Configuration and specifications of an unmanned aerial vehicle for precision viticulture

Configuración y especificaciones de un dron para viticultura de precisión

M. Erena*[1], S. García-Galiano[2]

[1] GIS and Remote Sensing Group, IMIDA, 30150, La Alberca, Murcia, Spain

[2] Universidad Politécnica de Cartagena, Paseo Alfonso XIII, 52. 30203 Cartagena, Spain

Abstract

Unmanned Aerial Vehicles (UAVs) with multispectral sensors are increasingly attractive in geosciences for data capture and map updating at high spatial and temporal resolutions. These autonomously-flying systems can be equipped with different sensors, such as a multispectral camera and miniaturized sensor systems, for navigation, positioning, and mapping purposes. These systems can be used for data collection in precision viticulture. In this study, the efficiency of a light UAV system for data collection, processing, and map updating in small areas is evaluated by the generation of correlations between classification maps derived from remote sensing and production maps, based on the comparison of the indices derived from UAVs incorporating infrared sensors with those obtained by satellites (Sentinel IIA and Landsat 8). The results indicate that UAVs are a promising option for the characterization of vineyard plots with high spatial variability, despite the low vegetative coverage of these crops.

Keywords: UAV; calibration; multispectral; Sentinel IIA; Landsat 8.

Resumen

Los vehículos aéreos no tripulados (UAV) con sensores multiespectrales son cada vez más atractivos en ciencias de la tierra para la captura de datos y actualización de mapas con alta resolución espacial y temporal. Estos sistemas de vuelo autónomo pueden equiparse con diferentes tipos de sensores, tales como cámaras multiespectrales y sensores miniaturizados, para facilitar la navegación, el posicionamiento y la elaboración de mapas de alta resolución. Estos sistemas ya se están utilizando para la recolección de datos en la viticultura de precisión. En este estudio, se pretende evaluar la eficiencia de los estos vehículos para la recolección de datos, procesamiento y actualización de mapas en áreas pequeñas, así como su comparación con otros índices derivados de los satélites (Sentinel IIA y Landsat 8). Los resultados indican que los UAV son interesantes para la caracterización de las parcelas de viña con alta variabilidad espacial, a pesar de la baja cobertura vegetal de estos cultivos.

Palabras clave: UAV; calibración; multiespectral; Sentinel IIA; Landsat 8.

* E-mail: manuel.erena@carm.es

1. INTRODUCTION

This article presents a multiscale approach designed to obtain different vegetative parameters. The characterization of the spatial variability in water status across vineyards is a prerequisite for precision irrigation. In this work we used simultaneous unmanned aerial vehicle (UAV) and aircraft surveys and Landsat 8 and Sentinel II satellite images, acquired over vineyards in south-eastern Spain, to assess the capability of each system to represent the intra-vineyard vegetation patterns, to evaluate the similarities of images taken at different spatial resolutions, and to perform an evaluation that combines operational and economic factors. Particularly useful are aerial images in the thermal (TIRS) infrared [1] and near-infrared (NIR) spectrum [2]. UAVs with multispectral sensors are becoming increasingly attractive for data capturing and map updating at high spatial and temporal resolutions in viticulture. Airborne thermal and multispectral images have also been applied successfully to the detection of water stress at larger scales. The normalized canopy temperature [3] and photochemical reflectance index [4] were demonstrated to be the best indicators of early and advanced water stress.

The investigation was based on a set of aerial images recorded during the flights performed with a UAV system over a commercial vineyard plot in Jumilla and an experimental vineyard in Bullas (Murcia, Spain). Additionally, biophysical indices obtained with the UAV were compared with those obtained by processing Landsat 8 and Sentinel IIA images and using multispectral and thermal cameras on-board of an airplane. These tests show the preliminary results for the configuration of a UAV-based system to be used for practical applications in precision agriculture [5,6].

2. MATERIALS AND METHODS

2.1 Study site and data

Two vineyards, hereafter referred to as V1 (38°34′05′′N, 1°21′14′′E) and V2 (38°06′39′′N, 1°40′59′′E), were chosen as test sites in the Murcia Region (Spain). The vineyards have similar agronomic characteristics. The commercial vineyard plot is divided into four zones, according to their lithology and the age of the plantation on the plot.

In the commercial vineyard (V1), the Droning D650 UAV was used, which carried a stationary point-and-shoot camera, model Canon IXUS 125 HS with a Blue filter. The Canon camera acquires 16.1-megapixel images (Infrared, IR; Green, G; and Blue, B, bands) with 8-bit radiometric resolution. The UAV images were collected on June 26th 2015, T13:30Z to T13:55Z. The efficiency of a UAV system for data collection, processing, and map updating in small areas is evaluated using different indices like enhanced normalized difference vegetation ENDVI [7]. The aerial images were collected on June 26th 2015, T13:30Z to T13:55Z, using a six-band multispectral camera (model Tetracam mini-MCA-6) and FLIR thermal cameras on-board an airplane. The indices calculated are canopy temperature and PRI.

