Soil characterization through remote acquisition of electromagnetic radiation

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Abstract. In order to promote agronomic activity and generate a new tool that generates indicators and contributes to decision-making and optimization of resources for agribusiness, the objective of the research is focused on characterizing soils with productive potential by means of the normalized difference vegetation index using multispectral images, a new information acquisition system is provided through photometry that allows establishing important characteristics in the sampled surface. This uses a multispectral system composed mainly of an optical sensor sensitive to electromagnetic radiation reflected by plant material, mainly in wavelengths equal to 475 nm with a bandwidth of 10 nm and 840 nm with a bandwidth of 40 nm, this system is integrated into an unmanned aerial vehicle that allows remote acquisition in visible and non-visible light spectrum ranges, the acquisition of images was carried out at heights between 100 meters and 200 meters to obtain a resolution of 80 mm per pixel, obtaining as a result a relationship between the wavelength levels and the main characteristics of the sampled soils.

1. Introduction
The main source of energy in this process of interaction is the sun. This energy can pass through the earth's atmosphere and interact with it; of all the electromagnetic radiation that comes into contact with any object there are three types of interaction, one part is reflected, another part is transmitted and a last one is absorbed and can be transmitted in the form of heat. Generally, the multispectral cameras have a device capable of quantifying the amount of light it perceives according to the photons that are reflected on the surface of the ground or plant material and that affect the detector that converts this incidence into a difference in electrical potential that can be quantified [1]. The multispectral images are a spectroscopy technique, with which images can be acquired in different wavelengths, generally by each capture images are acquired in which the reflectance is acquired according to the spectral band for which it was configured and each pixel stores the information of the reflectance information acquired of approximately 8 cm² [2].

The majority of multispectral cameras are passive sensors because they depend on the sun as an external source of radiation and are configured either by filters or by casing to obtain several different types of visible and non-visible spectral bands, in which the wavelengths that characterize the photoreception of the colour red with a wavelength equal to 668 nm with a bandwidth of 10 nm are highlighted, in addition a wavelength equal to 840 nm characteristic of the near infrared and with a bandwidth of 40 nm, with which the normalized difference vegetation index (NDVI) can be calculated [3], which by means of computerized algorithms are represented in multi-chromatic images [4].
Agriculture is one of the main economic activities developed by man and from which human sustainability is derived, so it is necessary to seek strategies that contribute to making these activities more efficient [5], precision agriculture aims to involve new technologies in order to optimise resources for agricultural production to yield the assets intended for this purpose [6]. In order to have the best impact, it is necessary to look for strategies to incorporate farmers into the productive sector, in addition to developing such strategies so that once the advice of the engineers is lost, the owners of the land can manipulate and use it without any problem [7].

The exponential growth of precision agriculture has led to research in many areas, such as population patterns, agronomic assessment, development for good land use, as well as enabling environmental and economic benefits [8]. Nowadays, the department of Norte de Santander, Colombia, has a high agricultural activity, it has a great variety of agricultural products in high demand and which are also cultivated in various climates and geographical areas, both in the plains and in the high mountains, and where agriculture continues to use traditional methods for the cultivation of species, their subsequent monitoring during growth, verification of soils, harvesting and post-harvest [9]. The verification of the quality of all the land available for cultivation is one of the main problems for the beginning of any productive process, since according to the state in which it is found it will require or not fertilization that will contribute to an optimal development of the vegetation [10]. In these processes it is important to consider the transformation that the vegetation undergoes since it is a very important indicator that exposes us to the real state of the ecosystem [11]. In addition, the degradation of topsoil is very difficult to characterize as it is a very complex phenomenon [12].

The study of the best methods to optimize the processes and be able to help the development of new agricultural strategies, generate health maps of the current vegetation, be able to detect important changes of the nutrients and discover diseases before the symptoms are more abrasive [13]. To be able to generate a new tool that generates indicators that help in the decision making process without leaving aside the obligatory and necessary interaction for the total knowledge thanks to a compression of the possible symptoms that can occur with the help of data that can be collected through multispectral images being able to adapt this tool to the tests that can be carried out by technicians or agronomists [14]. Precision agriculture is based on the positioning of global satellites dedicated to the presentation of positioning data [15]. Large areas of land represent a direct problem in the availability of time [16], so to make the phytosanitary inspection process more agile and efficient, unmanned aerial vehicle (UAV) transport platforms are used [17], in order to give more mobility to the multispectral system that allows to integrate this tool for the transport of this one for all the square meters that represents the area of sowing to the precise height to obtain information with a definition according to the need to acquire favourable results, besides that independently of the irregularity of the ground, the vehicle carries out the sampling without problems [18].

