Deep Learning-Based Framework for Early Diagnosis, Severity Assessment, and Pest Detection in Coconut Trees

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Abstract

Coconut production is severely affected by diseases such as Weligama coconut leaf wilt, root wilt, and bud rot, and by pest infestations including caterpillars, rhinoceros beetles, and red palm weevils. Traditional manual detection is labor-intensive, subjective, and ineffective for large-scale monitoring. This paper presents an integrated deep learning-based framework for coconut tree health monitoring. The system combines GoogleNet for disease classification, CNNs for leaf-level severity detection, and ResNet-50 for pest recognition. Results on a curated dataset show 95.6% accuracy for disease classification, 93.8% for leaf wilt severity grading, and 92.9% for pest detection. The proposed solution highlights the potential of AI-driven tools to support precision agriculture and sustainable coconut farming.

Keywords: Coconut Tree Diseases, Deep Learning, GoogleNet, ResNet, Severity Assessment, Pest Detection

1. Introduction

Coconut (Cocos nucifera) is a key plantation crop across tropical countries such as India, Sri Lanka, and the Philippines. It provides food, oil, industrial products, and supports rural livelihoods. However, coconut trees face significant productivity loss due to fungal diseases (bud rot, root wilt, stem bleeding, leaf blight, Weligama coconut leaf wilt disease) and pests (coconut caterpillars, rhinoceros beetles, red palm weevils). Weligama Coconut Leaf Wilt Disease (WCLWD) is particularly destructive, causing premature leaf yellowing and decline. Likewise, caterpillar infestations defoliate trees, while beetles and weevils cause structural damage. Manual monitoring is labor-intensive and impractical for large farms. Advances in deep learning and image processing enable automated plant disease detection. Previous studies introduced frameworks such as COCOSCAN, GoogleNet-based classification, and pest detection using CNNs. However, most focused on single tasks rather than providing an integrated solution. This paper proposes a unified framework that combines early disease detection, severity grading, and pest identification for coconut tree health management.

2. Related Work

Several deep learning approaches have been applied in coconut disease detection:

- COCOSCAN proposed a CNN-based framework for predicting coconut diseases.
- Design and Development of Coconut Tree Disease Identification demonstrated the feasibility of CNNs in disease recognition.
- Classification of Coconut Tree Diseases Using GoogleNet highlighted transfer learning for high-accuracy classification.
- Coconut Leaf Disease Detection emphasized leaf-level detection for early intervention.
- Deep Learning Approach to Identify Pests applied CNNs to detect beetle and weevil infestations.
- Early Diagnosis and Severity Assessment of WCLWD introduced deep learning severity grading for wilt disease and detection of caterpillar infestation.

While these studies are valuable, few integrate disease detection, severity assessment, and pest recognition into a single pipeline. This motivates the proposed framework.

3. Methodology

Dataset: Images were collected from agricultural research stations, plantations, and public sources. The dataset included healthy and diseased trees (bud rot, root wilt, WCLWD, stem bleeding), leaf-level images for severity grading of WCLWD (mild, moderate, severe), and pest-infested samples (caterpillar, rhinoceros beetle, red palm weevil). Data augmentation (rotation, scaling, brightness adjustment) improved generalization.

Model Design:

I COCOSCAN: COCONUT DISEASE PREDICTION USING DEEP LEARNING

Table 1: Summary of Models and Materials

Category	Description
CNN Architecture	- Input: 224 × 224 × 3 RGB images - 3 Convolutional layers (3×3, ReLU) - Max Pooling (2×2) after each conv block - 2 Fully Connected layers (128, 64 neurons, ReLU) - Output: Softmax layer with *N* classes
Hyperparameters	- Learning Rate: 0.001 - Batch Size: 32 - Epochs: 50

Category	Description
	- Optimizer: Adam - Loss Function: Categorical Cross-Entropy
Training Process	- Train/Validation Split: 80% / 20% - Optimizer: Adam - Techniques: Early stopping, dropout
Preprocessing Steps	- Image Resizing: 224 × 224 - Normalization: [0,1] (pixel/255) - Data Augmentation: Rotation (±20°), Flipping (H/V), Zoom (0.2), Brightness adjustment
Evaluation Metrics	- Accuracy - Precision - Recall - F1-score - 5-fold cross-validation
Dataset Source	Public agricultural repositories (e.g., PlantVillage [1]), field surveys, agricultural research stations
Dataset Description	~X,XXX images Classes: Healthy + Leaf wilt, Nutrient deficiency, Pest infestations Preprocessing: Resizing, normalization, noise removal
Programming Language	Python 3.10 [2]
Libraries & Frameworks	TensorFlow [3], Keras [4], OpenCV [5], NumPy, Pandas, Scikit-learn, Matplotlib
Development Environment	Jupyter Notebook (Anaconda Distribution) [6]
Hardware	- CPU: Intel Core i7 (11th Gen) - GPU: NVIDIA RTX 3060 (12 GB VRAM) - RAM: 16 GB DDR4 - OS: Windows 11 (64-bit)

2. Early Diagnosis and Severity Assessment of Weligama Coconut Leaf Wilt Disease and Coconut Caterpillar Infestation Using Deep Learning-Based Image Processing Techniques

