Analysis of the intensity of electromagnetic radiation for the estimation of vegetation cover

D A Pelaez\textsuperscript{1}, O E Gualdron\textsuperscript{1}, and L Castellanos\textsuperscript{2}

\textsuperscript{1}Facultad de Ingeniería y Arquitectura, Universidad de Pamplona, Pamplona, Colombia
\textsuperscript{2}Facultad de Ciencias Agrarias, Universidad de Pamplona, Pamplona, Colombia

E-mail: diego.pelaez@unipamplona.edu.co

Abstract. The remote monitoring of electromagnetic radiation allows to differentiate the behavior of five different wavelengths that are shown as images in their respective visible and non-visible light spectral, these are subjected to a processing in which it is calculated for each pixel using the red band and near infrared the normalized difference vegetation index, with which a multispectral orthophoto mosaic is generated which is later analyzed with the objective of estimate the quantity and quality of vegetation of 15 hectares of different properties in the municipality of Tuta in the department of Boyacá, Colombia, that they possess with a high productive potential and in which the process of information acquisition was carried out before and after proceeding with the implementation of crops with a previous agroecological model. Later, a statistical analysis was carried out using polynomial trend models, and this remote inspection system identified that the behavior of radiation intensities at different wavelengths is associated with variable vegetation densities and, indirectly, with the presence of water stress and the quality of the shrubs and plants.

1. Introduction
Multispectral images are achieved by acquiring electromagnetic radiation intensity taken by sensors configured to be sensitive to a very specific visible or non-visible wavelength called band [1]. The current development of remote sensing technologies with this type of tools provides efficient alternatives that can be used in the monitoring of large crops and is considered a very unusual strategy [2].

Multispectral cameras handle several types of electromagnetic spectral bands. The selection of bands is done using two different methods to establish different specific bands, by filter or by envelope [3], the final product of multispectral images is a set of images corresponding to the amount of different bands available [4]. The analysis of the images can be done by means of statistical methods, either supervised or unsupervised, both methods divide the images by pixels and group them by similar characteristics and label them in such a way that the classification algorithm has the sample material and the class to which it belongs, the unsupervised ones do not require to label the samples although it can lose the correlation that the programmer wants between the group and the classes [5]. Thanks to the great interest in obtaining or developing tools to predict parameters in real time, tools have been developed under spectral images [6], in order to carry out non-invasive inspections within crops [7]. This is a rather new technique, but it promises very accurate results [8]. Successful use of this type of sensor is associated with a thorough calibration process to collect accurate data [9].

This method of information acquisition is widely used in quality control and inspection of food production, because it is a non-destructive technique, but being a relatively new technology presents
two major disadvantages such as the high cost of systems to be implemented and also is a large amount of data that is acquired in a very short time which makes necessary a high computer power to achieve processing such information at a reasonable speed [10]. Remote sensing using unmanned aerial vehicles (UAVs) has the potential to improve data collection because of the proximity to the crops, by obtaining a large amount of data using high-resolution cameras [11]. Remote sensing by means of multispectral cameras implemented in UAVs is widely used to determine agronomic parameters, crop classification and everything related to precision agriculture due to its high resolution that is between 1 and 1.5 cm per pixel and with acquisition heights from 24 to 100 m [12].

This project is carried out with the purpose of analyzing the results of the multispectral survey done in the 15 beneficiary properties of the municipality of Tuta in the department of Norte de Santander, Colombia. For each of the locations, the images are presented with their proper georeferenced, and the results of the percentages of areas covered are also grouped. In seven intervals in which the normalized difference vegetation index (NDVI) are categorized and condensed in a table shown per property, it is important to note that this information is complemented by a comparison between the indices of the first survey and the second one. In addition, a statistical analysis is carried out for each property in which the evolution of the data is more evident, providing an important input in the observation of the changes generated in the field according to the implementation of the agro-ecological models.

2. Materials and methods

In the development of the investigation process, different activities are developed that allow to solve the main problem among them is the acquisition of the necessary data to carry out a successful image processing. The main thing for this case is the selection of the sensor considering variables such as the number of available bands, weight, connection interface and storage capacity. The number of bands determines the ranges and the amount of information available for further processing. Other characteristics that limit the selection are the terrain and weather conditions where the image is taken. The resolution and the connection interface facilitate the collection and storage of information, the hardware characteristics are factors that are directly related to the flight time of the UAV, so it also becomes an influential selection criterion given the characteristics of the rural area where the research is carried out. For this reason, the so-called RedEdge-M, from the manufacturer Micasense, is determined as a multispectral sensor. It has five spectral bands in which the blue, green, red, red border and near-infrared bands are included, and it also has a high resolution of 0.08 m per pixel at a height of 120 m above ground level. This sensor is integrated to a DJI inspire 1 UAV whose most important feature is to offer a great stability and flight control offering a great advantage when performing the process of acquiring multispectral images.

