REVISTA de la FACULTAD de AGRONOMIA

Correlation between UAV multispectral Imagery and spectroradiometer measurements in sunflower developmental stages

Correlación entre las imágenes multiespectrales de UAV y las mediciones del espectrorradiometer en las fases de desarrollo del girasol

Correlação entre imagens multiespectrais de VANT e medições de espectrorradiômetro nos estágios de desenvolvimento do girassol

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Rev. Fac. Agron. (LUZ). 2025, 42(2): e254223
ISSN 2477-9407
DOI: https://doi.org/10.47280/RevFacAgron(LUZ).v42.n2.VII

Crop production
Associate editor: Dra. Evelyn Pérez Pérez
University of Zulia, Faculty of Agronomy
Bolivarian Republic of Venezuela

Received: 15-01-2025
Accepted: 09-04-2025
Published: 01-05-2025

Keywords:
Sunflower
Spectroradiometer
Correlation
Multispectral bands
UAV

Abstract

Oilseed crops are among the product groups with a supply deficit in the world. The sunflower oil crisis experienced after 2020 ha increased the importance of sunflower cultivation. The most important stages in agricultural applications are to understand whether the plant is healthy in the early stages before it is formed and to prevent negative results in harvest. With the developing technology, the use of unmanned aerial vehicles (UAVs) and multispectral cameras in agricultural applications has gained enormous importance. Thanks to UAVs, agricultural temporal resolution can be adjusted according to the user's request, and spatial resolution can be adjusted according to the ability of the sensor used and the flight altitude. Spectral resolution is directly proportional to the number of bands and the band wavelength. We performed correlation analysis in this study by comparing the accuracy of the band values with ground measurements made with a spectroradiometer. We measured the sunflower in its vegetative, R-3, and R-5 phases and found that there was a strong correlation (r=0.894) in the green band, r=0.845 in the red, r=0.789 in the red edge (RE) band, and r=0.725 in the near infrared band (NIR). The results show a strong connection between the spectral bands and the spectroradiometer measurements, especially in the green and red bands.

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Resumen

Los cultivos oleaginosos están entre los grupos de productos con déficit de suministro en el mundo. La crisis del aceite de girasol experimentada después de 2020 ha aumentado la importancia del cultivo de girasol. Las etapas más importantes en las aplicaciones agrícolas son entender si la planta está sana en las primeras etapas antes de que se forme y prevenir resultados negativos en la cosecha. Con el desarrollo de la tecnología, el uso de vehículos aéreos no tripulados (VANT) y cámaras multiespectrales en aplicaciones agrícolas ha ganado una enorme importancia. Gracias a los UAV, la resolución temporal agrícola puede ajustarse según la solicitud del usuario, y la resolución espacial puede ajustarse según la capacidad del sensor utilizado y la altitud de vuelo. La resolución espectral es directamente proporcional al número de bandas y a la longitud de onda de las bandas. Realizamos un análisis de correlación en este estudio, comparando la precisión de los valores de las bandas con las mediciones en el terreno realizadas con un espectroradiómetro. Medimos el girasol en sus fases vegetativa, R-3 y R-5 y encontramos que había una fuerte correlación (r=0.894) en la banda verde, r= 0.845 en la roja, r=0.789 en la banda del borde rojo (RE) y r=0.725 en la banda del infrarrojo cercano (NIR). Los resultados muestran una fuerte conexión entre las bandas espectrales y las mediciones del espectroradiómetro, especialmente en las bandas verde y roja.

Palabras claves: girasol, espectroradiómetro, correlación, bandas multiespectrales, VANT

Resumo

As culturas oleaginosas estão entre os grupos de produtos com déficit de oferta no mundo. A crise do óleo de girassol vivida após 2020 aumentou a importância do cultivo de girassol. As etapas mais importantes nas aplicações agrícolas são entender se a planta está saudável nas fases iniciais antes de se formar e prevenir resultados negativos na colheita. Com o desenvolvimento da tecnologia, o uso de veículos aéreos não tripulados (VANTs) e câmeras multiespectrais em aplicações agrícolas ganhou uma enorme importância. Graças aos UAVs, a resolução temporal agrícola pode ser ajustada de acordo com a solicitação do usuário, e a resolução espacial pode ser ajustada de acordo com a capacidade do sensor utilizado e a altitude de voo. A resolução espectral é diretamente proporcional ao número de bandas e ao comprimento de onda da banda. Realizamos uma análise de correlação neste estudo comparando a precisão dos valores das bandas com medições de campo feitas com um espectrorradiómetro. Medimos o girassol em suas fases vegetativa, R-3 e R-5 e encontramos uma forte correlação (r=0,894) na banda verde, r=0,845 na banda vermelha, r=0,789 na banda de borda vermelha (RE) e r=0,725 na banda do infravermelho próximo (NIR). The results show a strong connection between the spectral bands and the spectroradiometer measurements, especially in the green and red bands.

