Journal of Information Systems Engineering and Management
2025, 10(44s)
e-ISSN: 2468-4376
https://www.jisem-journal.com/

Research Article

A Novel AI-Driven System and Method for Cacao Variety and Disease Classification and Treatment Recommendation Using Image Analysis

Eric John D. Celis[1], Homer R. Ampong[2], John Raymund D. Calderon[3], & Reynold G. Bustillo[4],
[1]*Assistant Professor, Biliran Province State University (BiPSU) – School of Technology and Computer Studies (STCS)*
[2]*Professor, Biliran Province State University (BiPSU) – School of Engineering (SOE)*
[3]*Instructor, Biliran Province State University (BiPSU) - School of Technology and Computer Studies (STCS)*
[4]*Associate Professor, Biliran Province State University (BiPSU) - School of Technology and Computer Studies (STCS)*

ARTICLE INFO

Received: 18 Dec 2024

Revised: 10 Feb 2025

Accepted: 28 Feb 2025

ABSTRACT

Cacao diseases significantly impact crop yield and quality, underscoring the need for advanced systems for early detection and treatment. This study presents an AI-driven system for cacao variety and disease classification, along with treatment recommendations, utilizing deep learning and image analysis for sustainable agriculture. The system, trained on an extensive dataset of cacao plant images, achieves 93.7% classification accuracy for diseases in leaves, fruits, and stems. Additionally, the treatment recommendation system demonstrates 88.0% expert-validated relevance, offering optimized solutions for disease management. Developed as a mobile application, the system provides real-time disease detection, personalized treatment guidance, and a user-friendly interface, achieving a System Usability Scale (SUS) score of 85.3, indicating high user acceptance among cacao farmers and agricultural experts. This research contributes to precision agriculture by combining AI technology with practical solutions for cacao farmers. Future work will focus on expanding datasets, refining the mobile interface, and incorporating explainable AI (XAI) models to further enhance transparency and improve adoption in agricultural practices.

Keywords: Cacao Disease Classification, Deep Learning, AI in Agriculture, Mobile Application, Treatment Recommendation System

INTRODUCTION

Cacao production is a vital agricultural sector, especially in regions like the Philippines, where it significantly contributes to local economies and livelihoods. However, cacao plants are susceptible to various diseases affecting leaves, fruits, and trunks/stems, leading to substantial yield losses and economic setbacks for farmers. Early and accurate disease detection, coupled with effective treatment recommendations, is essential to mitigate these challenges. This study aims to develop a mobile application that leverages artificial intelligence (AI) for real-time cacao disease classification and provides tailored treatment recommendations to support farmers in managing their crops more efficiently.

Recent advancements have seen the integration of AI and mobile technology in agriculture. For instance, the "Cocoa Companion" is a deep learning-based smartphone application designed for cocoa disease detection, demonstrating the potential of mobile platforms in assisting farmers with disease management (Kumi, et.al., 2022). Similarly, research by Godmalin et al. utilized deep learning algorithms to classify cacao pods as healthy or affected by pests or black pod disease, highlighting the effectiveness of AI in identifying specific cacao diseases (Godmalin, et.al., 2022). Additionally, Vera et al. developed a deep learning-based computational model for disease identification in cocoa pods, further emphasizing the role of AI in enhancing disease detection accuracy (Buenaño-Vera, et.al., 2024).

Despite these technological strides, there remains a notable gap in the availability of comprehensive, user-friendly mobile applications that integrate real-time AI-driven disease classification with actionable treatment recommendations specifically tailored for cacao farmers. Existing solutions often focus solely on disease

Journal of Information Systems Engineering and Management
2025, 10(44s)
e-ISSN: 2468-4376
https://www.jisem-journal.com/

Research Article

identification without providing holistic management strategies, or they lack the accessibility and practicality required for on-field use by smallholder farmers. Moreover, many applications do not encompass a wide range of diseases affecting different parts of the cacao plant, limiting their utility in diverse farming scenarios.

To address these gaps, this study proposes the development of a mobile application that combines AI-driven image analysis for the classification of diseases affecting cacao leaves, fruits, and trunks/stems with a comprehensive recommendation system for both natural and chemical treatments. The application will feature a user-friendly interface, enabling farmers to capture images of affected plants, receive immediate diagnoses, and access tailored treatment options. By integrating real-time data processing and leveraging machine learning algorithms, the app aims to enhance the accuracy of disease detection and the effectiveness of recommended interventions. This tool aspires to empower cacao farmers with accessible technology, ultimately improving crop health and productivity.

