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Using UAVs and digital image processing to quantify areas of soil and vegetation

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Abstract. Unmanned aerial vehicles (UAVs) are becoming a very popular tool for remote sensing and crop monitoring. They are more easily deployed, cheaper and can obtain images with higher spatial-resolution than satellites. Some small, commercial UAVs can obtain images with spatial-resolution as low as 1.5cm per pixel. This opens up the range of possible remote sensing and monitoring applications. Moreover, they can cover large areas in very little time, such as 50 ha in about 20min, which makes UAVs the ideal tool for monitoring large farms and plantations. On the other hand, it is important to know precisely the area covered by farms in order to avoid invasion of other properties or preserved areas, and also to detect flaws in the plantation area. However, it is difficult to measure planted areas in some cases, such as Eucalyptus crops. Therefore, this paper aims to evaluate the use of UAV imagery for precise area measurement in Eucalyptus crops. We developed an image-processing algorithm to segment regions of soil, low biomass and high biomass and tested it on a Eucalyptus plantation in the city of Lenís Paulista -SP, Brazil. Results show that the area quantification is very accurate especially for bare soil regions and this method can be used to estimate areas in other scenarios.

1. Introduction

The production of eucalyptus presents an important role in the international economy. With rapid growth, high yield, wide variety of species, great capacity of adaptation and applications in different industrial processes, the eucalyptus is the raw material for a wide range of products such as wooden panels, cellulose and paper and charcoal [1].

Precision agriculture [2], combined with unmanned aerial vehicles (UAVs) and remote sensing, can be used to increase productivity by monitoring crop status, estimating yield, counting plants, detecting flaws in the crop, assessing water stress and detecting plagues and diseases.

Remote sensing consists in the combined use of sensors, airships, satellites, and other equipments in order to study the Earth environment by recording and analysing the interactions between electromagnetic radiation and the materials that make up the planet Earth [3]. The advantages of the remote sensing in agriculture are the capacity of mapping vast areas in little time and also the possibility of an aerial vision of the crop, which can reveal details that otherwise couldnt be seen from ground level.



UAVs have been used in remote sensing because they have a smaller cost of acquiring high spatial resolution data when compared to manned airplanes or satellites [4]. Moreover, images obtained by UAVs tend to be more accurate and can be obtained anytime, including more than once per day, as opposed to satellites that only obtain images from the same area every few days.

Vegetation indices are values obtained from measures of spectral reflectance and can be used for several ends, including estimation of biomass, vegetation cover and production assessment. Among these indices, the Normalized Difference Vegetation Index (NDVI) [5] stand out as a tool for agricultural monitoring. It is calculated by the difference between Near-Infrared (NIR) reflectance and red reflectance as shown in Equation 1.

$$NDVI = \frac{NIR - Red}{NIR + Red} \quad (1)$$

2. Methodology

The proposed methodology can be divided into two stages: (i) image acquisition and (ii) image processing.

The first stage was performed in a commercial plantation of eucalyptus in the city of Lençóis Paulista in Brazil. The images were obtained using a Canon ELPH 100 HS, a camera that captures the green (G), red (R) and near-infrared (NIR) channels, aboard the eBee, a small sized UAV made by Sensefly¹. Spatial resolution is 4 centimeters per pixel, flight altitude was about 130 meters and radiometric resolution is 2⁸ bits.

After image acquisition, we can begin the second stage, which is the processing of the images obtained using C++ with the OpenCV library.

The first step is to calculate the value of the NDVI for each pixel and then create a pseudo color image with the HSV (Hue, Saturation, Value) model. In this model, the H value of a given pixel is proportional to the NDVI value of that same pixel. That is, if a pixel has a high NDVI value (close to 1), the pixel will be colored with a high H value (such as blue or magenta).

The use of this color scheme makes it easier to differentiate the elements in the image and therefore, facilitates the segmentation of the objects. In that way, it is possible to isolate the soil by selecting pixels with values between red and yellow (very low NDVI). Moreover, the same can be made for vegetation with low and high biomass by selecting, respectively, pixels between green and cyan (low to medium NDVI), and between blue and magenta (high NDVI).

This threshold generates six binary images (pixels with value either 0 or 255), one for each primary color of the HSV scheme, which are then merged into three images, one for each area of interest (soil, low biomass and high biomass). This method, however, generates some noise in the low and high biomass images that can be removed with a median filter of size 7x7, making the segmented areas more homogeneous and continuous.

Finally, with the regions already split, the process of quantifying the areas becomes very straightforward: simply count the number of pixels in each image and multiply by the area of each pixel and multiply by the spatial resolution. Therefore, we can estimate the areas of soil, and of vegetation with low and high biomass. Figure 1 shows every step in the algorithm described.

3. Results

The image of the area observed obtained from the eBee is shown in Figure 2a. Figures 2b and 2c show the results of the NDVI in gray scale and in pseudo colors using the HSV model, respectively. Figure 3 shows the segmentation results for (a) soil, (b) low biomass and (c) high biomass. Table 1 shows the size of the three types of areas considered.

