RADIOMETRIC PERFORMANCE OF MULTISPECTRAL CAMERA APPLIED TO OPERATIONAL PRECISION AGRICULTURE

J. González-Piqueras[1], S. Sánchez[1], J. Villodre[1]; H. López[2], A. Calera[1], D. Hernández-López[1] & J. M. Sánchez[1].

[1]GIS and Remote Sensing Group. Instituto de Desarrollo Regional. Universidad de Castilla-La Mancha. Campus Universitario S/N, 02071 Albacete (Spain). Jose.gonzalez@uclm.es

[2] Instituto Técnico Agronómico Provincial (ITAP) and FUNDESCAM, Parque Empresarial Campollano, 2ª Ave, 61, 02007 Albacete (Spain)

ABSTRACT

The use of multispectral sensors onboard of unmanned vehicles is nowadays a common practice in precision agriculture. Their radiometric behavior is an important issue to ensure comparable information along space and time. A calibration of a Sequoia® camera is conducted in terms of reflectance and NDVI, taking benefit from a wheat cover field work. The output reflectance values in the green and red channel show linear behavior in the range of 0.00 to 0.45, with a saturation over this value. The red edge and NIR channels show linear behavior in the whole reflectance range, with better performance in the NIR than in the red-edge channel. The NDVI has a good agreement with field measurements, near the 1:1 line, showing the highest variability for the lower values due to heterogeneity of soil brightness linked to variations in soil moisture.

Index Terms— Reflectance, Multispectral Camera, Radiometric Calibration, NDVI

1. INTRODUCTION

Remote sensing using proximal sensors onboard aerial platforms is nowadays providing valuable information in precision agriculture for the management of crops at convenient spatial and temporal resolutions. They can provide crop nutrition and water status maps through different approaches. Using combinations of spectral reflectance values from different bands, known as vegetation indices [1,2], is the simplest and most operational way. The multispectral configuration of these sensors ranges red to near infrared, including the red edge spectral band (720 ± 40 nm). This is a transition region where a rapid change in leaf reflectance occurs, caused by the strong pigments absorption in the red, and leaf scattering in the near infrared ranges. The behaviour of the reflectance in this region of the spectrum has been proved sensitive to crop canopy chlorophyll and consequently to nutrition status [3].

The information provided by these sensors must be coherent with other routinely applied at different spatial and temporal scales, such as field spectroradiometers and other onboard satellite platforms. Therefore, a sensor calibration is desirable to check the radiometric behavior of each pixel in different spectral regions. Ground-truth measurements of reflectance over different surfaces, using a calibrated spectroradiometer [4], can be used for this aim. For this purpose, the manufacturers are nowadays implementing irradiance sensors that simultaneously acquire the radiation to the flight or reflectance patterns. A good knowledge of the sensor radiometric behavior is then crucial to provide comparable information along space and time [5].

The objective of this work is to study the radiometric performance of an operational multispectral camera Sequoia® manufactured by Parrot, within a routinely field monitoring work, in order to set the best working range and the quality of the data provided at reflectance and vegetation index levels.

2. MATERIALS AND METHODS

This work was carried out in “Las Tiesas” experimental farm, located in La Mancha region (Spain) (39° 2'54.24"N, 2° 4'38.90"W), during the year 2017. This is an experimental area used for research and precision agriculture purposes. This site allows covering a variety of crops at different development stages within a same scene. In our case, a collection of different varieties of wheat and barley were considered (Figure 1).

