Proposal of a System Based on Direct and Indirect Techniques and their Correlation by Chlorophyll Quantification

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Abstract. The prediction of normalized vegetation indices in coffee crops using multispectral images obtained by aerial mapping aims to generate a technological strategy using aerial mapping employing drones (RPAS) to predict normalized vegetation index (ENDVI) in coffee crops. During the research process, reference is made to the ENDVI according to the multispectral footprints generated by the different nutrients on the plants in the production stage of the coffee crop, using RPAS for the realization of aerial mapping works in precision agriculture. This reflects the importance of implementing technological tools to improve the planning of agricultural activities, predict damage and decide in situations that affect the development of coffee crops. This study took multispectral images of coffee crops from aerial mapping in the coffee plantations of the Popayan plateau region. It will also analyze the health status of the plants using a chlorophyll meter. From this comparative analysis of the different ENDVI, it is possible to define management alternatives to improve production. However, the images will be captured with unique cameras incorporated in the RPAS, allowing the identification of the variations of the lots and coffee plants in the formative stage of their phenological development, the absorption of nutrients, and the water stress of the crop. Finally, some strategies for integrating expert systems in aerial mapping are proposed.

Keywords. Aerial mapping, Precision agriculture, Spectral index.

1 Introduction

Coffee is one of the most important crops worldwide; it generates an income of over 15 billion dollars and is a source of direct and indirect employment for almost 20 million people. Specifically, in Colombia, coffee is the flagship export product; However, there have been some problems concerning the yield of its production; according to the Federación Nacional de Cafeteros, there has been a decrease in the production of this fruit in recent years, caused by the persistence of unfavorable weather. Besides the above, there are other causes, such as crop renewal, low planting density, and lack of support from state entities regarding technical help [1].

Specifically, in the Cauca department, coffee production is quite rudimentary compared to other geographic zones; this is because, besides the climatic causes mentioned, it can be said that the low productivity is also because of the lack of training, support for the correct implementation of technologies and production and monitoring methodologies based on phenology and evidence of stress in the plants. This makes it possible to identify the farmer's lack of technical competencies and agronomic and extension tools for the management of specialty coffee crops and the scarce technological innovation in their management [2].

In this line, the technologies applied to coffee production could be an excellent alterna-tive to improve fruit production, thus achieving a better capitalization of the production and consequently improving the producers' profit margins. Some technologies that have been applied to coffee production in Cauca are multispectral images, genetic engineering, and biotechnology applied to productivity [3]. Specifically, a study carried out by Cenicafé mentions that there are some activities within the production of the fruit that are carried out manually, which damages the production chain and the speed with which it is carried out; therefore, some alternatives are proposed, such as a portable back vacuum cleaner that is technically and economically viable in Colombian coffee production [4]. Another study shows that soil acidity is the main factor affecting the availability of nutrients, and it should adapt its management according to soil mineralogy. Therefore, in [5], a device is proposed that measures this variable, allowing one to estimate crop production at an optimal scale. Another technology that has positively impacted Caucasian coffee growing is multispectral imaging. In [6], the authors propose a statistical relationship between spectral index and laboratory techniques such as optical spectrophotometry, finding high correlations between these techniques, concluding that it can be an excellent alternative to avoid damaging the coffee when studying chlorophyll.

With the above, it is possible to state that the department in question lacks scientific studies regarding the adoption of technologies in the coffee production processes, limiting coffee growers from promoting their products in the market. In addition, there are no intensified studies on the study of soils, coffee physiology, more productive varieties, pest control, and climatic conditions that allow the definition of alternative solutions to mitigate the conditions expressed [7]. Therefore, this research proposes a quantification system based on indirect and direct techniques for quantifying chlorophyll, which allows the determination of the statistical relationship between these techniques to be later implement in professional systems.

2 Emphasis

Coffee is a complex productive chain that articulates not only the careful processes of transformation and processing of the bean but also the management of the crop, the plant, and the land in which it is grown, affecting the specific characteristics of the quality of the bean and the cup profile, which in the end is the accurate indicator of quality [8]. The Department of Cauca is competitive in the production of high-quality coffees because it has an unbeatable environmental offer that added to the commitment to the activity of over 87 thousand coffee-growing families that cultivate close to 74 thousand hectares of coffee, guarantees an essential contribution to the economic development of the department and the national industry [9]. The internal competitiveness agenda generates a specific productive bet for specialty coffees, which is expected to strengthen the productive system [7]. Therefore, it is proposed to contribute through precision agriculture, specifically aerial cartography images captured through RPAS, the phenological monitoring allowing more accurate planning of the production processes based on the early identification of deficiencies and problems in the crop, which vary according to the microclimatic, agroecological and productivity conditions within the different cultivation lots.