¹ www.sensefly.com

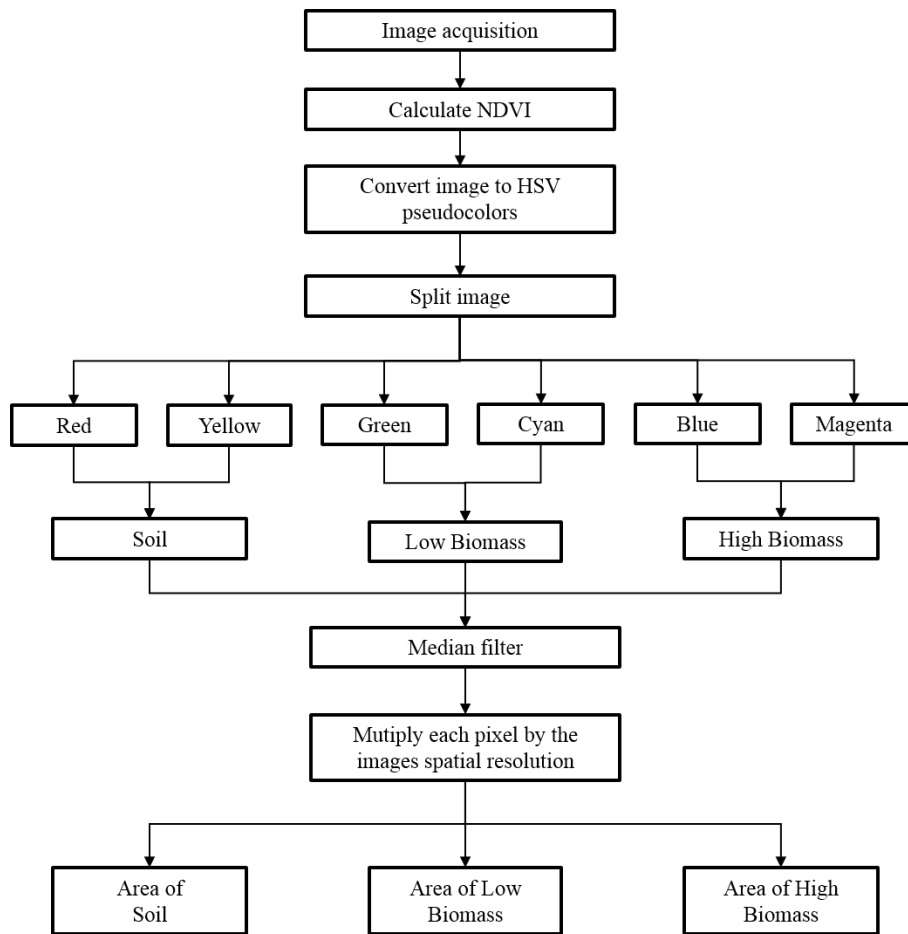


Figure 1. Algorithm for area quantification

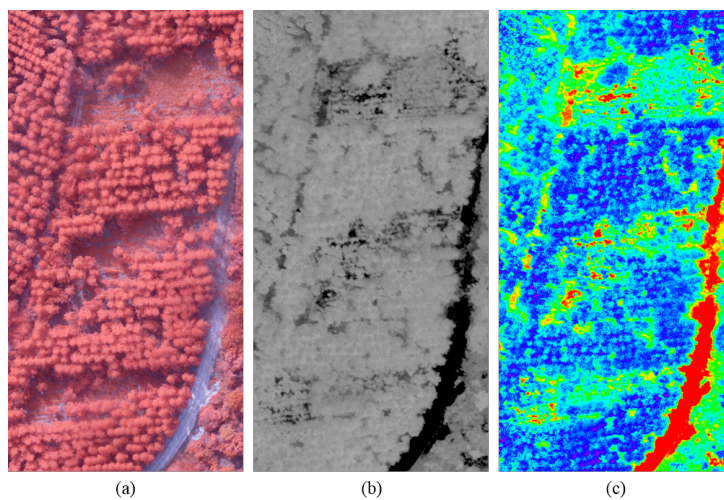


Figure 2. (a) Area of study, (b) Grayscale NDVI, (c) Pseudo colors NDVI

The results of the segmentation can be seen in Figures 3a, 3b and 3c, respectively.

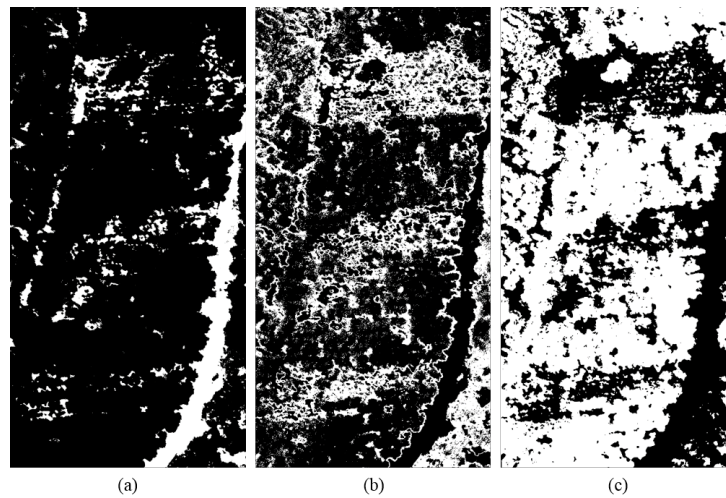


Figure 3. Segmentation results for (a) soil, (b) low biomass, (c) high biomass

Table 1. Areas of soil, low and high biomass present in the region shown in Figure 2a

	Soil	Low biomass	High Biomass	Total
Pixels	799559	1920186	3773618	6493363
m ²	1279.29	3072.3	6037.79	10389.38
ha	0.12	0.3	0.6	1.02

4. Conclusions

The goal of this study was to use aerial near-infrared images obtained from an UAV to quantify areas of soil and of vegetation with low and high biomass. For that, we developed an algorithm to process the images, segment the regions and estimate the given areas.

The algorithm for area quantification achieved very good estimatives, specially with the area of soil. However, it obtained a few errors in the classification of areas of low and high biomass because the values of the NDVI can be similar in some cases. Therefore, future works should aim to enhance the accuracy of this method in order to obtain more precise information about planted areas or areas with flaws in the plantation.

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