IFERP
ISSN (Online) 2394-2320
International Journal of Engineering Research in Computer Science and Engineering (IJERCSE)
Volume 11 Issue 01 January 2024

Coffee Crops Semaphore: A Web Tool to Help in Detection of Diseases and Plagues in Coffee Crops

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Abstract— ***Coffee plant can be damaged by a variety of pests and diseases, which are favoured or inhibited by specific climatic conditions like temperature and humidity. As a consequence of climate change, these pests could increase their distribution across a range of territories, infecting plantations at a global level.***

Artificial Intelligence based systems can help in monitoring and prevent the rising of plagues in crops. Here it is presented a prototype called Coffee Crops Semaphore, which is a web application that estimates the probability of the presence of diseases in coffee bushes from data collected in situ regarding values and indicators of its phenology (v. gr. relative humidity, temperature and date of reading). It does offer a dashboard to visualise the estimations, presented as a traffic-light indicator for a better understanding of the potential risk, with other functionalities like uploading new data banks, and applying different Machine Learning algorithms or models to analyse them.

What is presented here belongs to a first phase of the Coffee Crops Semaphore, called Coffee Rust Semaphore, which is specifically oriented to the estimation of the presence of this fungus (Hemilea vastarix), based on data banks and images at mesosystem level (coffee plant).

Index Terms— ***Coffee rust, Coffee crops, Machine Learning, Artificial Intelligence applied to Agronomy.***

I. INTRODUCTION

In the current world of agriculture that has been present from its very beginning is the loss of plantations or crops, due to different climatological factors or due to the presence of diseases and pests across different frames of time. It does generate concerns between producers and governments if taking into account the constant increase in the number of the world's population.

According to Mexican official sources in the area of Agriculture and Rural Development [4], areas devoted to agriculture activities decreased by 0.7 % comparing the production from 2022 to 2023, although the harvested area and the amount of production increased, recently its trade rate was affected [6].

In order to provide solutions to this agricultural problem, different solutions have been tried where disciplines such as molecular biology and immunology have been involved. However, due to the high cost of implementation, it has been decided to use computer models as tools to support farmers as they can be helpful in monitoring, prevention and performing planning based on data [3].

One of the most important agricultural products is coffee, particularly in Mexico, where it is one of the most popular beverages and its production in the country is so extensive that it is currently the 11th largest producer in the world. Introduced in 1795, it is a crop of enormous importance not only economically and socially, but also culturally and ecologically [INAES, 2019]. So, it is very important to provide digital tools to producers in order to decrease the damages caused by diseases and plagues in crops. To do so, in this work it is presented as a first step of the general proposal that takes as study case coffee crops, particularly the coffee rust plague.

This paper is organised as follows, Related Work is presented in Section II. Section III discusses the traffic light based system to identify the conditions where coffee rust can be present in crops. Section IV presents the results of rust detection, and to close the paper, the main highlights and contributions are presented in the Section of Conclusion.

II. RELATED WORK

Pest and disease detection is traditionally performed manually, with farmers walking through the plantations and checking crops plant by plant.

Currently there are computational tools that allow us to help and improve producers to keep safe crop conditions. Such tools implement models either statistical or based on other advanced techniques like Artificial Intelligence, and are enforced by new digital equipment like sensors *in situ*.

Tools for classifying certain plant diseases are discussed in papers [1,2,3,5,6,7]. Most of them use computer vision to classify crops and weed diseases. One of the most widely used models are those based on Deep Learning and other Machine Learning (ML) techniques such as Supervised Vector Machines (SVM), classifiers and clustering. Crops such as wheat, maize, curcuma leaves, and tomato are analysed. On the other hand, the technical means they use are mainly web application developments and mobile based applications like PlantSnap that can identify several plants, flowers, trees, fungi, in any field.