Humanity will have to produce more food than was generated in all past years combined in the next four decades. Otherworld authorities show that food production will have to increase by 70-100% by 2050 to feed the estimated population of 9 billion people by then [10]. A possible solution to this need can be found in precision agriculture, a concept gaining momentum in recent years. Traditional agriculture is based on the premise of homogeneity, in which the processes of land preparation, phytosanitary control, sowing, and harvesting are carried out in the same way throughout the field. Precision agriculture is based on the principle of variability, which recognizes the existence of inequalities in soil properties within the same territory, which require different treat-ment according to their conditions.

3 Materials and methods

The project starts with an experimental design based on pixel quantification of the photographs, looking for the best relationship between illumination and drone flight distance to determine if there is a correlation between the normalized vegetation index obtained from the multispectral images and the samples obtained by direct methods with the chlorophyll meter and spectrophotometer.

The project contemplates the following phases:

- **Phase I:** Implement a docking system for multispectral sensors adaptable to the aerial vehicle**.**
- **Phase II:** Determine standardized vegetation index (ENVI).

- **Phase III:** Evaluate statistical techniques to determine the relationship between the different methods of chlorophyll estimation.

The materials to be used are Phantom 4 drone, CCM 200 chlorophyll meter, GENESYS^{TM} 20 visible spectrophotometer, multispectral camera micasense red-edge-MX, and MX blue. In addition, supplies such as 90% acetone.
For the acquisition of multispectral images, it drew a flight plan up. Afterward, with the chlorophyll meter, the spectral indexes will be taken through the images, then the coffee leaves of the study will be selected, and it will quantify the chlorophyll a and b in the leaves of the coffee plant employing the chlorophyll meter. Finally, the samples (leaves) will be taken to the laboratory for processing using the spectrophotometer.
For optical spectrophotometry, a wave range is used to calculate chlorophyll content between 350-750 nm. For this procedure, the maximum absorbance value of the spectrum obtained must be between 0.5 and 1.5 units. Otherwise, the sample must be further diluted in acetone. Finally, the results are compared with equations (1) and (2) proposed in [11] to determine the chlorophyll content in mg/L..

$$h \quad \overline{3} = 11.93 \;\; 664 - 1.93 \;\; 647 \qquad (1)$$

$$h \quad \overline{{}_{3}\quad} = 20.36 \;\; 647 - 5.50 \;\; 664 \qquad (2)$$

4 Partial Results

After making the CAD design of the prototype (Image 1a) in SolidWorks software based on the dimensions of the camera and drone, the realization of the 3D printing using CAM software, the assembly of the cameras to the drone using the parts obtained (Image 1b) and the tests made in the field, ideal results were obtained concerning to the resistance of the prototypes, guaranteeing the stability of the center of mass of the drone at the time of flight, in addition, the drone's camera is accessible and visible for its respective use.

Image 1. (a) 3D design of support prototype. (b) Assembly of support to the drone.

However, different proposals have been made regarding the algorithm for the determi-nation of spectral index to determine these mathematical equations and perform the radiometric and geometric correction process. The first prototype (Image 2) was deve-loped in Matlab and can determine almost 20 normalized indexes.

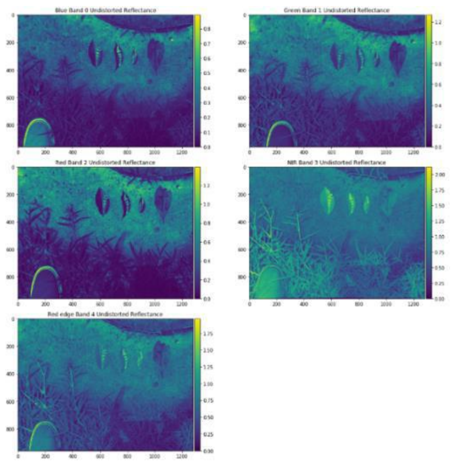

Image 2. Processed spectral images by the proposed algorithm.

5 Conclusions

The proposed docking system for the multispectral cameras is efficient and aerodynamic thanks to the breaks in the sides, considering the strong air currents where the flights will take place. Also, the drone has good maneuverability when tethered with the mounts and the multispectral cameras. Finally, the drone's battery life in flight depletes faster with incorporating supports and sensors. However, it is sufficient for the expected captures per flight.

Regarding the spectrophotometer, initial evidence shows it will obtain linear relationships for indirect sampling using the multispectral cameras attached to the RPAS.

The next activity consists to use of the chlorophyll meter for direct sampling of the chlorophyll value in the coffee tree of the selected area in order to contrast these data with those derived from the normalized vegetation index from the multispectral images obtained by aerial mapping and to estimate the relationship of direct and indirect chlorophyll quantification methods.

Finally, future work includes incorporating expert systems that will allow more efficient determination of spectral indices, thus finding patterns in the measurements of multispectral images.

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