# Convolutional Neural Networks Applied to the Performance of a Coffee Tree

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**Abstract.** The use of artificial neural networks has been a significant advancement in the field of computer science, as it supports various fields of study in many traditional sciences. Over the years, numerous models of artificial neural networks have been tested, serving as cornerstones in scientific research. These models have been a starting point for integrating artificial neural networks as support for the detection and analysis processes in situations of risk in food plantations. In this research, the aim is to highlight previous works that have emerged to address the problem of diseases in crops, specifically in coffee. As an experiment to substantiate the importance of artificial neural networks, a prototype has been developed. This prototype consists of a convolutional neural network trained to recognize diseases in coffee trees, a regression neural network for making projections based on the results obtained from the first mentioned network, and a web application where both networks coincide and work together to provide accurate results. In conclusion, it was demonstrated that the use of artificial neural networks is feasible for maximizing productions and reducing losses in crops, particularly in coffee plantations. The algorithms are in constant development, expanding the possibilities to create increasingly robust, simple, and intuitive tools accessible to everyone.

## 1 Introduction

Artificial neural networks have been a key advancement in computer science, driving scientific research and the automation of data analysis. Major technology companies have integrated them into their devices and continue to invest in research for their use in everyday applications.

Understanding artificial neural networks is beneficial due to their broad applicability in software and applications. There is constant work in improving these techniques and algorithms to make them more efficient and robust. Thess networks has being used in different applications in the agricultural industry [1].

This article focuses on research and experimentation that employs a trained convolutional neural network to detect specific sectors in a coffee plantation. Subsequently, a regression network is used to analyze the data and predict percentages of healthy leaves,

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leaves with rust, and fruits. A total of 400 photographs from both proprietary sources and the web are utilized to train the network. Similar works have been developed in coffee [2] and in cocoa beans [3].

This experiment aims to demonstrate the effectiveness of integrating two types of neural networks through a web application, with potential applications in the detection of diseases in crops. Academic literature is reviewed to provide a foundation for the research, and the goal is to test the positive impact of these networks on agriculture and the efficiency of the developed tool.

The success of the project relies on a solid theoretical foundation, a robust structure of the networks, a functional tool, and an intuitive interface. Positive results are anticipated in both the detection of diseases in crops and the usability of the tool, regardless of the user's level of computer knowledge.

## 2 Related Works

As a fundamental basis for this research, we will conduct a critical and in-depth analysis of the academic studies that various researchers have conducted regarding the detection of diseases in crops. These studies are influenced by the use of artificial neural networks, which come in various types such as convolutional and regression networks. These networks, in turn, provide the opportunity to create intelligent models to enhance the performance of food production.

The article "A Deep Learning Approach for on-site Plant Leaf Detection" [4], written by Huu Quan Cap, Katsumasa Suwa, Erika Fujita, addresses the issue of plant diseases in global agriculture and the need for early detection to reduce economic losses and mitigate food-related problems.

Trained with 1.44 million images split into training (60%) and testing (40%) sets. The classes included complete leaves, incomplete leaves, and no leaves. It consists of seven layers, including convolutional, max-pooling, and fully connected layers. It was evaluated with 100 wide-angle images, achieving an average accuracy of 80.8%, a recall of 75.3%, and an F1 score of 78.0%.

The study "Crops Disease Diagnosing using Image-based Deep Learning Mechanism" [5] by Hyeon Park, Eun JeeSook, and Se-Han Kim addresses the challenge of diagnosing diseases in crops, specifically in strawberries, using deep learning techniques. The aim is to respond to the economic losses that these diseases can cause in agricultural production.

The process involves using a Convolutional Neural Network (CNN) with an input layer, multiple hidden layers (convolutional, pooling, and fully connected), and an output layer. It was trained with a dataset of images of healthy and diseased strawberries after image preprocessing. The results indicate that the model achieves an accuracy of up to 92% in image classification.

This study, titled "High-Order Residual Convolutional Neural Network for Robust Crop Disease Recognition" [6], validated by Weihui Zeng, Lei Chen, Miao Li, among other authors, focuses on robust and accurate recognition of diseases in crops.