It is worth to mention one digital tools that use crop image processing, but like the tools mentioned above, they are not indicated for exclusive use in coffee plantations [5]: Kali-Toolbox, that allows you to take a picture of your crop, and through it, identify whether it is nutritionally deficient or healthy, while providing you with appropriate recommendations for optimal nutrition.

In the case of web-based systems, other tools that can be mentioned for crop pest detection are the following (none of them is specified for exclusive use on coffee crops [5]:

Atfarm (Yara, Norway): allows to monitor biomass level, fertilise variably using satellite information and optimise the amount of nitrogen applied.

Mide Maps: allows measurements of different plots via GPS from our mobile phones and to have an instant map of the terrain.

Farm Manager: allows you to record machine procedures and access that information and create a history of fertiliser use (including type and date of application) as well as track machine use and maintenance.

Yara ImageIT: designed to measure nitrogen uptake in crops based on leaf coverage, leaf colour and browning areas, generates recommendations based on photographs of leaves, virtually turning a farmer's camera into a high-tech crop nutrient tester. It provides recommendations for quality fertilisers, agricultural inoculants and soil improvers to help you maintain an ideal environment for microorganisms.

iSOYLscout: Field scouting app that allows you to simply record areas or points of interest either by hand, while travelling on foot or in a vehicle using the built-in GPS, the app can be used to record crop yields, pests or weeds, as well as any other features you wish to locate in the crop.

However, as has been said before, still there are few options for coffee cultivation which is the study case we are focusing on as a first step in the building of the whole proposal.

In this regard, there are some applications that are devoted to the coffee crop enhancement using computing based systems like the following subsection is showing.

A. Computing and Coffee Crops

In the coffee industry, technology has enabled a significant improvement in production processes and crop care, and others. Among the most outstanding advances we can mention the implementation of drones for monitoring plantations, which has allowed a more efficient and detailed observation of crops [8]. Technology has made coffee cultivation more efficient and sustainable. In this regard, one of the most important innovations are sensors for measuring soil moisture and nutrients. These devices allow farmers to have a better understanding of the needs of their crops and to make informed decisions about the amount of water and nutrients to supply [8].

Before the advent of sensors, farmers had to rely on intuition and experience to determine how much water and nutrients to apply to their crops. This often resulted in excessive use of resources, which was not only costly but also detrimental to the environment. In addition, excess water and nutrients can also affect coffee quality and decrease crop yields [8].

Mobile applications have changed the way coffee farms are managed. These tools allow farmers to have complete control over their crops from anywhere and at any time, they also help farmers to stay organised and keep track of daily tasks in the field [8].

The proposal presented here is a work in progress that is focused on the web at this first stage before being integrated in a hybrid web-mobile application. This first stage copes with coffee crops, and it tackles a highly problematic plague for coffee crops: the rust fungus (*Hemileia vastatrix*). In the next sections the whole proposal is depicted, particularly the first advances in its development, the Coffee Rust Semaphore.

As far as is known, there are no specific applications or computer systems for the automatic detection of coffee rust [4]. So, the proposal presented here is a pioneering system in the field.

III. A COFFEE CROP SEMAPHORE

The coffee plant can be damaged by various pests and diseases, which are favoured or inhibited by specific climatic conditions of temperature and humidity. As a consequence of climate change, these pests could increase their distribution over an altitudinal range, infecting plantations on a global level.

The Coffee Crops Traffic Light (SCC) is a web application that estimates the probability of the presence of rust in coffee bushes based on data collected *in situ* regarding values and indicators of their phenology, like relative humidity, temperature and date of reading. It does consider offering a visualisation panel of the estimations, indicators and variables of the monitored coffee plantations.

The SCC allows either new databanks to be uploaded to the system and being analysed by different algorithms and models, or exploring the available databanks coming from other users. In the following subsections these main components are explained.

A. System Architecture

In Fig. 1 the diagram of components of the CCS is depicted. The main modules of the systems are: *Databank Manager* (in charge of uploading and managing new databanks), *Machine Learning* (in charge to apply algorithms to analyse databanks or performing statistical profiles and analysis).