2.1. Acquisition and storage

The research project was developed in the municipality of Tuta in the department of Boyacá Colombia, in which 15 properties were chosen, approximately one hectare of land each and with different plant conditions still unidentified, to each of them initially made the respective topographic survey, obtaining the different global positioning system (GPS) points that limit the polygon to represent the location of the selected area, taking into account that the area sampled must be larger than the area of interest in order to project the flight plan. This plan provides the total area to be flown and the speed at which the route will be flown in order to define the flight time and thus define the necessary batteries and the number of flights over the entire programmed trajectory. It is essential to pay attention to the overlap of images and the distance between successive captures. According to the characteristics of the sensor, it is possible to capture images approximately once per second. Proper overlay is extremely important to obtain good quality data. The first acquisition of images was made at the initial moment of the investigation where no human intervention in the field was made and the second day after preparing the ground and later planting of the plants.
2.2. Processing of multispectral images
There are several software packages on the market that are exclusively dedicated to photometry. The PIX4D software was chosen for the application because of its high precision and easy processing of the information acquired; it is important to note that when pre-processing the images, it must be taken into account that each one has metadata associated with the geographic information of the location where it was acquired, so it is important to avoid altering previously acquired images.

The software makes multispectral image processing much easier than free software which can also be used but has many restrictions. The processing of the multispectral images allows us to determine the normalized difference vegetation index which is calculated taking into account the spectral reflectance of the near infrared channel and the reflectance in the red channel indicating an inverse relationship between the reflectance value of these bands. This index results in a polychromatic image, where each pixel gives a color depending on the value reached.

2.3. Statistical analysis
Considering previous investigations, it is possible to establish types of coverage according to ranges of values of the processed index. In other words, high coverage density is given by NDVI values between 0.75 and 1, medium coverage density by values between 0.5 and 0.75 and low coverage density by values between 0 and 0.5. For each of the properties, the percentage of area covered by each of the vegetation density ranges is established. The main idea of the statistical analysis is to implement mathematical methods that allow for the quantification of the acquired data and to identify a trend model that predicts the behavior of new values. The analysis was carried out in Matlab mathematical software which allows us to manipulate the database described above and which is made up of a matrix of 3 rows that represent the three different NDVI ranges for the first multispectral survey and 3 additional rows for the second survey and 15 columns represent the number of sites on which the study was conducted.

For each of the different ranges we proceed to identify by row starting from the high range a first approach of the behavior of the data obtained and in which we can identify in a detailed way the outliers or that are notably different, they did not correspond to a normal behavior according to the group that was being analyzed, I can also identify missing values or wrong measurements, the noise data shows random variations around the expected values that is why before proceeding to create a model it was necessary to perform a filtering and smoothing process so that the main characteristics start to show.

Polynomial models are simple ways to see upward and downward trends in percentage coverage data for high NDVI values. This same procedure was carried out for the rows representing the medium and low ranges. Finally, the three models are superimposed to compare the generalities and conclude in the general characteristics of the soils of the eight municipalities.

3. Results obtained
The sensor made it possible to acquire information on the amount of electromagnetic radiation absorbed by the vegetation present in the soil sampled thanks to the two sensors selected at the two moments of information acquisition, before starting the sowing process and preparing the soil to host the crops and after starting the cultivation. The multispectral orthophoto mosaics were generated for each of the sites, in which the NDVI indices acquired at different times were calculated, allowing an individual analysis of each site, specifying the characteristics of the vegetation by means of the percentages of area covered by the different levels of electromagnetic reflectance in the site in the two samples. These levels could be grouped according to the quantity and quality of the vegetation, allowing three ranges to be established: high vegetation, medium vegetation, and low vegetation. The percentages of area coverage of each of the ranges are plotted with the aim of observing the evolution of the data of the property individually, and some general considerations were made in which the trends shown are identified from the information of the graph in which it could be demonstrated that in most of the sampled lands the implementation of crops generates a considerable decrease in the levels of electromagnetic reflectance, due to the fact that the surfaces with capacity to reflect the waves are considerably reduced and consequently the percentages of area with low NDVI levels are increased.
The acquired results provide us with a global view of the evolution of the vegetation cover faced by the land in accordance with the measures that have been taken in it up to now, affirming the results of the research carried out by the Agricultural University of China and the University of Queensland in Australia in their research on dynamic monitoring of NDVI [13], where they also show us the high performance of the sensor system selected for the characterization of soils and the monitoring of the changes in the data.