Validated with 9,214 images of six diseases in rice and cucumber, encompassing variations in size, angle, pose, background, and illumination. It employs high-order residual blocks to recognize diseases even in the presence of noise. In experiments using the AES-CD9214 dataset, it outperformed other methods in accuracy, even under noise interference.

This study, titled "Crop Disease Detection Using Deep Learning" [7] and conducted by Omkar Kulkarni from the Pune Institute of Computer Technology, focuses on the early detection of diseases in crops as a crucial measure to prevent significant losses in agricultural production. This is especially relevant in the context of drastic climate changes and the vulnerability of crops to diseases.

The identification process is based on a Convolutional Neural Network (CNN), which includes an input layer, hidden layers, and an output layer. A dataset called "Plant Village" with 54,306 images of crop leaves was used. These images were segmented, resized to 224 x 224 pixels, and converted to grayscale.

In experiments, the model achieved an impressive accuracy of up to 99.74% in the classification of crop leaf images, successfully identifying various diseases.

Rust is a severe disease in coffee that can reduce production by up to 45%. The study "Coffee Leaf Rust Detection Using Convolutional Neural Network" [8], conducted by Alexandre Pereira Marcos, Natan Luis Silva Rodovalho, and André R. Backes from the Federal University of Uberlândia, proposes the use of Convolutional Neural Networks (CNN) to detect rust on coffee leaves.

The early detection of plant diseases is essential in agriculture. The study "Quantitative Analysis of Deep Leaf: A Plant Disease Detector on the Smart Edge" [9], conducted by Fabrizio De Vita and others, proposes the use of Quantized Convolutional Neural Networks (Q-CNN) to identify diseases in plants.

The study emphasizes the importance of Artificial Intelligence in Intelligent Cyber-Physical Systems (ICPS) and edge computing to reduce latency and enhance security.

The study "Plant Leaf Diseases Detection and Classification Using Image Processing and Deep Learning Techniques" [10], conducted by Marwan Adnan Jasim and Jamal Mustafa AL-Tuwaijari from the University of Diyala, employs a CNN to detect and classify diseases in plant leaves such as tomatoes, peppers, and potatoes, using a dataset of 20,636 images of various diseases. The system achieves an accuracy of 98.29% in training and 98.029% in testing.

These images are resized to expedite the training of a Convolutional Neural Network (CNN) consisting of multiple layers. The network is trained using 70% of the dataset and tested on the remaining 30%.

The coffee production in India is impacted by crop diseases such as Coffee Rust and Cercospore Leaf Spot. This study [11] by Manoj Kumar, Pranav Gupta, Puneet Madhav, and Sachin from the Delhi Technological University proposes a solution using Convolutional Neural Networks (CNN) to detect these diseases at early stages. Transfer Learning is employed to expedite training, and Data Augmentation techniques are used to enhance accuracy. The model achieves an impressive accuracy of 97.61%.

The dataset comprises images of coffee leaves categorized into five classes: Healthy leaves, Phoma-infected leaves, Leaf Miner, Coffee Rust, and Cercospore Leaf Spot. The model utilizes a sequential structure with approximately 21 million parameters and is implemented in Python with Keras. Mini-Batch Gradient Descent (MBGD) is employed as the optimization algorithm, and Categorical Cross-Entropy loss function is used for multiclass classification.

This project [12] by M S P Rahul and Rajesh M. from the Amrita School of Engineering in Bengaluru aims to create a robot capable of autonomously identifying and removing defective plant stems, primarily in cotton plants.

A system is proposed with a robot equipped with a camera and a robotic arm that identifies and cuts stems of defective plants. Image processing in MATLAB and Raspberry Pi is employed to decide whether a stem should be cut. Diseases on leaves are detected using digital image processing techniques.

The study [13], conducted by Angelia, R. E., Cavan, K. C., Recto, K. E., and Bactat, R. B., proposes a device that uses image processing and machine learning to classify coffee beans based on their quality. Convolutional neural networks are employed for this classification, leveraging their ability to discover data representations with multiple levels of abstraction.