Palavras-chave: girassol, espectrorradiômetro, correlação, bandas multiespectrais, VANT

Introduction

Nature sustains agriculture as an economic activity. Substantial yield and quality reductions may arise from any stressor in agricultural production, potentially leading to production interruptions. It is essential to address global climate change and enhance agricultural productivity sustainably. Agriculture employs remote sensing techniques across numerous domains, with recent research augmenting their application. Vegetation mapping in agricultural regions is a crucial component of remote sensing applications for precision agriculture (Geipel *et al*., 2014). Images acquired by platforms such as aircraft, satellites, and unmanned aerial vehicles (UAVs) enable the generation of data regarding vegetation and plant health, as well as the provision of solution recommendations (Adeleke & Babalola, 2020). Remote sensing technologies are effectively utilized in applications that include monitoring, identifying, and differentiating natural objects on Earth, as well as analyzing temporal changes. Notable among these applications are studies that examine plant varieties, species diversity, spatial distribution, development, health and disease, as well as structural aspects of plant species (Ateşoğlu *et al*., 2022). In conducting this research with remotely sensed photos, it is essential to ascertain and analyses the spectral features of natural objects. Consequently, it is evident that spectroradiometer data are utilized to assess spectral qualities (Çölkesen & Yomralıoğlu, 2014). Sunflower is a significant oilseed crop indigenous to South America, presently cultivated in numerous places globally for its nutritional and therapeutic properties (Adeleke & Babalola, 2020). According to 2023 data, Turkey accounts for 3.06 % of the world's sunflower cultivation areas and 3.57 % of the production quantity (Food and Agriculture Organization of the United Nations, 2025).

Sunflower, a significant oil crop globally, is the oilseed plant with the biggest cultivation area and output volume in Turkey, which fulfills nearly 50 % of its vegetable oil requirements from sunflower (Semerci & Durmuş, 2021). Sunflower is a significant oilseed crop for vegetable crude oil extraction, possessing a high oil content of 22-50 % in its seeds. Sunflower accounts for 46.00 % of Turkey's vegetable crude oil output (United States Department of Agriculture and Forestry, 2024). In 2023, the total area dedicated to sunflower cultivation in Turkey was 728,000 ha, according to the Turkish Statistical Institute. Oil sunflowers accounted for 89.3 % of this area, or 650,000 ha. The provinces with the most extensive sunflower agriculture are Tekirdag (142,000 ha) and Edirne (90,000 ha). Tokat comprises 2.5 % (16.25 thousand ha) (Semerci & Durmuş, 2021).

Jafari & Lewis (2012) conducted a study on the differentiation of arid land components in South Australia utilizing Earth Observing 1 (EO-1) Hyperion hyperspectral images and employed the ASD FieldSpec spectroradiometer to ascertain the spectral properties of these components and categorize them.

Günal *et al.* (2021) sought to evaluate the efficacy of UAVs for the geographical and temporal assessment of chlorophyll levels in sunflower (*Helianthus annuus*) plants. To do this, the chlorophyll and vegetation indices derived from the multispectral images captured by the UAV were compared with the chlorophyll measurement sites established by the SPAD meter. Consequently, correlations were established at a 99 % significance level between the computed indices and chlorophyll values.

Herbei *et al.* (2023) employed Sentinel-2 satellites to examine sunflowers and generate yield estimates in their research, utilizing eight series of photos from the designated study region within Timisoara, Romania. A link was observed between the Normalized Difference Vegetation İndex (NDVI) - Normalized Pigment Chlorophyll Ratio Index (NPCRI) and Normalized Burn Ratio (NBR) indexes. They determined a strong association for NDVI and NDMI (r=0.95), NDVI and NBR (r=9.97), and a moderate correlation for NDVI and NPCRI (r=0.88). They achieved an exceptionally high correlation coefficient in these plant indices (r=0.99).