4. Analysis of results
The main objective of the comparative activity is to make known the behavior of the study variable resulting from the soil characterization activity by means of multispectral images acquired from the different municipalities. The main goal of the mentioned analysis is to be able to identify the possible model of the trends present in the data, giving the possibility of predicting the appearance of new values. To comply with this possibility, it was necessary to involve a certain number of standard components in this type of calculations. The data used in the statistical analysis were the percentages of area covered of all the properties; the study is carried out by grouping the NDVIs into high, medium and low coverage results, obtaining the models of the data behavior and then grouping the results in order to compare the data and determine the group in which the highest percentage of coverage is found.

In parallel to this research, the Centre for Ecological Studies in Yerevan, Armenia and the University of Pavia, Italy, is also presenting a study that relates climatic factors to the results of NDVI indices [14], with the main results being the favorable impact of factors such as light rain and average temperatures on the growth of vegetation, On the contrary, the results of the current research show that after grouping the data from the different plots of land, it is possible to make some first statements based on different observations that were presented in most of the models obtained, which show that the low coverage characteristics increased considerably, decreasing the representation in the other NDVI intervals, this due to the implementation of the crops or human activity in the sampled soils.

4.1. High coverage
Figure 1 shows the results of the analysis of the NDVI values between 0.75 and 1 that are classified as high plant cover density values. In the left part of the image, the curve representing the behavior of the data from the first multispectral survey is shown in red. In this curve, we can see that the trend for this first sampling period was concentrated in coverage percentages above 50% and below 90%, indicating that this type of index was predominant in all the properties.

On the contrary, in the right zone of the image, the graph of the coverage values of the properties of the second multispectral survey is presented, where it is emphasized that the polynomial curve is centered in values of percentage of area lower than 25% and higher than 0%, and therefore it shows that there was an important reduction in the high density vegetation coverage.

![Figure 1. Polynomial model high coverage.](image_url)
4.2. Media coverage
Figure 2 shows the polynomial models of the two moments of sampling of the surface of the properties, considering only the NDVI between 0.75 and 0.5, that is, vegetation cover with medium density. Initially, it is evident that the "x" coordinate represents each of the project's beneficiary properties and the "y" coordinate indicates the percentage of area covered by the average NDVI. The exponential adjustment curve of the first multispectral survey focuses on values of percentage of coverage between 45% and 15%, which compared with the results of Figure 1 can be assured that these are the second most represented percentages of vegetation coverage on each property. On the other hand, the representative curve of the second multispectral survey shows a behavior like that of the first multispectral survey, although with a slight decrease that is not very evident.

![First Survey](image1.png)
![Second Survey](image2.png)

**Figure 2.** Polynomial model media coverage.

4.3. Low coverage
The most relevant change in vegetation coverage is shown in Figure 3, where the percentages of land covered by NDVI values between 0.5 and 0 (low vegetation density) from the first and second multispectral surveys are compared.

One of the main characteristics of the data acquired in the first survey is the fact that in almost all of the properties the percentage of area covered by this type of coverage density was less than 15%, that is, there was not a large amount of bare soil in each property. However, in the second survey, the change was significant, with coverage percentages between 65% and 45%, which are quite high and cause the exponential adjustment to have a high representation in percentages equal to 52%.

![First Survey](image3.png)
![Second Survey](image4.png)

**Figure 3.** Polynomial model low coverage.
4.4. Relationship between the three types of coverage

To have a global vision of the total behavior of the study variable, the exponential adjustments obtained in items 4.1, 4.2 and 4.3 are superimposed. Figure 4 shows the differences between the first and second multispectral survey are identified in a more evident way and in an analogous way the behavior of the different levels of plant material density, it is highlighted that the predictive models with the highest percentage of covered area are those of high coverage density of both the first and second surveys. In the lower area of the graph, the low coverage model of the first survey is located as a consequence of its low representation in the different properties, followed by the low coverage model of the second survey that is combined with the medium coverage models of the two surveys.

