Unmanned Aerial Systems for Early Detection of Downy Mildew in Tobacco Fields: Enhancing Financial Outcomes through Precision Monitoring

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ABSTRACT

Downy mildew, caused by *Peronospora hyoscyami* f. sp. *tabacina*, constitutes a significant threat to tobacco production worldwide, leading to substantial economic losses. Early detection and timely management are crucial for successful disease control. In recent years, the integration of unmanned aerial vehicles (UAVs) into agriculture has shown promising results in crop monitoring and disease detection. In a tobacco crop field aerial imagery captured by drones equipped with high-resolution hyperspectral camera RedEdge-M 5.5, allowed for the detection of subtle changes in plant health (vegetation) indicator NDVI. By employing advanced image processing techniques, the change in the vegetation indicators was identified via spectrophotometry in the field and mapped in real-time. The association of this change in plant health with the disease initiation (early symptoms) was done macroscopically, in the specific site, as appointed by the aerial unmanned monitoring system. The acquired data assisted the farmer to perform a targeted fungicide application, thus containing the spreading of the disease among the field. By facilitating timely decision-making, farmers can implement appropriate disease management practices to reduce yield losses and minimize environmental impacts associated with excessive pesticide use. Collaborative initiatives involving farmers, agronomists, and researchers can benefit from drone technology to establish comprehensive disease monitoring networks. Continued research and technological advancements in this field hold significant promise for enhancing crop health management and ensuring global food security in the face of emerging agricultural challenges.

Keywords: Financial outcomes, precision agriculture, NDVI, tobacco, disease

INTRODUCTION

Blue mould (Peronospora hyoscyami f. sp. tabacina) is one of the most important foliar diseases of tobacco that causes significant losses in the Americas, south-eastern Europe and the Middle East. It was first reported in tobacco-growing areas of Australia during the 1800s. Blue mould epidemics have resulted in annual losses exceeding $200 million in North America [1]. The pathogen is capable of infecting tobacco plants in growing regions worldwide throughout the growing season (including transplant production) and can spread rapidly under favourable weather conditions. If the weather is cloudy and cool, the disease can result in complete crop destruction. Early detection and timely management are crucial for successful disease control. However, plant diseases are commonly diagnosed macroscopically using conventional techniques, which are labor-intensive but frequently subjective, reliant on the observer, and inaccurate. Furthermore, due to human error and/or the presence of cryptic symptoms that are not mild, human scouting is costly and frequently impracticable, making early diagnosis challenging [2]. Therefore, the integration of unmanned aerial vehicles (UAVs) equipped with digital, multispectral sensors in agricultural systems may assist in the detection and the quantification of the symptoms induced by plant pathogens in crops [3]. Drones' autonomous systems can sample data simultaneously at different altitudes in the sky; and provide these data to the farmers allowing them to manage the plant disorders on time [4].

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METHODOLOGY

The flight campaign was conducted by Surveying and Geoinformatics company, Exorixi SA, on June 15, 2023, on a tobacco field located at Serres, Greece. UAS multispectral images were acquired with a DT-5Bands imaging instrument, based on the MicaSense RedEdge M 5.5 camera sensor. This sensor consists of five independent high accuracy sensors. The vegetation index was recorded at five spectrum bands (SB): blue, green, red, red-edge, and near infrared (NIR). With a UAV flying at 5 m/s, the flight height was set at 110 m. These parameters allowed the best possible photogrammetric processing, with an 85% forward and a 72% side overlap. The accompanied software Pix4D enterprise (https://pix4d.com/) was used to manage and process the UAV images. Images were orthorectified and the number of overlapping images computed for each pixel of the orthomosaic was over 5.

DATA

The NDVI vegetation index and its variants BNDVI and GNDVI were calculated from the five spectral bands (SB) of the UAV images based on the formulas:

$$NDVI = \frac{NIR-R}{NIR+R}, \quad BNDVI = \frac{NIR-B}{NIR+B}, \quad GNDVI = \frac{NIR-G}{NIR+G}$$

where R—Red; G—Green; B—Blue; NIR—Near InfraRed.

These were chosen because of their potential relevance to discriminate vegetation’s greenness, density, and vigor. Furthermore, the selected VIs were used for monitoring and mapping temporal and spatial variations of biomass and plant throughout the crop cycle based on how plants reflect specific electromagnetic spectrum ranges.

RESULTS

In the present study NDVI and its variations provided a detailed status of the tobacco field. Vegetation indices combined spectral information from selected wavelengths into a single value, which is related to a specific characteristic or property of the vegetation. Most indices combine the high vegetation reflectance in the near-infrared (caused by the refraction of energy due to the cellular structure of the leaves) and lower reflectance in the red region, which is caused by chlorophyll absorption. In cases where vegetation cover is not complete, the contribution of the underlying soil to the reflectance signal was taken into account. By examining reflectance in the near-infrared, we determined whether there were many plants in a field or not, as well as which of them are photosynthesizing to a greater or lesser extent. By combining this information with phytopathology and knowledge of the biological cycle of each crop, we managed, by studying two or more images during a growing season, to determine the disease initiation and take the appropriate measures (Fig. 1). Satellite imagery can also be used to verify farmers' claims about seedbed areas established, tobacco crop sizes in irrigated and dry land areas, and varietal proportions in the fields, as well as monitoring disease development and compliance with legislation. The effects of varietal distribution, nutrients, and cultural management can also be easily monitored and factored in. Satellite sensors' ability to detect subtle differences in crops is significantly affected by their spatial resolution [5]