Two types of satellite images have been used: Sentinel IIA has an optical instrument payload that samples 13 spectral bands: four bands at 10 m spatial resolution, six bands at 20 m, and three bands at 60 m. These images were collected on July 6th 2015, at T11:03Z, using the spectral band numbers 2, 3, 4, and 8 (10 m) of the MSI sensor. Landsat 8 data products comply with all the standard Level-1 specifications: OLI multispectral bands 1-7, 9: 30 meters; OLI panchromatic band 8: 15 meters; TIRS bands 10-11: 100 meters; Orthorectified; 16-bit pixel value. These images were collected on July 7th 2015, at T17:25Z, using the OLI and TIRS sensors.

2.2 Image acquisition

The set of UAV aerial images was collected on June 26th 2015, T12:00Z - T13:30Z. The index obtained was ENDVI with a resolution of 10 cm (Fig. 1). The flight with the AV was performed with sensors, a 6-band multispectral imager (Tetracam, model mini-MCA), and a thermal camera (FLIR) a resolution of 50 cm. The images were collected on June 26th 2015, T12:00Z - T13:30Z (Fig. 2). The automatic IMIDA processing system generates agro-meteorological products from Landsat 8. Each Landsat 8 image received is processed to generate the following products covering Murcia (Fig. 3): radiance, reflectance, NDVI, land surface temperature-LST (B10 and B11), soil-adjusted vegetation index-SAVI, leaf area index-LAI, and air temperature-AT [8]. The description of the processing system and products is available on the website http://idearm.imida.es/.

3. RESULTS AND DISCUSSION

This paper first presents a camera system designed for georeferenced NIR orthophoto generation, which was reliably used on a UAV. The results obtained with the thermal camera on the AV highlight the great differences in water stress among the different plots of the farm, which condition the production - in terms of quantity and quality - of the vineyard.

This UAV platform is proposed as a tool that can meet the needs of precision viticulture in terms of remote sensing, being distinguished by the low cost, timeliness, and flexibility of the measurements, customization of the equipment, full automation of the flight plan, and high precision quality of the data acquired. The tests performed show that the UAV platform may provide a tool that can be implemented at the farm level, even for small businesses. For future research, the development of advanced UAV systems with thermal and spectral cameras (Flir-Tau/Tetracam mini-MCA) would allow water stress to be monitored plant by plant. Regarding the existing studies on the application of UAVs to plant monitoring, the UAV flight must be configured to achieve an optimal spatial resolution between 20 and 50 cm, adequate for precision viticulture [9].

4. CONCLUSIONS

The understanding of the intra-vineyard variability is a keystone to implement effective precision agriculture practices, especially in Mediterranean environments where the land-use patterns are highly fragmented and vineyards present high heterogeneity because of variability in the soil, morphology, and microclimate. Our study, based on the comparison of different remote sensing platforms, shows that different resolutions provide similar results in the case of vineyards characterized by pronounced vegetation gradients and large vegetation clusters. On the contrary, in vineyards characterized by low vegetation gradients and high vegetation patchiness, low-resolution images fail to represent intra-vineyard variability and its patterns. Furthermore, considering the peculiarity of the crop structure of vineyards, our work points out the impossibility of distinguishing the canopy and inter-rows in the case of low-resolution images. The cost analysis shows that, beyond technical aspects, an economic break-even between UAV and the other platforms exists between 1 and 30 ha of area coverage, and that aircraft remote sensing remains competitive with satellites above this threshold.

5. REFERENCES

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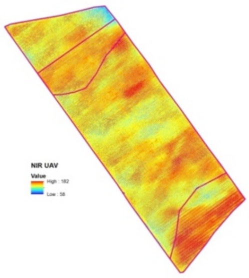

Figure 1. ENDVI 2015/06/26T1300Z (0.1m)

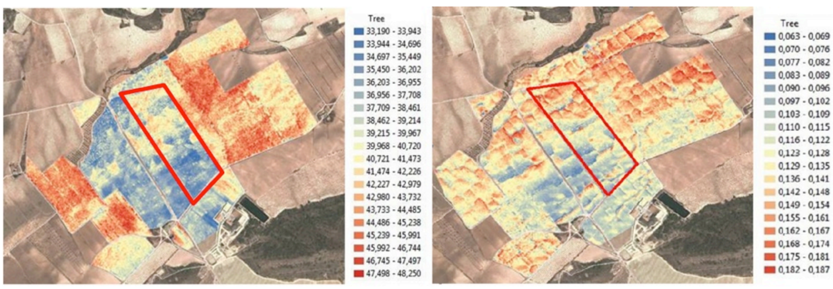

Figure 2. Canopy temperature (°C) and PRI index 2015/06/26T1330Z (0.5 m)

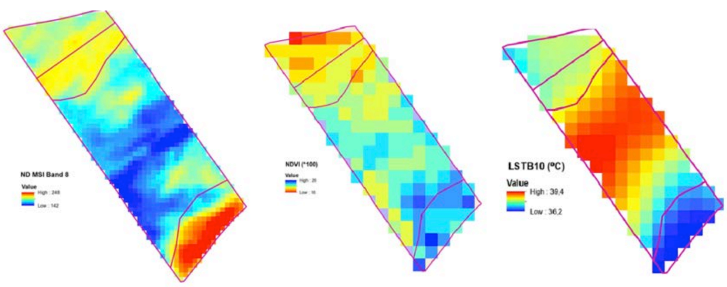

Figure 3. SII-MSI 2015/07/6:T11Z (10 m), NDVI, and L8 LSTB10 2015/07/09:T17Z (30 m).