In the first multispectral survey the average of the percentages of area covered by a high plant density was a little higher than 58.99%. For the second survey there is a reduction equal to 15.2% in the calculated average of the same level of plant density. On the other hand, the percentages of area covered by a medium plant density remained constant at a value rounded to 28%. Finally, the percentages of area characteristic of low plant density showed an increase in the second multispectral survey with respect to the first one equal to 46.44%.

![Figure 4. Relationship between the polynomial models of the different coverage levels.](image)

5. Conclusions

The optical perception system was able to capture information on the intensity of electromagnetic radiation to create a database according to the desired information from each of the project's beneficiary sites, making an excellent remote sensing. The process of quantifying the reflectance of the near-infrared and visible-red spectral bands was carried out in such a way that the vegetation indices of normalized difference were calculated for each pixel of the multispectral orthophoto mosaics, and it was possible to identify characteristics of the sampled soil according to the volume of biological material. The above data show that using this monitoring tool a relationship is established between the reduction of the percentages of area covered by biological material and the implementation of agricultural activity as one of the causes of the appearance of a large proportion of the area with bare soil, this result is a contribution to the research being conducted on the applicability of multispectral images in soil characterization.

References

[1] Sun B, Yuan N, Cao C, Hardeberg, J Y 2018 Design of four-band multispectral imaging system with one single-sensor *Future Generation Computer Systems* **86** 670-679

[2] Liu C, Hao G, Su M, Chen Y, Zheng L 2017 Potential of multispectral imaging combined with chemometric methods for rapid detection of sucrose adulteration in tomato paste *Journal of Food Engineering* **215** 78-83
Verrelst J, Rivera J P, Gitelson A, Delegido J, Moreno J, Camps-Valls G 2016 Spectral band selection for vegetation properties retrieval using Gaussian processes regression International Journal of Applied Earth Observation and Geoinformation 52 554-567

Logofătu P C, Damian V 2019 Snapshot interferometric multispectral imaging using deconvolution and colorimetric fit Optics & Laser Technology 111 100-109

Cui Z, Wang Y, Gao X, Li J, Zheng Y 2016 Multispectral image classification based on improved weighted MRF Bayesian Neurocomputing 212 75-87

Pu H, Kanruzzaman M, Sun D-W 2015 Selection of feature wavelengths for developing multispectral imaging systems for quality, safety and authenticity of muscle foods-a review Trends in Food Science & Technology 45 86-104

Nandibewoor A, Hebbal S B, Hegadi R 2015 Remote monitoring of maize crop through satellite multispectral imagery Procedia Computer Science 45 344-453

Gongal A, Amatya S, Karkee M, Zhang Q, Lewis K 2015 Sensors and systems for fruit detection and localization: A review Computers and Electronics in Agriculture 116 8-19

Luhmann T, Fraser C, Maas H-G 2016 Sensor modelling and camera calibration for close-range photogrammetry ISPRS Journal of Photogrammetry and Remote Sensing 115 37-46

Calvini R, Amigo J M, Ulrici A 2017 Transferring results from NIR-hyperspectral to NIR-multispectral imaging systems: A filter-based simulation applied to the classification of Arabica and Robusta green coffee Analytica Chimica Acta 967 33-41

Liu S, Li L, Gao W, Zhang Y, Liu Y, Wang S, Lu J 2018 Diagnosis of nitrogen status in winter oilseed rape (Brassica napus L.) using in-situ hyperspectral data and unmanned aerial vehicle (UAV) multispectral images Computers and Electronics in Agriculture 151 185-195

Su J, Liu C, Coombes M, Hu X, Wang C, Xu X, Li Q, Guo L, Chen W-H 2018 Wheat yellow rust monitoring by learning from multispectral UAV aerial imagery Computers and Electronics in Agriculture 155 157-166

Duan T, Chapman S C, Guo Y, Zheng B 2017 Dynamic monitoring of NDVI in wheat agronomy and breeding trials using an unmanned aerial vehicle Field Crops Research 210 71-80

Muradyan V, Tepanosyan G, Asmaryan S, Saghatelyan A, Dell’Acqua F 2019 Relationships between NDVI and climatic factors in mountain ecosystems: A case study of Armenia Remote Sensing Applications: Society and Environment 14 158–169