The spectral reflectances were measured during different mid to late stages of the crop development. An spectroradiometer ASD FieldSpec 3 Hi-Res ® was used for the field measurements, concurrent to the unmanned aerial vehicle (UAV) flights provided with a multispectral camera. This acquisition strategy has a double objective, monitoring the vegetation and using well-known calibration surfaces to

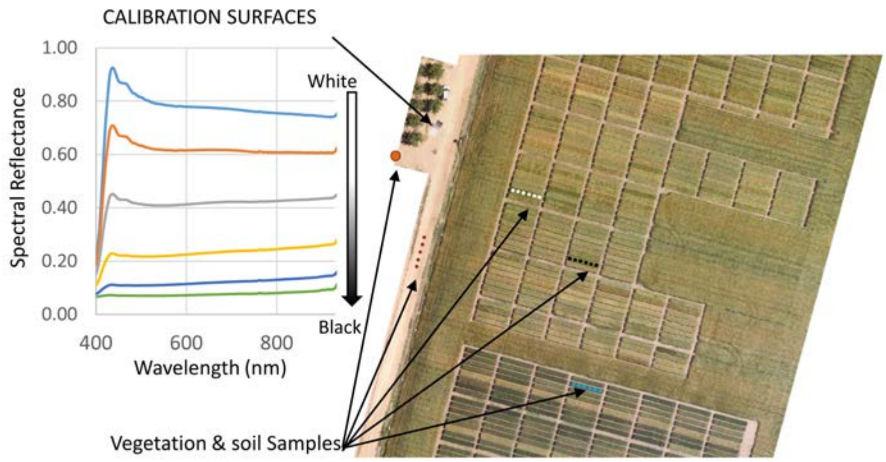

Figure 1. Location of the experimental area, indicating the calibration surface tarps with their spectral reflectance, and the points of soil and vegetation measurements.

provide a complete range of reflectance values in each flight at the same time.

Field measurements of reflectance are provided with a bandwidth of 1.5 nm in the range 400-1100 nm. The calibration surfaces are self-designed and spectrally characterized in the laboratory using the spectroradiometer. In addition, a complete range of reflectance measurements were made simultaneously to the flights, at six levels, ranging from an average albedo of 0.1 (black) to 0.8 (white) as seen in Figure 1. The sampling was based on averages of 6 points for each surface combined with averages of 10 measurements each, to minimize electronic and random errors. The same strategy was applied to the vegetation and soil measurements, selecting five subplots for five different dates (see Figure 1): 08/06/2017, 12/06/2017, 14/06/2017, 21/06/2017, 23/06/2017.

The UAS images were acquired with a multispectral Sequoia ® manufactured by Parrot (https://www.parrot.com/es/profesional/parrot-sequoia#parrot-sequoia-) incorporating four multispectral channels, located in the Green (550 nm with a bandpass of 40 nm), Red (660 nm with a bandpass of 40 nm), Near infrared (790 nm with a bandpass of 40 nm) and Red Edge (735 with a bandpass of 10 nm). The flights were designed accounting for the footprint of the camera with a minimum overlapping of 80 % between images and lines of flight. Additionally, acquisition times were between 10:00 and 11:00 and flight lines were oriented perpendicular to the solar plane, in order to avoid hot-spot effects due to the coincidence of high elevation solar angle and the wide field of view of the camera. Prior to all flights, an initial capture was done over a calibration panel in order to get information on directional measurements (such as the position of the sensor and the sun), irradiance measurements (using tools such as light sensors or reflectance panels), as well as gain and exposure data from the camera. Considering these factors, a first calibration acquisition was enabled in the mosaicking process done with Pix4D ® software for the conversion of raw digital numbers (from the raw imagery) to surface reflectance values. The reflectance map generated in all bands was a 10 cm of GSD (Ground Sample Distance).

3. RESULTS

3.1. Reflectance

The processing chain of the UAV multispectral images yields images of the spectral surface reflectance for each band. To make field measurements comparable, the filter function of the camera was applied to the ASD data to reproduce the reflectance at spectral camera resolution. Those measurements were averaged over each of the homogeneous plots selected and compared band by band over the calibration surfaces (see Figure 2). This comparison shows that the green and red visible bands saturate at reflectance values of 0.45, whereas the red-edge and near infrared bands show a linear behavior for the full range. This saturation effect in the visible bands is mainly due to the configuration of the sensor mostly oriented to increase its sensitivity to vegetation monitoring, where this cover shows medium to low values in this spectral range and it gains more resolution. Both bands show a linear relationship in the range 0-0.45, with similar slope, bias, and fit parameters. The red edge band shows a worse linear fit, due to its narrow bandwidth and a higher sensitivity of the sensors to spectral and spatial variations.