Li *et al*. (2020) conducted a study using a multispectral camera on a UAV. In this study, it was aimed to reveal the plant development level and classify different plant species in plant production areas grown in the Jingyuetan (China) agricultural region.

Material and Method

In the study, sunflower planting area was determined in the Tokat-Kazova region, and three different trial areas were established. In this area, images were taken with the multi-band camera on the UAV platform at certain periods, and the correlation between the spectroradiometer measurements of sunflower development stages (table 1) and the reflection values obtained from the unmanned aerial vehicle was examined. A spectral library of sunflower will be created with the spectroradiometer measurements made.

Table 1. Sunflower stages are measured by a spectroradiometer (Field SpecPro 4 High-Res) (Schneiter *et al*., 1981).

Stage	Description
(V1, V2, V3...V12)	Stage: real leaves at least 4 cm long are seen on the stem stalk.
R-3	Stage when the flower plate that has not yet started to open is attached to the stem, and the distance between the top leaf and the plate is more than 2.0 cm.
R-5	This is the initial stage of flowering. This is the phase during which the flowers have either fully opened or have begun to open at specific rates.

Abbreviations: V is vegetative stage.

Study Area

This section of the study will provide information about the study area and the planted area. Additionally, measurements taken from the spectroradiometer will be compared with UAV data. The study area has been selected as the Kazova region in Tokat province, Turkey (figure 1).

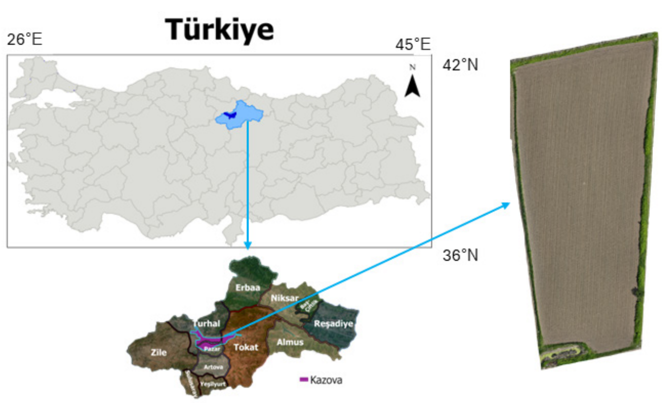

Figure 1. Location of the study area in the Kazova Region of Tokat Province, Turkey.

The area depicted in figure 1 was segmented into three equal plots to establish a trial zone. The area sizes were adjusted to ensure proximity to one another. This study measured the coordinates of ground control points, spectroradiometer measurement points, and soil sample points (figure 2).

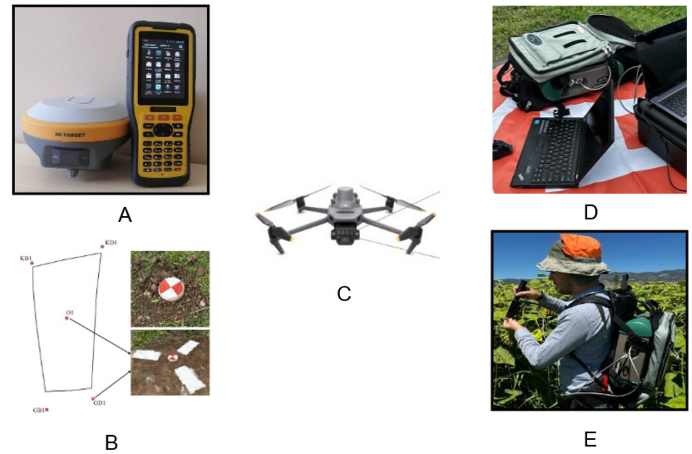

Figure 2. Equipment used to determine the coordinates at the measurement points. A) GNSS (Global Navigation Satellite System) Receiver, B) GCP (Ground Control Points), C) UAV (Unmanned Aerial Vehicle) (DJI Mavic 3M), D) spectroradiometer, E) spectroradiometer sampling.

