disease detection with 99% accuracy. Dataset consisted of 3500 images of infected and healthy banana plants. Existing techniques have drawbacks in accuracy and time consumption. Improvement in CNN using inception functionality and global pooling layer. Tomato disease identification achieved 90% accuracy with object detection techniques.	Proposed technique shows 99% accuracy compared to other deep learning techniques.
Image Processing based Banana Leaf recognition and recommendation using machine learning Auti et al., 2018	Deep Learning, Convolutional Neural Network, Machine Learning, Image Processing	Deep-learning approach to detect and classify banana leaf diseases. Uses Convolutional Neural Network and KNN algorithm for disease prediction. Predicts diseases like mosaic, black sigatoka, yellow sigatoka, panama wilt, streak. Provides an analysis report with symptoms and remedies of predicted disease.	Not stated
AI-powered banana diseases and pest detection Selvaraj et al., 2019	Artificial Intelligence, Deep Learning, Convolutional Neural Network	The paper explores a novel method using deep transfer learning for banana pest and disease detection. The developed model can detect the difference between healthy and infected plant parts. The model achieved accuracy between 70 and 99 in experimental results.	The accuracy of the banana disease and pest detection models was more than 90%.
An Improved Agro Deep Learning Model for Detection of	Deep Learning	Agro deep learning improves disease detection accuracy and reduces misdiagnosis risk.	The accuracy of Panama wilt disease identification is estimated to be between 80 and 90.

Panama Wilts Disease in Banana Leaves Sangeetha et al., 2023		Also detects diseases faster than traditional methods and automates disease detection, saving time and resources.	The proposed ADLM achieved 91.56% accuracy.
Thrips incidence prediction in organic banana crop with Machine learning Manrique-Silupu et al., 2021	Machine Learning	Precision agriculture for pest control in organic banana cultivation. Prediction of pest incidence using machine learning techniques. IOT sensor network and cloud-based data logging system in banana plantation.	Not stated
A Deep Learning-based Approach for Banana Leaf Diseases Classification Amara et al. 2017	Deep Learning	Deep learning-based approach for classifying banana leaf diseases. Effective even under challenging conditions like illumination and complex background	Not stated
Identification, classification & grading of fruits using machine learning & computer intelligence: a review Behera et al., 2020	Image Processing, Machine Learning	Current research focuses on identification, classification, and grading of fruits. Automated tools using image analysis can identify and classify fruits accurately.	The accuracy of fruit identification using morphological and color features was 90%. The RF algorithm with SIFT features achieved an accuracy of 96.97%. The proposed hybrid classification method achieved an accuracy of 89.1%. The proposed computer vision-based system for apple grading had an accuracy of 100%. The proposed system for tomato leaf and fruit classification achieved an accuracy of 89%. The proposed strategy for fruit grading based on color features had an accuracy of 89.5%. The classification of strawberry fruits based on shape and size had an accuracy of 94-97%. The proposed system for passion fruit ripeness classification had an accuracy of 90%.

C. *Comparative analysis of different Machine Learning approaches in this context*

Convolutional Neural Networks, as demonstrated in the study on banana disease classification using a Hybrid CNN, showcase a remarkable accuracy rate of 99%, positioning it as a powerful tool for disease detection. Support Vector Machines, on the other hand, excel in type determination, attaining an accuracy rate of 99.1%. The systematic review on banana growth and yield estimation reveals that multiple linear regression and artificial neural networks outperform in specific scenarios, emphasizing the importance of tailoring approaches to the unique requirements of banana agriculture.

IV. DISCUSSION

A. Analysis of findings within the context of banana assessment:

The findings within the context of banana assessment highlight the pivotal role of Machine Learning in addressing key challenges in the banana supply chain. The accurate prediction of banana quality, ripeness, and disease incidence through advanced algorithms like CNNs and SVMs signifies a transformative potential for the agriculture industry. These findings align with the growing need for efficient and technology-driven solutions to enhance productivity and sustainability in banana cultivation.

B. Comparisons with existing literature on banana analysis and Machine Learning:

The outcomes of this study align with and extend existing literature on banana analysis and Machine Learning. Notably, the accuracy rates achieved in various studies surpass previous benchmarks, showcasing the continual evolution and improvement in the application of Machine Learning to banana assessment. The integration of multiple-input techniques, as seen in the Dual Channel Banana Grading System, represents a novel approach, further contributing to the literature on technological advancements in banana quality evaluation.

C. Exploration of the implications and limitations of Machine Learning in this specific application:

While Machine Learning demonstrates remarkable success in banana assessment, certain limitations and implications warrant consideration. The robustness of models in diverse environmental conditions, generalization across different banana varieties, and scalability to large-scale agricultural settings are areas that demand further exploration. Additionally, the reliance on extensive datasets for training and potential biases in data could impact the model's effectiveness. These implications emphasize the need for ongoing research and refinement of Machine Learning models in the context of banana agriculture.

D. Addressing any unexpected or divergent findings in banana assessment:

Throughout the analysis, unexpected or divergent findings were notably absent, indicating a consistency in the positive impact of Machine Learning applications on banana assessment. The absence of divergent outcomes may be attributed to the rigorous selection of studies adhering to PRISMA guidelines, emphasizing the reliability and coherence of the reported findings.

V. CONCLUSION

A. Summarization of key findings in Machine Learning for banana quality assessment:

The key findings in Machine Learning applications for banana quality assessment underscore the potential for transformative advancements in banana cultivation. The high accuracy rates achieved in tasks such as grading, ripeness detection, and disease classification position Machine Learning as a valuable tool for improving efficiency and precision in banana agriculture.

B. Overall interpretation and significance of the study:

This study significantly contributes to the understanding of Machine Learning applications in banana assessment by providing a comprehensive overview of recent advancements. The adoption of diverse techniques, coupled with a critical analysis of their outcomes, enhances the overall interpretation and significance of this research. The demonstrated accuracy rates reaffirm the potential of Machine Learning to revolutionize banana agriculture.

C. Implications for future research in Machine Learning applications for banana agriculture:

Addressing the identified limitations and refining models for real-world applicability should be a priority. Furthermore, collaborative efforts between researchers and industry stakeholders can facilitate the development and implementation of robust Machine Learning solutions tailored to the specific challenges of banana cultivation.Future research should focus on expanding the use of machine learning technologies in different aspects of banana agriculture and in different regions. This can help to further improve the accuracy and applicability of these technologies. Additionally, efforts should be made to make these technologies accessible and affordable for small-scale farmers in developing countries.

D. Closing remarks on the study's contribution to advancing banana assessment using Machine Learning:

This study makes a substantial contribution to the field of banana assessment by providing a comprehensive analysis of Machine Learning applications. The reported outcomes, coupled with the PRISMA-guided selection process, enhance the reliability and relevance of the findings. As agriculture embraces technological advancements, the study serves as a stepping stone towards more efficient, accurate, and sustainable banana cultivation practices through the integration of Machine Learning.

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