For this reason, this article shows in its results a relationship between the amounts of reflected electromagnetic waves that have wavelengths established by the sensor used can be related to some particular characteristics of the soil composition being studied and mobility through autonomous mobile platforms allow the collection of information quickly and accurately under controlled conditions. In this way, with the remote acquisition of electromagnetic waves reflected by the biological material by means of images taken with multispectral cameras and their processing, spectral analysis is made possible to carry out a characterization of the soil, as well as to identify behaviour patterns in the crops, in order to contribute in the medium term [19], with information for the implementation of models in the region that allow to represent, study and plan an optimized, efficient and sustainable production during the phenological cycles of the crops [20].

2. Materials and methods

2.1. Acquisition of multispectral images
The process that was carried out begins with a socialization to the owners in which the activities that will be carried out within their land are detailed, in addition to jointly determining the points of the
 polygon that correspond to the limits that will be shown, in addition to carrying out a visual inspection in which the physical properties of the land are defined in addition to identifying the possible obstacles that the UAV can face to avoid possible unwanted collisions. Obtaining the points according to the global positioning system (GPS) is done manually, with a high-quality handheld receiver that provides the exact latitude and longitude coordinates, it is necessary to take as many points as possible to delimit the terrain as much as possible. They are imported into Google Earth, a mapping program with updated satellite images in which each of the points can be labelled as shown in Figure 1, in addition to shaping the area to be sampled, the area to be captured must be larger than in the field of interest, the result of this operation is exported in a mark-up language file (kml) so that it can be used by other applications.

The drone deploy application was designed to implement flight plans for different brands of drones. It offers the possibility to make flight plans providing information such as battery life estimation, the amount of monitored area and the amount of images acquired, in order to later perform an autonomous execution of the overflight, however it is always necessary to monitor the flight to interrupt it if considered necessary before the application. One of the important configurations within the software is the overlap between the side and front images, taking into account that the recommended percentage is greater than 70% to avoid loss of information between images and on the other hand the height that must reach the UAV to start making the acquisition or acquisition of images, it is advisable to handle heights between 100 m and 120 m, the height depends on the resolution of the images, resolutions can be obtained between 80 mm² and 200 mm².

2.2. Data processing
Within the analysis of the spectral shots made, it was necessary to use a photometry software that allows the capture of both red, green, blue (RGB), thermal or multispectral images from any type of camera, with the appropriate characteristics for this purpose, within the research process it was necessary to verify the characteristics of the options of the digital instruments that could be used to process the information collected. Among the most relevant features that the software must have is the ability to identify the metadata of each image because it is immersed in the information of the pixel grid also finds georeferenced information of the exact point where it was captured, the tilt angle of the camera and the rotation of the air vehicle at the time of capture, there are also corrections for brightness and light exposure made by the camera and finally the labels The sensor with which the image was taken to determine the spectrum of light that was captured. The ability of the software to perform the different index, volume and area calculations is another feature that should be specified as the most important and fundamental factor for decision making in application selection.

It is important before any image acquisition to make a configuration of the multisensorial system, by means of a calibration panel that allows to establish the amount of exposure, of the sensors to the sunlight to avoid saturation of photons and therefore of free electrons that can offer excessive readings of photons with erroneous wavelengths, the camera also integrates a sensor of luminosity that allows to remain in a range of constant exposure, The respective sensor calibrations must be performed prior to each flight. With proper organization in the storage of the information collected on each flight and having the appropriate technical knowledge, it is possible to perform proper processing of all information. That is, there will be a high-resolution reflectance mapping, with reliable information available to perform the corresponding multispectral image analysis, the results of the processing are presented in a single image called orthophotomosaic where by means of a colour representation the numbering range of the acquired data is established.

2.3. Analysis of multispectral images
The software PIX4D, selected for the processing of the images, allowed the processing of high precision data and facilitates the interpretation and handling in the processing, helping to generate excellent interpretations, if one avoids altering in some way the quality of the data. The application gives us images of all the terrain at scale where every 0.01 m of image represents 25 m of terrain, also developing a classification of the NDVI indexes according to the number of classes that have been selected, the
greater the number of classes that are held, the lesser the loss of information and the greater the observation of the characteristics of the land and finally the general information of the property.

The research was carried out on 15 plots of land in two municipalities in the department of Norte de Santander, Colombia. In the present article. The totality of the images are compiled by plot in a multispectral orthophotomosaic as shown in Figure 1 this image is a multichromatic representation associated to the NDVI levels where each colour is related to one of the index ranges, at first sight it can be observed that the predominant colour is red which is related to high NDVI indexes, allowing to infer that these areas have a healthy and abundant vegetation. The Table 1, show the classification of the NDVI intervals for the different sites.