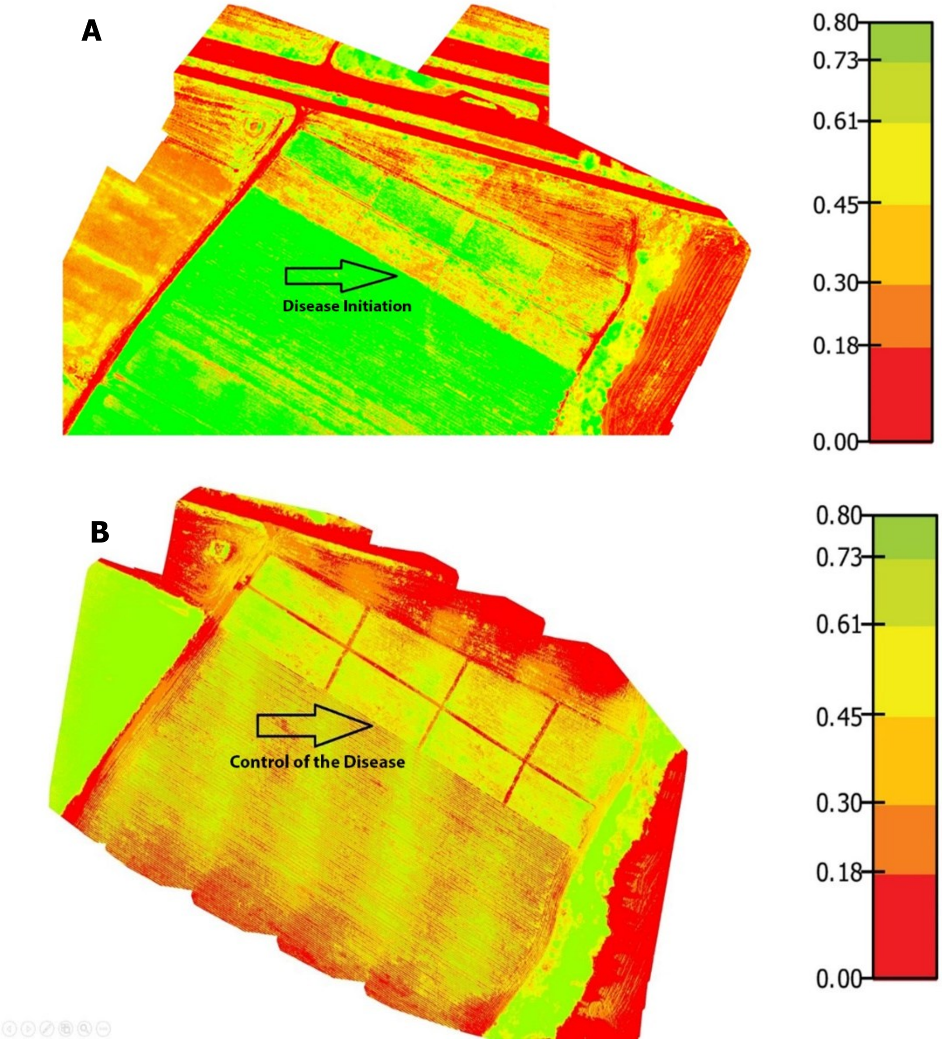

Figure 1. Normalized Difference Vegetation Index map for disease detection and control A. on June 15, 2023 and B. on July 17, 2023, respectively. Values close to 1: the more intense the green, the more vigorous the vegetation and vegetation cover. Values close to 0: correspond to areas with very little vegetation, early stages of cultivation, bare soil, or non-productive areas.

CONCLUSION

Given the high level of training and expertise required, there is a clear need to develop simplified and more automated analysis methodologies for greater dissemination in real operational fields. The University of North Dakota in the United States first employed remote sensing data to help farmers confirm the efficacy of fungicide treatments in preventing plant diseases in a sugar beet crop [2]. Albertis et al.[6], showed high correlation between NDVI index and symptoms from grapevine leaf stripe disease (GLSD). The most widespread method to manage diseases and infestations in plants is routine spraying with appropriate formulations (fungicides, insecticides, etc.). The issue is that diseases do not affect the entire crop from the beginning but appear in scattered, isolated spots as patches. In the present study, the acquired data assisted the farmer to perform a targeted fungicide application, thus containing the spreading of the disease among the field. By facilitating timely decision-making, farmers can implement appropriate disease management practices to reduce yield losses and minimize environmental impacts associated with excessive pesticide use. Additionally, these technologies strive to ensure traceability and environmental sustainability by minimizing the use of chemical inputs [7]. The skills required for the interpretation of UAS images represent one of the key points for the development of the sector and go beyond flight planning and its implementation. The development of user-friendly software could be a turning point for the complete dissemination of these methodologies, still too difficult to be performed by those who do not have specific training. Using machine learning techniques on open data obtained from satellites is one of the most cost-effective and accurate ways of monitoring and estimating tobacco crops [8].

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