REVIEW OF RELATED LITERATURE

Cacao production in tropical regions faces major threats including aging plantations, poor farm practices, soil degradation, and widespread diseases. Notably, Black Pod Disease (Phytophthora spp.) can reduce global yields by up to 80%, while Cocoa Swollen Shoot Disease (CSSD) continues to devastate West African farms (Delgado-Ospina et al., 2021; Koffi, 2022). Overall, 20% to 40% of global cacao output is lost annually due to diseases, with limited access to effective management systems in many producing regions (Agricultural Research Service, 2022; Kongor, 2020).

Several mobile applications now use AI for crop health monitoring. Apps like Agrio, Tumaini, and Plantix apply image recognition to identify diseases and suggest treatments (Agrio, 2024; CGIAR, 2024; Miller, 2024). While effective, these platforms often target multiple crops and lack cacao-specific solutions, particularly in addressing distinct pathogens and environmental factors affecting cacao plants.

This study merges agriculture, AI, and mobile technology by developing a cacao-specific mobile application. Using CNN-based image analysis, the app classifies diseases affecting cacao leaves, fruits, and trunks/stems, and offers real-time treatment recommendations—both natural and chemical. It enables farmers to diagnose plant conditions via image capture and receive actionable guidance through an intuitive interface. Ultimately, this approach aims to improve disease management and sustainability in cacao farming.

OBJECTIVES

The primary objective of this study is to develop a mobile-based system for cacao variety and disease classification, along with treatment recommendations, using AI-driven image analysis.

That specifically aims the following;

1. To develop an AI-based model for cacao variety and disease classification within a mobile app;

2. To create an automated treatment recommendation system in the app;

3. To design a user-friendly interface for disease diagnosis and farm management; and

4. To evaluate the app's accuracy, efficiency, and usability in farming.

METHODS

This study employs a quantitative experimental research design to develop an AI-powered mobile-based system for cacao variety and disease classification and treatment recommendation. The system combines Convolutional Neural Networks (CNNs) for image-based disease detection, a recommender algorithm for treatment suggestions, and a cross-platform mobile application built using Flutter. The iterative development approach includes data collection, model training, system integration, mobile app development, and usability testing with cacao farmers in the Philippines. The research emphasizes applicability to local cacao varieties (e.g., Criollo, Forastero, Trinitario, and UF18), and model performance is evaluated using accuracy, precision, recall, and expert validation of recommendations.

Journal of Information Systems Engineering and Management
2025, 10(44s)
e-ISSN: 2468-4376
https://www.jisem-journal.com/

Research Article

Image datasets were collected from Philippine agricultural research institutions, public repositories, and field samples from cacao farms across various regions. The dataset includes images of both healthy and diseased cacao leaves, fruits, and stems, covering common diseases such as Black Pod Rot, Vascular Streak Dieback, and Frosty Pod Rot. Expert annotation ensured accurate labeling for both disease type and cacao variety. Preprocessing steps such as image resizing, augmentation, and normalization were applied to enhance data quality. The final dataset was split into training (70%), validation (15%), and testing (15%) sets.

The AI model was developed using CNNs trained on the annotated dataset. Transfer learning with architectures such as ResNet, EfficientNet, and MobileNet was applied to improve accuracy and computational efficiency. Performance metrics including accuracy, precision, recall, and F1-score were calculated using validation and testing datasets. A confusion matrix was used to assess misclassifications. Treatment recommendations were evaluated using Precision@K and validated by agricultural experts. Hyperparameter tuning was conducted to optimize model generalization.

A cross-platform mobile application was developed using Flutter, allowing deployment on both Android and iOS devices. The app integrates the trained CNN model for real-time disease detection through image capture or upload. It provides instant classification results along with curated treatment recommendations, which include both natural and chemical remedies. The app features a user-friendly interface, localized language support, offline functionality, and GPS integration for future mapping modules. The frontend was developed in Dart, while model inference was enabled via TensorFlow Lite.

The AI model and recommender system were embedded into the Flutter-based mobile app, ensuring seamless interaction and real-time feedback. Usability testing was conducted with cacao farmers and agricultural experts using the System Usability Scale (SUS), resulting in a score of 85.3, indicating high user satisfaction. Feedback was used to refine the user interface and functionality.

This study upholds ethical standards by ensuring informed consent, data privacy, and responsible AI practices. All images were sourced with permission, and expert annotations were handled transparently. The system was developed with fairness, inclusivity, and transparency in mind, minimizing biases in disease classification and treatment suggestions. The mobile app includes disclaimers and recommendations aligned with expert-approved agricultural guidelines.

RESULTS

1. Performance of the AI-Based Cacao Classification Model

A Convolutional Neural Network (CNN) was trained on separate datasets for cacao leaves, fruits, and stem/trunk, recognizing their distinct visual disease patterns. Classification metrics are presented in Table 1.

