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Developing a neural-network model for detecting Aflatoxin hotspots in peanut fields

Abstract.

Aflatoxin is a carcinogenic toxin produced by a soilborne fungi, called Aspergillus flavus, causing a difficult struggle for the peanut industry in terms of produce quality, price and the range of selling market. This study aims to develop a successful U-Net CNN (Convolutional Neural Network) model, a reliable image segmentation method, that will help in distinguishing high probability zones of occurrence of Aflatoxin in peanut fields using remotely sensed hyperspectral imagery. The research was delegated to two objectives; 1.) Enabling research to understand and mitigate aflatoxin contamination in the field: Infield aflatoxin hotspot prediction and management and 2.) Deep learning-based postharvest aflatoxin detection using hyperspectral fluorescence imaging.

Keywords.

Aflatoxin, Aspergillus flavus, remote sensing, hyperspectral imagery, artificial neural networks, convolutional neural networks, U-Net CNN model, deep learning.

Developing a neural-network model for detecting Aflatoxin hotspots in peanut fields

The U.S. peanut industry is struggling with the problem of aflatoxin, a carcinogenic toxin produced by the soilborne fungi Aspergillus flavus and Aspergillus paraciticus (hereafter both referred to as A. flavus) under hot and dry conditions growing conditions. Aflatoxin contamination of peanut kernels has caused huge losses to the industry in terms of revenue and market share.

Vellidis et al. (2006) discovered that Aflatoxin is spatially distributed and related to other spatial data leading to the emergence of the hypothesis that Aflatoxin is spatially distributed within peanut fields and can be correlated with easily measurable field parameters. In support of this Boken (2008) found a linear relationship between NDVI and Aflatoxin showing Aflatoxin contaminated zones in peanut fields reflected low NDVI values. This has to do with the heat and water stress tolerance of the peanut plant. Peanut plants under hot and dry conditions, make their leaves fold up as an adaptation to these extreme conditions but also, Aflatoxin flourishes in these extreme conditions, hence there is always high probability that whenever these conditions are found in a peanut field, Aflatoxin may be present in high contamination amounts.

The goal of this project is to develop a mathematical model to predict the likelihood of the occurrence of aflatoxin hotspots within peanut fields using these behaviors and parameters that cause these behaviors. Those hotspots can then be segregated during harvest. To train the model, the first objective to be accomplished is to collect spatially explicit data sets of ECa, soil texture, soil moisture, elevation, spectral response of the plant canopy, plant physiological measurements including leaf temperature, stomatal conductance, and chlorophyll a fluorescence, precipitation, ambient and soil temperature, humidity, solar radiation, and pathogens and weeds in rainfed peanut fields with high spatial variability of soils and terrain, to identify the factors affecting Aflatoxin and obtain a model that predicts probability of Aflatoxin occurrence using all the above mentioned parameters that can be categorized as physiological parameters, soil parameters, weather parameters and entomological aspects.

Soil moisture will be measured continuously from planting to harvest with a soil moisture sensor network, developed by UGA called the SSA matric potential sensors. We will collect hyperspectral imagery and lidar data derived from UAV platforms to identify sections of the electromagnetic spectrum that may detect vegetation changes caused by A. flavus and to generate micro-relief elevation models. Beginning at 90 days after planting and on a biweekly schedule, we will begin collecting physiological measurements and plant samples on a dense sampling grid. Peanut kernels from the plant samples will be analyzed for aflatoxin concentrations. Once these datasets have been obtained, we will try to identify relationships between Aflatoxin occurrence and all the parameters measured. These relationships will be used to discover a mathematical model that will help in producing Aflatoxin occurrence probability maps that will be then fed to a image segmentation model, in this case, U-Net CNN model.

The convolutional neural network model that will be developed will have a design where each band-specific image will be resized to a lower resolution to be used as an input for a CNN model and then we will empirically determine which spectral band reveals the most extend of contamination and then each pixel of an image map will be labelled with whether it is indicating the presence of aflatoxin or not. In the final step, we will assess different candidate models focusing on semantic image segmentation approaches. Our models will consist of several blocks, each having a convolutional layer with 3×3 filter, followed by batch normalization and using different activation functions (e.g., LeakyReLU). We will determine the most efficient model by analyzing their performance for the different peanut cultivars based on standard DL performance metrics including sensitivity, specificity, area under the ROC curve, and accuracy. Statistical significance will be evaluated by multivariate analysis of variance (MANOVA) with respect to aflatoxin B1 and G1 presence/absence and below/above tolerance level.

For each sample, the system will have the capability (i) to make a high-confidence prediction (>90%) on aflatoxin presence and its concentration and (ii) to report the prediction within <1 s. The deliverable of the project is that the model predicts the probability of the occurrence of aflatoxin hotspots within a peanut field with an accuracy of >75% after 1 year of data collection, processing and model training and an accuracy of >95% after the 3rd year of the same.

References

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