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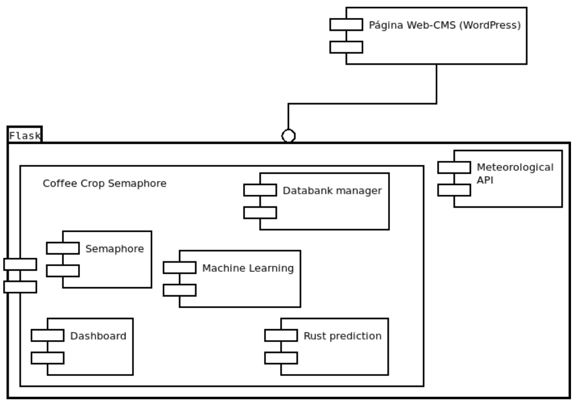

Fig. 1 Components Diagram of Coffee Crop Semaphore

Rust Prediction (aimed to provide an estimation of the condition where diseases, in this case coffee rust appears in the coffee crops, based on a traffic light signalling method), *Semaphore and the Dashboard* (the actual interface of the system in charge of sowing the options to the user and depicting the output).

B. A Traffic Light Alerting System

A key function of the system is to provide users with actionable information and a means to analyse their databanks. For doing so, a semaphore, i.e. a traffic light alerting system is integrated in the systems that takes tabular data from user stored databanks or from the uploads, and performs different analysis according to the user specification to estimate the presence of plagues or diseases, based on the estimators present in data. Fig. 2 portrays the flow of the operations to detect plages (using the coffee rust as a basis case).

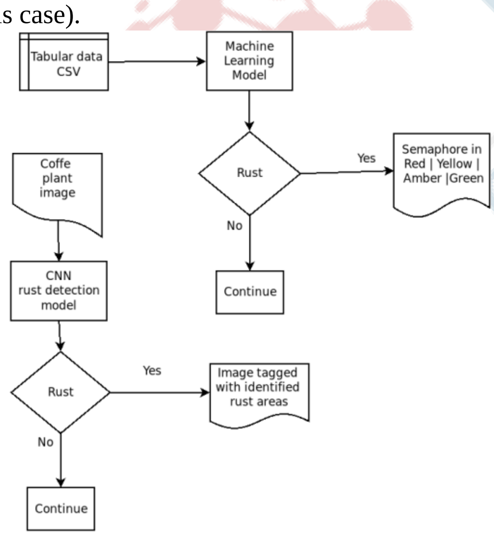

Fig. 2 Steps to identify the presence of plagues in coffee crops, either from a databank or an image, using the rust fungi as a case of study.

What is presented here is a first phase of the SCC, called the Coffee Rust Semaphore, which is specifically oriented towards estimating the presence of this fungus, based on data banks and images at the mesosystem (coffee plant) level. In the next section the SCC is presented.

IV. Coffee Rust Detection

The SCC started with a first stage focused on the detection of the *Hemilea vastatrix* fungus, commonly known as coffee rust. As a web based system it offers to users the two aforementioned options that are described below.

A. Rust detection based on dataframes

The presence of ruts in data coming from *in situ* sensors uploaded as CSV files is analysed via a variety of ML algorithms such as Time Series models or via other statistical analysis [9]. To identify the presence of conditions favouring the development of rust such as temperature and humidity.

For instance, the Time Series model (mainly based on Prophet [9]) registers from databank are converted to Time Series and compared with the modelled one.

In order to estimate the potential risk of rust development in the databanks under analysis, the considered variables present in data where Temperature (T) and Relative Humidity (RH) indicators were found to be within the following thresholds were considered:

- 25º T >= 22º,
- RH >= 95%

Subsequently, to determine the colour of the risk traffic light, the Time D during which these conditions are maintained is measured (1 hour is equivalent to 4 consecutive records in the Time Series).