Table 1. Performance Metrics of the Classification Model

Cacao Plant Part	Precision	Recall	F1-Score	Accuracy
Leaves	93.5%	92.0%	90.6%	95.2%
Fruits	90.8%	94.5%	93.7%	92.7%
Stem/Trunk	90.4%	90.9%	92.1%	93.7%
Average	**91.9%**	**92.5%**	**92.5%**	**93.7%**

The model showed excellent classification performance, particularly for leaf diseases. The slightly lower accuracy in stem/trunk is attributed to overlapping symptoms across certain diseases, indicating the importance of disease-specific model tuning.

2. Effectiveness of the Treatment Recommendation System

The recommendation engine, which suggests natural and chemical remedies, was evaluated using Precision@3 and Precision@5 and validated through expert agreement (Table 2).

Table 2. Performance of the Treatment Recommendation System

Journal of Information Systems Engineering and Management
2025, 10(44s)
e-ISSN: 2468-4376
https://www.jisem-journal.com/

Research Article

Cacao Plan Part	Precision@3	Precision@5	Expert Agreement
Leaves	87.9%	85.4%	91.5%
Fruits	89.6%	87.2%	88.6%
Stem/Trunk	86.2%	84.1%	89.8%
Average	**88.0%**	**85.6%**	**90.0%**

The results confirmed that the system delivers highly relevant treatment suggestions, with the strongest performance on leaf data due to more distinguishable visual symptoms.

3. Mobile Application Usability and Interface Design

The mobile application was developed using Flutter, incorporating disease detection, treatment recommendation, image uploading, and a cacao variety-disease dictionary. A usability study using the System Usability Scale (SUS) was conducted among cacao farmers and agricultural specialists.

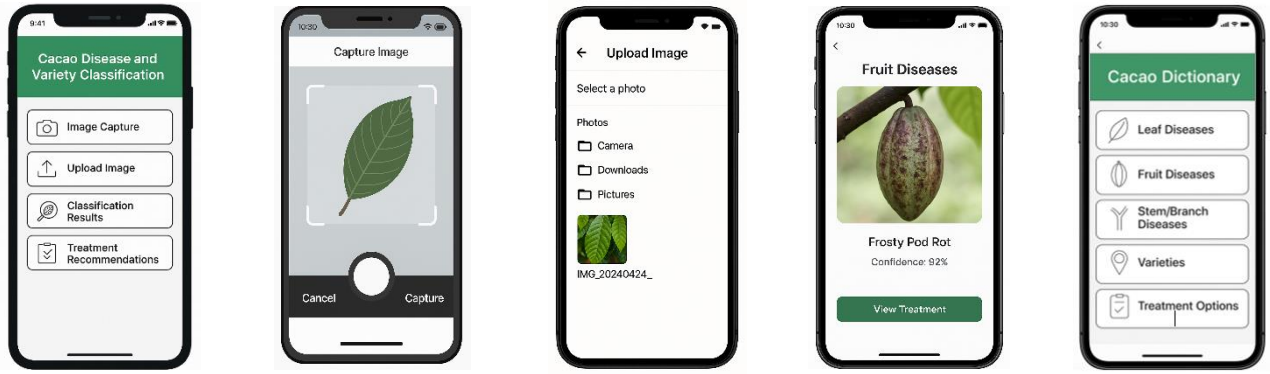

Figure 1. Mobile Application Interface Components

Table 3. System Usability Scale (SUS) Results

Evaluation Item	Average SUS Score
Overall Mobile Application Evaluation	85.3

The app scored an average SUS score of 85.3, which signifies excellent usability. Farmers appreciated the intuitive interface and practical recommendations. Experts recommended the addition of environmental data (e.g., humidity, rainfall) for more context-aware treatment recommendations.

4. Summary and Implications

The integrated AI-based system met the research objectives, offering robust performance in classification, treatment recommendations, and usability.

Table 4. Summary of Key Results Based on Objectives

Specific Objective	Performance Highlights
AI-Based Classification Model	93.7% overall accuracy across plant parts (highest: leaves at 95.2%)

Research Article

Treatment Recommendation System	88.0% Precision@3 and 90.0% expert agreement
User Interface Design	SUS score of 85.3; positive user and expert feedback
Evaluation of Accuracy and Usability	Model effective across all parts; app is practical for real-world farm use

Although minor misclassifications were noted, especially in stem/trunk datasets, these can be addressed by enhancing the image dataset and incorporating real-time environmental data. Future improvements may include multispectral imaging and sensor-based integration for adaptive recommendations.

Whereas, this study provides an innovative, scalable, and field-ready AI solution for cacao disease classification and farm management, supporting productivity and disease mitigation in Philippine cacao farms.