This study [14] from SJEC University in Mangaluru, India, proposes a Convolutional Neural Network (CNN) model to detect and classify diseases in coffee leaves into five categories: Healthy leaves, leaves with brown eye spots, Coffee Leaf Blight, Coffee Leaf Rust, and Coffee Leaf Miner.

A CNN model is proposed that utilizes image processing to detect diseases in coffee leaves with an accuracy of 88.35%. The BRACOL dataset is employed, containing images of both healthy and affected Arabica coffee leaves with various diseases.

Gabriel Grimaldo and Humberto Rodríguez from the Technological University of Panama present a model based on convolutional neural networks [15] that detects coffee leaves in images and classifies them according to common diseases in the Panamanian tropics, such as Cercospore leaf spot, coffee leaf rust, leaf miner, and phoma. The model achieved 100% accuracy during training and 90% accuracy in the validation for each disease and pest.

The proposed model utilizes advanced image processing techniques and machine learning to identify diseases in coffee plant leaves. In future work, there are plans to implement this architecture in the vision system of an agricultural robot, enabling farmers to inspect and manage their crops more efficiently.

In the study "Multi-Crop Leaf Disease Detection using Deep Learning Methods" [16], image processing techniques and deep learning are employed to identify diseases in leaves of various crops, with a particular emphasis on agriculture in India. The goal is to overcome the limitations of traditional manual approaches.

With a total of 37,950 images, data augmentation techniques were applied to enhance the model's robustness. Experiments were conducted with two CNN architectures, VGG-16 and Inception V3, training them on both color and grayscale images.

In the study "Detection and Classification of Coffee Leaf Disease using Deep Learning" [17], authors Eyobed Birhanu Paulos and Michael Melese Woldeyohannis address the application of deep learning techniques to identify diseases in coffee leaves.

With 1,120 images from an agricultural research center, they augmented the dataset to avoid overfitting, reaching a total of 3,360 images. Training from scratch achieved a performance of 98.5%, while transfer learning with MobileNet and ResNet50 achieved accuracy rates of 97.01% and 99.89%, respectively.

The authors of this study, titled "Identification of Coffee Leaf Rust Disease Using Convolutional Neural Network" [18], propose the use of a Convolutional Neural Network (CNN) to detect coffee leaf rust disease. Rust is caused by a pathogenic fungus and can reduce coffee production by up to 45%.

In the study "Crop Analysis and Prediction" [19], conducted by Dr. Ruchi Verma and presented at the IMPACT 2022 conference, machine learning techniques are employed to analyze and predict agricultural yields, identify diseases, and determine the most profitable crop with a high accuracy of 99.4%.

In the study [20], deep learning models and convolutional neural networks are employed to detect diseases in coconut trees and other plants from the early stages of growth, addressing the decline in agricultural productivity.

In the study [21], presented at ICOSEC 2022 by Rahul Kumar Madhukar and Anju Chaurasiya, the focus is on the classification of diseases in coffee leaves based on chronicity. It employs deep learning techniques, specifically convolutional neural networks (CNN), and a data augmentation technique to achieve an accuracy of up to 99.70% in the classification of diseases in Arabica coffee leaves in different states, including healthy, miner, rust, phoma, and cercospore.

The study [22], presented at ICIST 2022 by Shu Chen, Binghua Su, Jialin Tang, and Haijun Xie, proposes a solution based on Convolutional Neural Networks (CNN) for the recognition of diseases in plant leaves. It utilizes a CNN based on the Inception module

with additional features, including a large convolution kernel and depth wise separable convolution, as well as an attention module (CBAM). The experiments achieved an impressive accuracy of 99.55% on the test set using images of leaves from 9 common crops with 33 diseases, extracted from the Plant Village dataset.