The coordinates of the Ground Control Points (GCPs) are obtained using the Hi-Target V90 Plus type GNSS receiver. We employed the RTK (Real Time Kinematics) methodology to conduct measurements utilizing the GPS (Global Positioning System). RTK is a GPS measuring technique that facilitates concurrent measurements and is specifically intended for such applications. The study employed spectroradiometer measurements utilizing the Field SpecPro 4 High-Res, capable of measuring wavelengths from 350 to 2500 nanometers, which is part of the inventory of Cumhuriyet University Faculty of Engineering, Department of Surveying Engineering, owned by ASD firm. The spectroradiometer's reflections were exhibited and examined utilizing ViewSpec Pro software from ASD firm. To see how the reflection values from UAV images and those measured with a spectroradiometer compared, the following formulas were used to find the average for each band. Formulas express N as the number of measurements and lambda as the reflection value at the wavelength. Each land group received measurements from a total of 43 samples.

$$Green = \frac{1}{N}\sum_{i=544}^{576} \lambda_i \quad (1)$$

$$Red = \frac{1}{N}\sum_{i=634}^{666} \lambda_i \quad (2)$$

$$RedEdge = \frac{1}{N}\sum_{i=714}^{746} \lambda_i \quad (3)$$

$$NIR = \frac{1}{N}\sum_{i=834}^{886} \lambda_i \quad (4)$$

The investigation utilized the DJI Mavic 3M unmanned aerial aircraft. It is an imaging system including one 20 MP RGB camera and four 5 MP multispectral cameras. This platform offers images in the Green, Red, Red Edge, and Near-Infrared bands, delivering great resolution for agricultural applications (table 2).

Table 2. Camera Specifications (Wong, 2024).

Camera Specifications	
RGB Camera	20 MP
Multispectral Band	Green 560 nm ±16 nm Red 650 nm ±16 nm RedEdge 730 ±16 nm NIR 860 ±26 nm
Image Format	TIFF

In the flight program DJI Pilot 2, the altitude was set to 21 m (GSD ~ 1 cm), and the transverse and longitudinal overlap ratios were set to 80 %

Application

This section of the study presents details regarding the conducted field studies. Research conducted in the field during the vegetative, R-3, and R-5 stages of sunflower development examined the association between spectroradiometer readings and spectral bands. The Pix4D Field software integrated the photos acquired from the UAV platform. The ARCGIS software layered the orthophotos generated for each band. Figure 3 illustrates the resultant orthophotos.

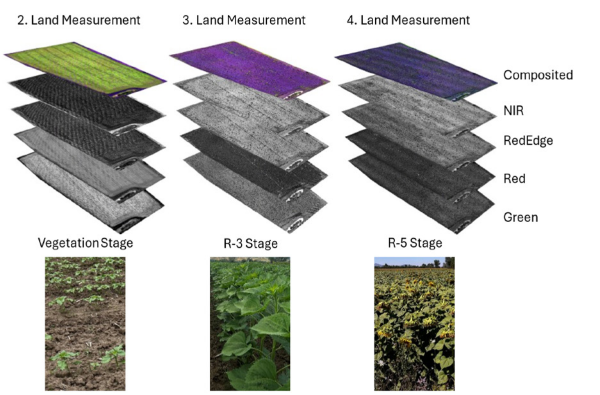

Figure 3. Orthophotos generated for each band in the field research during sunflower development. Vegetative stages, R-3 and R-5 (Schneiter *et al*., 1981).

Results and discussion

Land Measurement Correlation (Vegetative Stage)

The correlation analysis of UAV image bands and ground measurements obtained with the spectroradiometer is presented in table 3, which displays the Pearson correlation coefficient indicating the relationships among the values.

Table 3. Pearson correlation coefficients of the variables compared at phenological vegetation stage.

	G_SPEC	R_SPEC	RE_SPEC	NIR_SPEC
G_UAV	0.867**	0.592**	0.304	-0.056
R_UAV	0.592**	0.822**	0.094	-0.142
RE_UAV	0.536**	0.133	0.635**	0.412
NIR_UAV	0.042	-0.172	0.457	0.617**

n: 43; **Significant correlation at the 0.001 level (bilateral); G: green band; R: red band; RE: red edge band; NIR: near infrared band; UAV: Unmanned Aerial Vehicle; SPEC: spectroradiometer.