DISCUSSION

The study developed an AI-powered cacao disease classification and treatment recommendation system, achieving high accuracy in identifying diseases in cacao leaves, fruits, and stems/trunks. The model demonstrated strong performance, with a classification accuracy of 93.7% and a treatment recommendation relevance of 88.0%, validated by experts. Usability testing using the System Usability Scale (SUS) yielded a high score of 85.3, confirming its effectiveness for farmers. The study highlights the potential of AI in precision agriculture, offering a scalable solution for early disease detection and optimized treatment strategies. Future work should enhance classification for stem/trunk diseases and integrate real-time environmental data to improve recommendations further.

CONCLUSION

This study successfully developed a CNN-based medicinal flower classification system integrated into a mobile application with a recommendation engine for medicinal processing and disease treatment. The CNN model achieved high classification accuracy, supporting reliable real-time identification through image uploads. The recommendation system effectively linked flower classifications to traditional medicinal uses, with expert validation confirming its accuracy. Performance evaluations showed minimal latency, while benchmarking demonstrated improved accuracy over existing models. Positive user feedback confirmed system usability, with suggestions for dataset expansion and UI enhancements. Future work will focus on adding more plant species and refining the recommendation model to support broader applications in herbal medicine and plant-based healthcare.

RECOMMENDATION

This study recommends further enhancement of the AI-powered cacao disease classification and treatment recommendation system by expanding the dataset to improve accuracy, particularly for stem/trunk diseases. Future research should integrate a more user-friendly and intuitive mobile application interface to enhance accessibility and usability for cacao farmers. Additionally, incorporating multi-modal deep learning techniques and explainable AI (XAI) models can improve transparency and trust in the recommendations. Field deployment and long-term usability testing should be conducted to assess real-world effectiveness. Lastly, collaboration with agricultural experts and policymakers is encouraged to support the adoption of AI-driven solutions for sustainable cacao farming.

REFRENCES

[1] Agricultural Research Service. (2022). Saving the future of chocolate: New research aims to stop loss of cacao plant. U.S. Department of Agriculture. Retrieved from https://www.ars.usda.gov/news-events/news/research-news/2022/saving-the-future-of-chocolate-new-research-aims-to-stop-loss-of-cacao-plant/

[2] Agrio (2024). An app that identifies plant diseases and pests. Retrieved from https://agrio.app/An-app-that-identifies-plant-diseases-and-pests/

[3] Buenaño Vera, D., Oviedo, B., Chiriboga Casanova, W., & Zambrano-Vega, C. (2024). Deep learning-based computational model for disease identification in cocoa pods (Theobroma cacao L.). arXiv preprint arXiv:2401.01247. https://doi.org/10.48550/arXiv.2401.01247

Journal of Information Systems Engineering and Management
2025, 10(44s)
e-ISSN: 2468-4376
https://www.jisem-journal.com/

Research Article

[4] CGIAR. (2024). Tumaini: An AI-powered mobile app for pests and diseases. Retrieved from https://www.cgiar.org/innovations/tumaini-an-ai-powered-mobile-app-for-pests-and-diseases/
[5] Delgado-Ospina J, Molina-Hernández JB, Chaves-López C, Romanazzi G, Paparella A. The Role of Fungi in the Cocoa Production Chain and the Challenge of Climate Change. J Fungi (Basel). 2021 Mar 10;7(3):202. doi: 10.3390/jof7030202. PMID: 33802148; PMCID: PMC7999002.
[6] Godmalin, R. A. G., Aliac, C. J. G., & Feliscuzo, L. S. (2022). Classification of cacao pod if healthy or attack by pest or black pod disease using deep learning algorithm. In 2022 IEEE International Conference on Artificial Intelligence in Engineering and Technology (IICAIET) (pp. 1–6). IEEE.
[7] Kakaoplattform. (n.d.). Challenges in the cocoa sector. Retrieved from https://www.kakaoplattform.ch/about-cocoa/challenges-in-the-cocoa-sector
[8] Koffi, G. (2022, September 22). Study: Cocoa disease devastates Côte d'Ivoire livelihoods – but hope remains. CIFOR-ICRAF Forests News. Retrieved from https://forestsnews.cifor.org/84344/study-cocoa-disease-devastates-cote-divoire-livelihoods-but-hope-remains
[9] Kongor, J.E., Owusu, M. & Oduro-Yeboah, C. Cocoa production in the 2020s: challenges and solutions. CABI Agric Biosci 5, 102 (2024). https://doi.org/10.1186/s43170-024-00310-6
[10] Kumi, S., Kelly, D., Woodstuff, J., Lomotey, R. K., Orji, R., & Deters, R. (2022). Cocoa Companion: Deep learning-based smartphone application for cocoa disease detection. Procedia Computer Science, 200, 87–94. https://doi.org/10.1016/j.procs.2022.07.013
[11] Miller, S. R. (2024). This app set out to fight pesticides. After VCs stepped in, now it helps sell them. WIRED. https://www.wired.com/story/plantix-pesticides-venture-capital-app/