In the paper [23] presented at ICDCECE 2023, Krishna Mridha and his team propose a deep learning-based approach for the classification of diseases in coffee leaves. They use pretrained models such as MobileNet and ResNet50, trained on a combined dataset from Mendeley containing images of arabica coffee leaves affected by diseases. The results show high accuracy, with ResNet50 at 100%, MobileNet at 99%, and the traditional CNN at 98%. Additionally, they employ visualization techniques like Grad-CAM and Grad-CAM++ to generate heatmaps explaining the model's decisions and aiding farmers in understanding predictions.

## 3 Methodology

The project in development focuses on the detection of diseases in coffee crops, especially rust, using machine learning, specifically convolutional neural networks. These networks enable the identification of damage to the leaves through images and label it to quantify the affected area. Additionally, a regression neural network will be implemented to estimate the production of the analyzed trees.

The project's approach is quantitative [24], which involves gathering information to test pre-established assumptions through numerical measurements and statistical analysis. This facilitates the identification of behavioral patterns and the validation of underlying theories.

The Scrum agile methodology [25] is a collaborative and iterative approach used in the management of system engineering and software development projects. Scrum, as an agile methodology, provides an iterative and collaborative approach to project management in system engineering and software development [26].

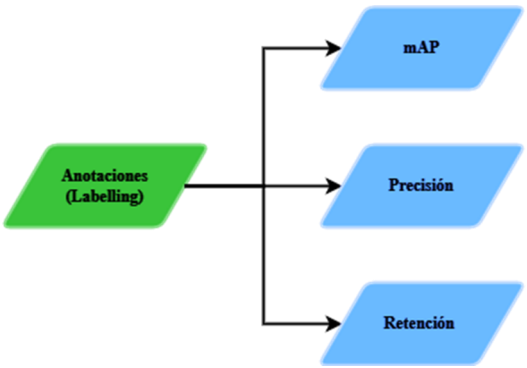


**Fig. 1.** Research Variables Diagram

## 4 Experiment

400 images of coffee plantations were used, divided into three categories: 200 healthy images, 100 with rust disease, and 100 with the crop fruit. These images varied in angle, quality, and size. The tool was implemented as a web application with a user-friendly interface. The convolutional neural network in Microsoft's Custom Vision is trained with supervised learning using images to enhance accuracy. It generates a JSON file upon completion for analysis and other implementations.

The main function of this tool is to predict the area in an image. It is programmed in Python, hosted on Google Colab, and utilizes libraries such as Keras and TensorFlow for data analysis and artificial intelligence.

The application consists of two buttons: one for loading an image and another for initiating the analysis. Once the image is submitted, it is processed using convolutional and regression neural networks. The result, representing the area as a percentage, is then displayed on the screen.

**Fig. 2.** Image without Filters, No Detected Areas

**Fig. 3.** Image with Area Recognition in Custom Vision

Final Result, it is the mAP value, expressed as a percentage, and it is a general measure of the model's performance in object detection across all classes.

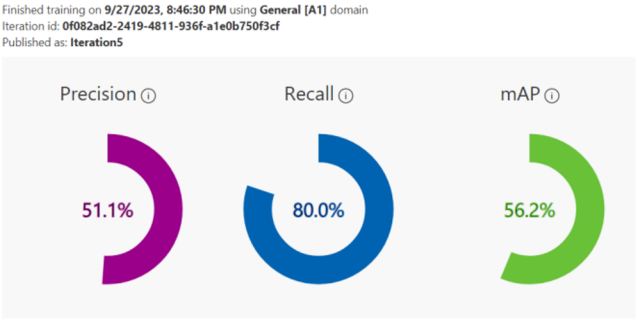


**Fig. 4.** Convolutional Neural Network Results

## 5 Conclusion

As has been observed, there is a growing interest in developing tools for detecting diseases in crops such as coffee, with the potential to increase production and reduce losses.

Building on the preceding analysis, artificial neural networks are the subject of ongoing research, with advancements in algorithms making them more accessible and effective for various applications.

Based on the collected evidence, these networks can be valuable in agriculture, but they require large datasets for optimal performance.

In conclusion, neural networks can adapt and benefit a variety of crops if applied properly.

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