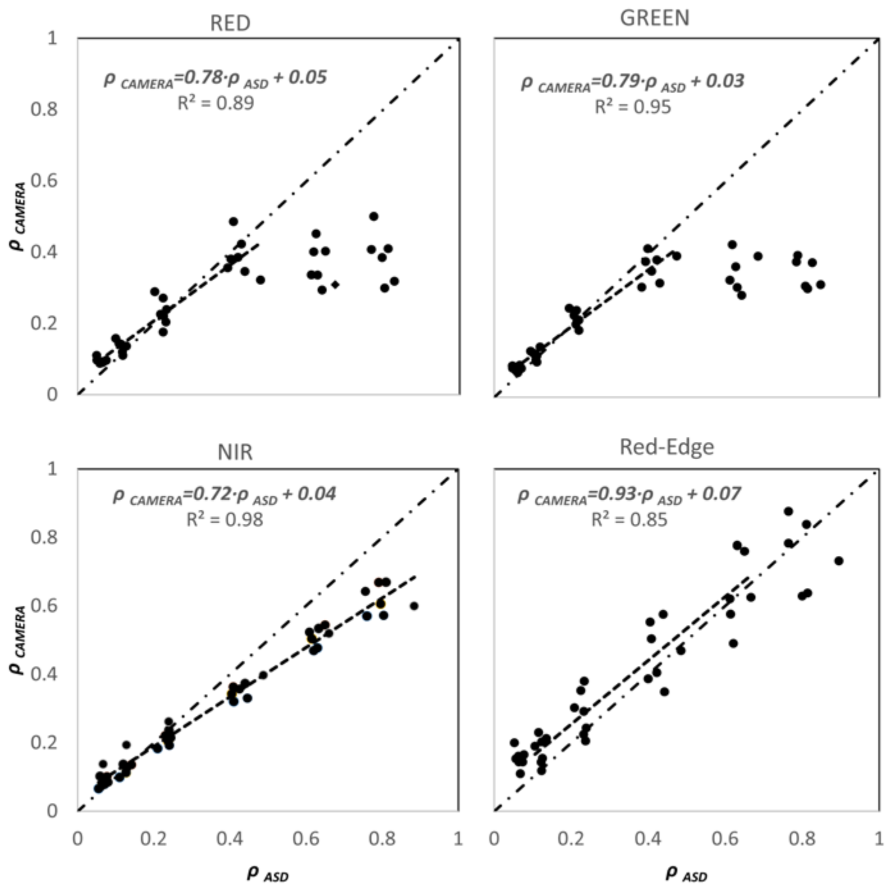

Figure 2. Comparison of reflectance values at the four channels (Green, Red, Red-Edge and NIR) of the multispectral camera with the field ASD measurements.

The reflectance over the soil and crops show the coupling between both covers when they are plotted over the reflectance space of near infrared (NIR) versus (R), that is known in remote sensing as the tasseled cap (Figure 3). The soil line can be located in this plot affected by the soil background humidity (darker for wetter soils), and the isolines of vegetation that converge to a maximum point [6]. The cover is under irrigation system, and the soil was under different water contents during the spectral measurements. The points shown for dry soils correspond to the measurements over bare soil and most of the time without irrigation. This plot shows the coherence of spectral measurements at field scale.

3.2. Vegetation Index

The NDVI vegetation index was calculated for the soil and crop covers obtained from field measurements and from the multispectral camera. The comparison shows a good agreement between both datasets with a slope of 0.98 and a very low bias of 0.02, with a regression coefficient of 0.99. This result confirms the design of the camera for vegetation monitoring, taking into account the saturation effects found in the red and green bands. This is a result of the range of reflectance in the visible bands for the vegetation at different cover levels, that does not take values over 0.20 and it is below the saturation values. This is a consequence of the similar slope in the calibration of the visible and near infrared bands that it is cancelled in the calculation of most of the vegetation indices published in the bibliography, similar to the NDVI.