A strong positive correlation (r=0.867) exists between G_UAV, representing the green band reflection value of the UAV, and G_SPEC, denoting the green band reflection ratios of the spectroradiometer (figure 4). The relationship is significant, as indicated by a statistical significance value of sig <0.001. The correlation between R_UAV and R_SPEC, representing the red band reflection values of the UAV and the spectroradiometer respectively, is significant (r=0.822). The statistical significance value is sig <0.001, indicating that this relationship is significant. A moderately positive relationship (r=0.635) exists between RE_UAV and RE_SPEC, specifically regarding the red edge band reflection value of the UAV and the red edge band reflection ratio of the spectroradiometer. The relationship is significant, as indicated by a statistical significance value of sig <0.001. A moderately positive relationship (r=0.617) exists between NIR_UAV and NIR_SPEC, indicating a correlation between the near-infrared band reflection values of UAVs and the near-infrared band reflection ratios of spectroradiometers. The relationship is significant, as indicated by a statistical significance value of sig <0.001.

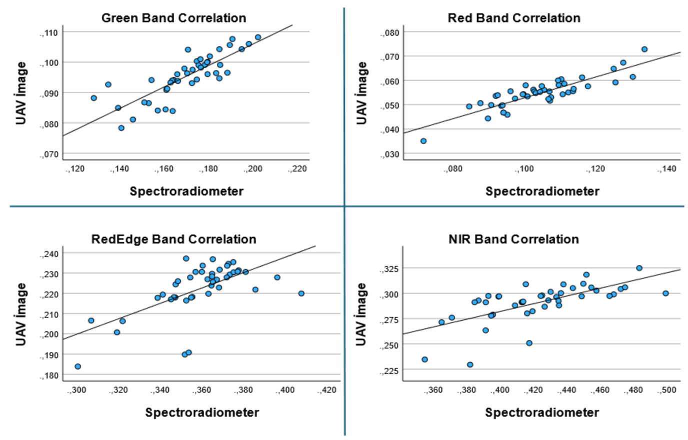

Figure 4. Vegetation Stage Land measurement correlation graphs show the relationship between UAV images and spectroradiometer measurements.

Land Measurement Correlation (R-3 Stage)

Table 4 presents the correlation coefficient values, illustrating the relationships between the values obtained from UAV images and the ground measurements taken with the spectroradiometer.

Table 4. Pearson correlation coefficients of the variables compared at phenological R-3 stage.

	G_SPEC	R_SPEC	RE_SPEC	NIR_SPEC
G_UAV	0.962**	0.740**	0.736**	0.418
R_UAV	0.788**	0.892**	0.594**	0.447
RE_UAV	0.754**	0.481**	0.899**	0.687**
NIR_UAV	0.604**	0.477**	0.763**	0.856**

n: 43; **Significant correlation at the 0.001 level (bilateral) :G: green band; R: red band; RE: red edge band; NIR: near infrared band; UAV: Unmanned Aerial Vehicle; SPEC: spectroradiometer.

This can be achieved via correlation analysis. The correlation analysis indicates a strong positive relationship, with a Pearson coefficient of r=0.962, between G_UAV and G_SPEC. The relationship is significant, as indicated by a statistical significance value of sig < 0.001. A strong positive correlation of r=0.892 exists between R_UAV and R_SPEC. The relationship is significant, as the statistical significance value is less than 0.001. A strong positive correlation of r=0.899 exists between RE_UAV and RE_SPEC. The statistical significance value is less than 0.001, indicating that this relationship is significant. A strong positive correlation of r=0.856 exists between NIR_UAV and NIR_SPEC. The statistical significance value of sig<0.001 indicates that this relationship is significant.

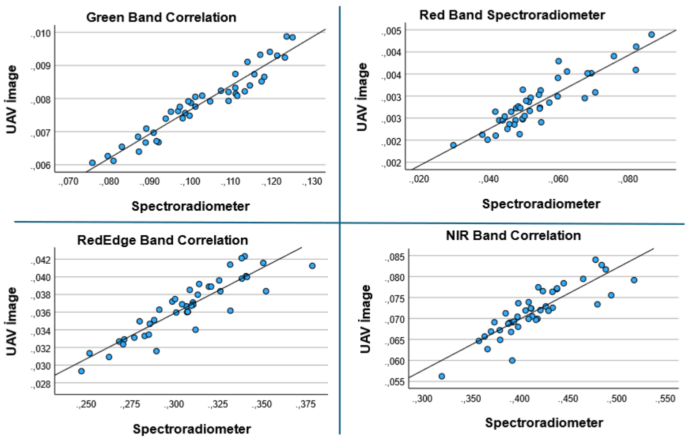

Figure 5. R-3 Stage Land measurement correlation graphs show the relationship between UAV images and spectroradiometer measurements.

Land Measurement Correlation (R-5 Stage)

Table 5 presents the correlation coefficient values, illustrating the relationship between the band values in UAV images and the ground measurements obtained with the spectroradiometer.