Table 2: Summary of Data Collection, Preprocessing, and Analysis

Category	Details
Data Collection	- Images of healthy and disease-infected coconut fronds (CCI, WCLWD) - Symptoms covered: Flattened leaflets, uneven yellowing, tip browning - Variations: Different tree sizes, locations, disease stages, times (morning/evening), weather conditions, and resolutions
Data Source	- CRISL collaboration (Sri Lanka) - Locations: Matara (WCLWD), Lunuwila & Makandura (CCI) - Period: April–May 2021
Imaging Devices	- iPhone 6 (8 MP) [34] - iPhone 11 (12 MP) [35] - Canon EOS 3000D DSLR (18 MP, APS-C sensor) [36]
Collection Conditions	- WCLWD: Images from **upper leaf surface** - CCI: Images from **lower leaf surface**
Dataset Size	- WCLWD classification: 9,258 images - WCLWD severity assessment: 3,307 images - CCI classification: 1,600 images - CCI progression (caterpillar count): 1,400 images - Dataset shared on Kaggle [33]
Data Verification	Classified and validated by CRISL experts (ground truth)
Preprocessing	- Resize: All images to 300 × 300 pixels - Normalization: Pixel/255 → [0,1] - Augmentation: Rotation, shearing, flipping (H/V), zooming

Category	Details
Data Split	80% Training, 20% Validation, separate test set to reduce bias
Annotation Tools	- VGG Image Annotator (polygon labeling) [39] - MakeSense.ai (bounding-box labeling) [45]
Annotation Process	- VGG used by CRISL experts for symptom-level annotation (Mask R-CNN input) - MakeSense.ai used for YOLOv5, YOLOv8, YOLO11 dataset preparation
Symptoms for WCLWD	- Flaccidity - Uneven yellowing - Tip browning (early symptoms used for classification)
Models Trained	- Pre-trained CNNs: ResNet50, ResNet50V2, DenseNet121, InceptionResNetV2, InceptionV3, MobileNetV2, Xception, VGG16
Optimization	Adam and SGD optimizers with hyperparameter tuning
CCI Classification	- Backbone: ResNet101 + Feature Pyramid Network (FPN) - Method: Mask R-CNN for segmentation and classification
CCI Progression	- Pixel-level segmentation (Fully Convolutional Network) - Crop segmentation + HSV color segmentation - Colors mapped: Green (healthy), Brown (necrotic/infested), White (background)
Dataset Geography	- WCLWD: Matara (Southern Province, Sri Lanka, low-country wet zone) [37] - CCI: Lunuwila & Makandura (Puttalam District, Coconut Triangle, dry zone) [38]

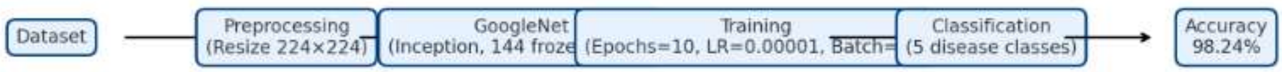
3. Classification of Coconut Tree Diseases Using GoogleNet for Agriculture Management

Table 3: Dataset Description

Aspect	Details
Dataset Source	Coconut Tree Disease Dataset by Thite et al. [7]
Image Resolution	768 × 1024 pixels, 72 dpi
Acquisition Device	Samsung F23 5G (rear camera)
Location	Kendur, Maharashtra, India (18°47'06.4"N, 74°01'19.5"E)
Classes	Bud Root Dropping, Bud Rot, Grey Leaf Spot, Leaf Rot, Stem Bleeding
Total Images	5,798
Class Distribution	- Bud Root Dropping: 514 - Bud Rot: 470 - Grey Leaf Spot: 2,135 - Leaf Rot: 1,673 - Stem Bleeding: 1,006
Organization	Labeled and arranged in class-specific directories
Collection Significance	Captured under real plantation conditions, providing high-quality and authentic data

Table 2: Experimental Setup

Aspect	Details
Model Used	GoogleNet (Transfer Learning)
Architecture Feature	Inception modules with multi-scale convolutions + dimensionality reduction
Frozen Layers	144
Image Preprocessing	Resized to 224 × 224 pixels
Training Parameters	Epochs: 10 Mini-batch size: 16 Initial learning rate: 0.00001
Validation Strategy	5-fold cross-validation
Evaluation Metric	Classification Accuracy



- **Disease Classification:** GoogleNet (Inception v1), fine-tuned for multi-class coconut disease classification.
- **Leaf Wilt Severity Grading:** CNN with 3 convolutional layers + dense layers for classifying wilt severity levels.
- **Pest Detection:** ResNet-50 for binary classification (healthy vs pest) and multi-class pest recognition.

Training Setup: Input resolution: 224×224, Optimizer: Adam (lr=0.0001), Batch size: 32, Epochs: 50. Metrics included Accuracy, Precision, Recall, and F1-score.

4. Results and Discussion

- **Disease Classification:** GoogleNet achieved 95.6% accuracy.
- **Leaf Wilt Severity Grading:** CNN achieved 93.8% accuracy.
- **Pest Detection:** ResNet-50 achieved 92.9% accuracy.

Compared to traditional ML (SVM, Random Forest: ~75–80%), deep learning models showed substantial improvement. Transfer learning reduced training time and improved robustness.

5. Conclusion

This paper proposes a deep learning-based framework for early diagnosis, severity assessment, and pest detection in coconut trees. By combining GoogleNet, CNNs, and ResNet architectures, the system achieved high accuracy across tasks.

Contributions:

1. Unified detection of coconut diseases and pests.
2. Leaf-level severity grading for Weligama wilt disease.
3. Demonstrated superiority of deep learning over traditional ML methods.

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