The soil background in the cover remains wet most of the time and it does not show saturation on reflectance values in the visible bands. For the dry soil, the values are near saturation and higher differences can be observed for lower values of NDVI. The saturation effects on the images corresponding to the brighter parts of the soil have consequences in the mosaic images, showing inconsistencies not shown in this work such as constant values in reflectance or non-value in vegetation index.

4. CONCLUSIONS

The automatic configuration of the multispectral camera is oriented towards the monitoring of green cover. This electronic configuration is applied using a calibration panel prior to each flight in order to account for directionality (such as the sensor-sun position), irradiance measurements, as well as gain and exposure data from the camera. The

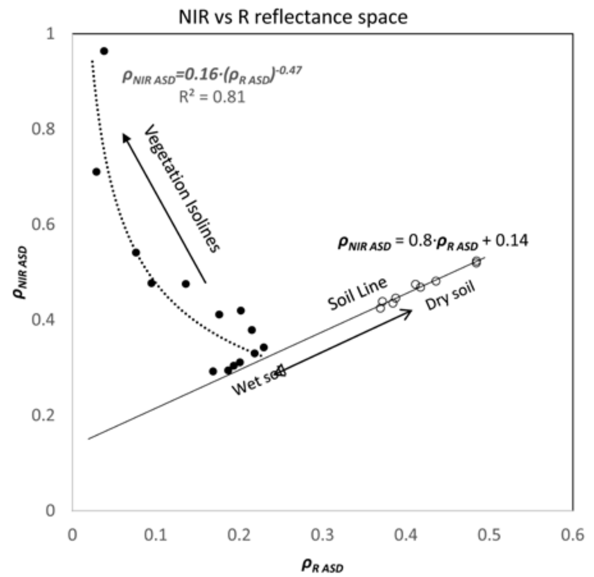

Figure 3. Reflectance space NIR versus R identifying the soil line and the vegetation isoline.

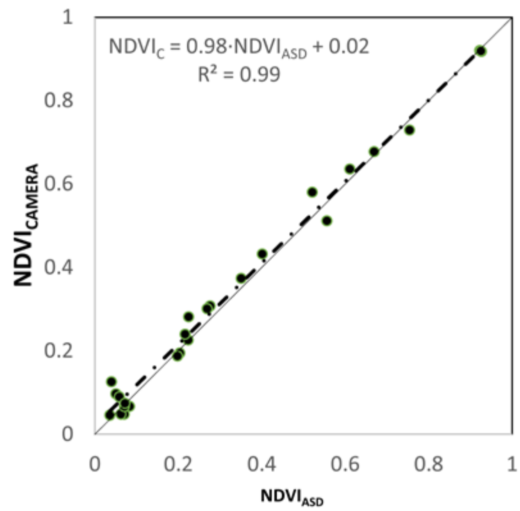

Figure 4. Comparison of NDVI obtained from multispectral camera with field data.

vicarious calibration of the mosaic generated using a commercial software shows that the channels in the green and red are linear in the range of reflectance from 0.00 to 0.45. The red edge channel is linear in the full range of reflectances, as well as in the near infrared despite worse fitting results, indicating more sensitivity to narrower bandpass. A better agreement with field data is observed in terms of vegetation indices such as NDVI. This is a consequence of the similar slopes in all bands, including the linear range in the red. Nevertheless, caution must be taken when observing surfaces with high reflectances in the visible range since saturation effects might appear and mosaicking process could be affected.

Future work will deal with the comparison of the camera response with sensors at different spatial resolutions but similar spectral configuration, such as SENTINEL 2A and 2B. Furthermore, a comprehensive analysis will be conducted in terms of vegetation indices beyond simple ratios, to reinforce the coherence of this information to monitor crop covers.

5. AKNOWLEDGEMENTS

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