The risk levels are defined in the following decision function for the traffic light, where red indicates higher risk and green indicates lower risk:

Time	Colour
D >5 hrs	Red
4hrs <= D < 5hrs	Amber
3hrs <= D < 2hrs	Yellow
D <= 2hrs	Green

In this regard, registers containing data with measures between 25 and 22 degrees of temperature, and more than 95% of humidity during certain time frames are commonly reported as a rust potential threat. This results obtained are aligned with the phenology of rust, since the risk of the development of this fungus is due to favourable climatic conditions occurring during the months of May, June, July, August, September and October, while in the months of January, February, March, April, November and December these conditions diminish, so no alerts should be raised in data with similar features.

B. Rust detection based on plant images

To determine the presence of rust in coffee plants a Convolutional Neural Network model was trained to analyse images at the mesosystem level, i.e. coffee bushes [4]. So, the image taken from the crop is tagged as having potentially rust areas in order to report the possible presence of rust in there.

The system offers the sections: *Home*, *Prediction*, *Upload Database*, and *Login*. In Fig. 3 the login page of the system is showed (In Spanish). Once the user is logged, it has the menu option *Prediction* which makes it possible to generate a prediction based on a databank. It is also possible to upload new data, or to select any of the available ones.

Fig. 3 Login page of the Coffee Rust Semaphore (In Spanish only).

Also, users have the possibility of creating a new model using any ML algorithm applied to an existing databank or to the one that was recently added. In Fig. 4 this functionality is shown.

Fig. 4 Menu options for uploading and analysing databanks, consulting and creating new models of analysis (In Spanish only).

In Fig. 5 to 7 the databank managing options are shown.

Fig. 5 Databank managing section of SRC (In Spanish only).

Fig. 6 Model generation section of SRC (In Spanish only).

Fig. 7 Prediction option of SRC to analyse a databank (In Spanish only).

Regarding the rust detection on images, the system provides the functionality of uploading and analysing images from crops as it is shown in Fig. 8 and the results are depicted in Fig. 9.

Fig. 8 Image analysis for rust detection (In Spanish only)

Fig. 9 Results of Image analysis for rust detection (In Spanish only)

It is worth to note that CRC for rust detection on images was trained using a set of synthetic data, i.e. artificially created images to resemble plants with rust on them. This is mainly because the availability of rust infected plants is difficult to find for the project, as we have collaborated with coffee producers that take care of the plants to avoid rust, and this plague is highly dependent on seasonal and climate conditions. So, as a first stage of development it was needed to create the synthetic data for training [4].

V. CONCLUSION AND FUTURE WORK

In this work a first stage of a technological tool to help in coffee crops care is reported. It is a web based system that provides to the user with different ways to analyse the health of coffee crops due the possibility of including ML models from *in situ* data, i.e. data coming from sensors allocated in crops directly. This tool also allows users to analyse pictures at the mesosystem level in order to determine the presence of diseases. It is a socially relevant work aimed to be helpful for producers and technicians of coffee crops.

The current development of the Semaphore of Coffee Crops is focused on coffee rust detection. The development of the prototype also considers the case of real-time risk monitoring for coffee crops. Consequently, there are areas for improvement and future work, as listed below:

- Use a larger set of ML models and other TS models to make estimates and test different prediction algorithms.
- Improve the estimation of rust incidence indicators for localised cases or taking into account particular meteorological conditions in each area.
- Enable the tool to work with *in situ* sensor readings in real time.
- Improve reports and visualisation of the behaviour of the prediction results.
- Increase the domain information to consider more agronomic data that could benefit the estimation of rust incidence in coffee plantations.
- Extending the analysis to other diseases and plagues that affect coffee crops.

ACKNOWLEDGMENT

Author thanks to Gustavo Ortiz, Guillermo Cruz, and Arnol Reyes for their contributions to this work.

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