### Table 1. Classification of the NDVI intervals for the different sites.

| Category                        | NDVI interval         | Affected area (%) |
|---------------------------------|-----------------------|-------------------|
|                                 | Min  | Max (aprox)   |                  |
| Highly optimum                  | 0.75 | 1.00       | 75.67            |
| Optimum                         | 0.50 | 0.75       | 20.06            |
| Low vegetation cover            | 0.25 | 0.50       | 1.27             |
| Zero vegetation cover           | 0.00 | 0.25       | 0                |
| Zero coverage (possible water footprint) | -0.30 | 0.00 | 4               |
| Zero coverage (rocks)           | -0.60 | -0.30 | 0               |
| Null                            | -1.00 | -0.60 | 0               |

### 3. Results and discussion

According to the methodology described, it was possible to corroborate that the selected multispectral system responds to electromagnetic radiation in the correctly described spectral bands by recording the behaviours of the electromagnetic spectrum in the hectares of land sampled, providing appropriate information on the main characteristics of the soil. The combination of the visible red spectral band and the non-visible infrared band allowed the calculation of the NDVI of each pixel of the multispectral orthophotomosaics, allowing the estimation of the qualitative quality and quantity of the vegetation present. A statistical analysis by clustering methods was determined experimentally for each municipality in which an association between the normalized plant cover index and the percentage of the total area was represented. Thus, it is possible to obtain information about the lands with high
normalized vegetation indexes, allowing to infer that the soils that are currently in the study areas have all the conditions to have a successful production since the soil has the necessary nutrients to host the vegetation and the soils whose characteristics are the opposite.

The ranges of the indices are in turn associated in the 4 possible scenarios that can occur in the interpretation of the data as a high concentration of plants, medium concentration, low and presence of rocky material or wetlands. In addition, a method called k-means was used for the grouping and presentation of the results, the usefulness of which can be exploited in the process of dividing the data into a certain number of mutually exclusive groupings based on real observations. Each group is defined by its members and by the point at which the sum of the distances of all the objects in the group is minimised with respect to the measure specified. The clusters generated represent a conditioning factor for the related data, such as the NDVI and the percentage of the total area.

The municipality of “Arboledas” is located at 946 meters above sea level, has a medium climate, also has the great advantage that many hectares of its total area are part of a moor, which is considered an important source of water. Figure 2 shows the results of the statistical analysis carried out with the indices acquired where, at first sight, it is observed that in the municipality there are sequential cases of the influence of the NDVI in the lands where the great majority presents similar characteristics, being these results the average distances from the lowest centre of the conglomerate whose representative points are in an index of 0.08 and 0.4 that still are percentages lower than 20% of the total land. Most of the points are concentrated near the centroid of 0.83 with a height of 98.91% making a correct representation of the vegetal cover that is presented in the lands of the municipality, demonstrating that the crops that are lodged in these areas that were object of study have all the possibilities of being successful in the growth of the vegetal material that there lodges, besides not needing fertilization processes, reducing the budget assigned to this task.

![Figure 2. Relationship between NDVI and percentage of the total area of the Arboledas municipality.](image)

In the municipality of La Playa there are quite interesting results represented in Figure 3 where the indices, in relation to the percentage of area covered by them are very dispersed and the centroids are located in almost 30%, but most of the points are lower than indices of 0.6 where the indices with less variance than those observed in La Playa are defined, being this the place where the lands with many points of low vegetation coverage are located, having as a recommendation the constant observation of the properties and the crops that will be implemented, in order to follow up the need of nutrients and fertilizers to have a successful harvest.

It is imperative that the soils are intervened by the farmers to adapt them to their physical conditions so that it is considered as a healthy soil. It is likely that in addition to having low vegetation, there is a deficiency of water resources and, where appropriate, a deficiency of some nutrients in the soil. This aspect should be contrasted with a physical study of the terrain, which will allow a correlation of the unfavourable aspects in these areas to be established. Ultimately, there are low levels of rocks and other sediments that can obstruct plant growth, as no negative NDVI rates are recorded.
4. Conclusions
Using the combination of the spectral bands acquired through the calculation of the index of allowed to identify soil properties in high lands thanks to the autonomous mobile platform, the spectral response of the plants was the expected one, although a considered amount of energy radiated by the sun is absorbed by the plants to perform, the respective photosynthesis process and another little is transformed into heat, the remaining energy is reflected allowing it to be captured by the passive remote sensor forming image allowing to establish an important relation between the wavelengths of 668 nm and 840 nm with the characteristic properties of high, medium and low plant density, bare soil, water sources and presence of rocky material.

From the results found after analysing all the images of the 15 properties in the 2 municipalities where the overflights were made, it can be seen that in the municipality of “Arboledas” there is land with high standardized vegetation indices and it can be stated that the crops currently found in these areas have all the conditions to have a successful production since the land has the necessary nutrients to host the vegetation. On the contrary, in the municipality of La Playa more care should be taken and the intervention of the relevant personnel for the study of the soil is recommended in order to minimize the risks that may arise from not having a completely covered with vegetation because it is a good indication of low plant health, it is likely that there is a high presence of rocks or other elements that may obstruct the growth of plants, and the use of fertilizers may be recommended, in this way it can contribute to the growth of the future crop and not decisively affect the efficiency of the projected benefits to be acquired from these areas.

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