Table 5. Pearson correlation coefficients of the variables compared at phenological R-5 stage.

	G_SPEC	R_SPEC	RE_SPEC	NIR_SPEC
G_UAV	0.953**	0.767**	0.767**	0.298
R_UAV	0.866**	0.821**	0.762**	0.380
RE_UAV	0.832**	0.664**	0.834**	0.549**
NIR_UAV	0.368	0.280	0.570**	0.704**

n: 43; **Significant correlation at the 0.001 level (bilateral) :G: green band; R: red band; RE: red edge band; NIR: near infrared band; UAV: Unmanned Aerial Vehicle; SPEC: spectroradiometer

The values were derived from a correlation analysis. The correlation analysis indicates a strong positive relationship, with a coefficient of r=0.953, between G_UAV and G_SPEC. The relationship is significant, as indicated by a statistical significance value of sig < 0.001. A strong positive correlation of r=0.821 exists between R_UAV and R_SPEC. The statistical significance value of sig<0.001 indicates that this relationship is significant. A strong positive correlation of r=0.834 exists between RE_UAV and RE_SPEC. The statistical significance value is less than 0.001, indicating that this relationship is significant. A strong positive correlation of r=0.704 exists between NIR_UAV and NIR_SPEC. The statistical significance value is less than 0.001, indicating that this relationship is significant.

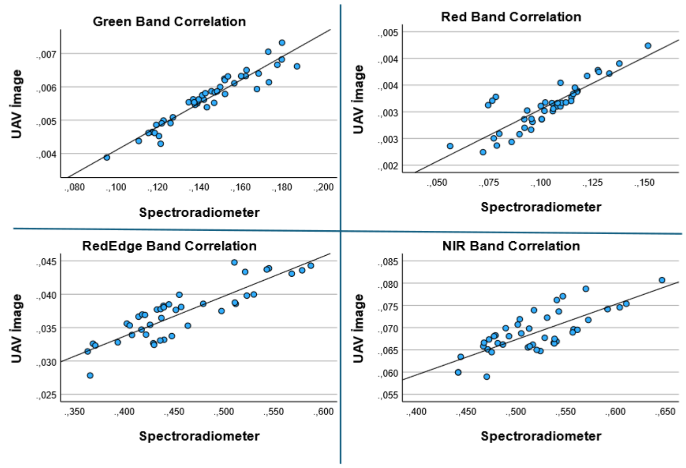

Figure 6. R-5 Stage Land measurement correlation graphs show the relationship between UAV images and spectroradiometer measurements.

A positive correlation was found between the reflection maps made from field images of sunflowers in different stages of development (vegetation, R-3, and R-5) and the correlation in the study areas that were set aside for the study. Lee *et al*. (2020) also found in their studies that each band has a strong and forceful positive correlation with its spectroradiometer. However, they also concluded that the bands have both negative and positive correlations with other bands. Zeng *et al*. (2017) did another study using two different approaches to figure out the correlation between the UAV and the spectroradiometer. They reached a strong and forceful positive correlation result, but in the ideal time offset they developed, they calculated a forceful positive correlation of r=0.97 across the spatial area. During the development stages, when the correlation was calculated, the NIR band's correlation was generally lower compared to the other bands. We can explain this effect as the sensitivity of the camera; while the other bands record at ±16 nm, the NIR band records at ±26 nm. This slight impact is due to the sensitivity of the camera.

Conclusions

The crop conditions of sunflowers vary according to many factors. Rainfall, seeds, fertilizer, temperature, among others, directly affect the quality and quantity of the crop. It is critical for the farmer to be knowledgeable about the crop in the field to minimize the damage caused by these variables. Drones play a crucial role in this situation. The correlation between the reflectance values of the images obtained by the multispectral camera integrated into the UAV used in field studies and the field measurements conducted with the spectroradiometer has been examined.

According to the results obtained at the end of the study, there is a strong and very strong positive correlation between the reflectance values obtained from multispectral bands and the spectroradiometer measurements. We observed that the R-3 phase images created a correlation with an r>0.85 value for the four bands analyzed. We found that the R-3 stage is optimal for yield estimation. Considering the importance of sunflower oil in recent years, monitoring the growth stages, health status, and yield is critical. With the advancing technology, UAVs and multispectral images have also found their place in agricultural applications. This research shows that the reflection values of multispectral cameras built into UAVs can be used to accurately and consistently track different stages of sunflower development.

Literature Cited

Adeleke, B. S., & Babalola, O. O. (2020). Oilseed crop sunflower (*Helianthus annuus*) as a source of food: Nutritional and health benefits. *Food Science & Nutrition, 8(9), 4666–4684*. https://doi.org/10.1002/fsn3.1783

Ateşoğlu, A., Kavzoğlu, T., Çölkesen, İ., Özlüsoylu, Ş., Tonbul, H., Yılmaz, E. Ö., & Öztürk, M. Y. (2022). türkiye'de hızlı büyüyen türlere ait spektral kütüphane kurulması: kavak türleri çalışması. *Bartın Orman Fakültesi Dergisi*, *24*(2), 324-338. https://doi.org/10.24011/barofd.1099984

Çölkesen, I., & Yomralioğlu, T. (2014). Arazi örtüsü ve kullanımının haritalanmasında worldview-2 uydu görüntüsü ve yardımcı verilerin kullanımı. *Harita Dergisi*, *80*(152), 12–24. https://www.harita.gov.tr/images/dergi/makaleler/b10d25cbe07aeb3.pdf

Food and Agriculture Organization of the United Nations. (January 10, 2025). *The State of Food and Agriculture*. https://www.fao.org/faostat/en/#data/QCL

Geipel, J., Link, J., & Claupein, W. (2014). Combined spectral and spatial modeling of corn yield based on aerial images and crop surface models acquired with an unmanned aircraft system. *Remote Sensing*, *6*(11), 10335–10355. https://doi.org/10.3390/rs61110335

Günal, E., Kılıç O.M., Dökülen Ş. (2021). İnsansız hava aracı teknolojisi kullanılarak ayçiçeği (*Helianthus annuus*) bitkisinin klorofil içeriklerinin tahmin edilebilirliğinin araştırılması. *EJONS International Journal on Mathematic, Engineering and Natural Sciences, 5*(19), 691–700. https://doi.org/10.38063/ejons.624

Herbei, M. V., Popescu, C. A., Bertici, R., & Sala, F. (2023). Estımatıon of sunflower crop productıon based on remote sensıng technıques. *AgroLife Scientific Journal*, *12*(1), 87–96. https://doi.org/10.17930/agl2023111

Jafari, R., & Lewis, M. (2012). Arid land characterisation with EO-1 Hyperion hyperspectral data. *International Journal of Applied Earth Observation and Geoinformation*, *19*, 298–307. https://doi.org/10.1016/j.jag.2012.06.001

Lee, D.H., Shin, H.S., & Park, J.H. (2020). Developing a p-NDVI map for highland kimchi cabbage using spectral ınformation from UAVs and a field spectral radiometer. *Agronomy*, *10*(11), 1798. https://doi.org/10.3390/agronomy10111798

Li, L., Zheng, X., Zhao, K., Li, X., Meng, Z., & Su, C. (2020). Potential evaluation of high spatial resolution multi-spectral images based on unmanned aerial vehicle in accurate recognition of crop types. *Journal of the Indian Society of Remote Sensing*, *48*(11), 1471–1478. https://doi.org/10.1007/s12524-020-01141-4

Semerci, A., & Durmuş, E. (2021). Analysis of oily sunflower production in Turkey. *Turkish Journal of Agriculture-Food Science and Technology*, *9*(1), 56-62. https://doi.org/10.24925/turjaf.v9i1.56-62.3688

Schneiter, A. A., & Miller, J. F. (1981). Description of sunflower growth stages1. *Crop Science*, *21*(6), 901–903. https://doi.org/10.2135/cropsci1981.0011183x002100060024x

United States Department of Agriculture and Forestry. (February 10, 2024). *Oil crops year book*. https://www.ers.usda.gov/publications/pub-details?pubid=98237

Wong, W. (2024). *What is the custom camera parameters for Mavic 3 Enterprise series and Mavic 3M?* https://sdk-forum.dji.net/hc/en-us/articles/12325496609689-What-is-the-custom-camera-parameters-for-Mavic-3-Enterprise-series-and-Mavic-3M

Zeng, C., King, D. J., Richardson, M., & Shan, B. (2017). Fusion of multispectral ımagery and spectrometer data in uav remote sensing. *Remote Sensing*, *9*(7), 696. https://doi.org/10.3390/rs9070696