COMPARING FOREST RESTORATION CANOPY COVER MEASUREMENTS USING RGB AND MULTISPECTRAL SENSORS ONBOARD DRONES

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ABSTRACT

Remotely Piloted Aircrafts (RPA) coupled with Red-Green-Blue (RGB) sensors have a high potential to monitor Forest Restoration (FR), but multispectral sensors onboard RPA are more expensive and still demand more studies when applied to FR monitoring. This work aims to compare an RGB and a multispectral sensor capacity to measure the canopy cover of a FR project. Four canopy cover methods were evaluated using: the point cloud data generated by the RGB sensor; a vegetation index for RGB sensors; the Normalized Difference Vegetation Index (NDVI); and the Near Infra-Red band (Nir) only. The point cloud data method was the most accurate and the only one that presented all accuracies greater than 0.9. However, the multispectral sensor presented more potential for scientific research because it seems to be capable of detecting different photosynthetic activities on the trees and, consequently, different responses to FR treatments, which should be confirmed by future studies.

Key words – *Remotely Piloted Aircrafts, Unmanned Aerial Vehicle, Red-Green-Blue, Infra-Red, Forest Restoration Monitoring.*

1. INTRODUCTION

Forest Restoration (FR) projects must be properly monitored to ensure that the objectives of the projects are being accomplished [1]. In early FR monitoring, the canopy cover is the most relevant indicator because at least 70% of the terrain must be covered by trees. After that, other indicators that assess the ecological attributes of the forest gain importance [1].

Remotely Piloted Aircrafts (RPA) - Drones - have a high potential to monitor FR because the structural attributes of the whole project area can be accurately measured [2, 3]. Such RPA potential was assessed using Red-Green-Blue (RGB) sensors, which have a low spectral resolution. Multispectral sensors may improve some measurements of the vegetation due to the Near Infra-Red band, but since such equipment increases the hardware costs, they must be properly studied [4, 5].

The use of RPA may improve the daily activities of professionals who: need to monitor FR projects [3]; and perform academic research for upscaling FR monitoring [6]. However, the choice of the right equipment is a decision that must be made carefully.

This work aims to compare RGB and multispectral sensors onboard RPA to measure the canopy cover of a FR project. Our results aim to contribute to research that involves RPA coupled with multispectral sensors and to help FR managers and scientists on deciding which kind of equipment suits their needs best.

2. MATERIALS AND METHODS

2.1. Study area

We evaluated a successful FR project that began in 2012, which was seven years old in December 2019, when the RPA flights were conducted. Figure 1 shows the study area located in the Brazilian Amazon and in the orthomosaic generated by the RGB sensor onboard the RPA.

2.2. Materials

We used: a Phantom 4 Pro coupled with an RGB 1-inch 20megapixel CMOS sensor (P4Pro) and an F550 coupled with a multispectral 1/3-inch 1.2megapixel CMOS sensor for collecting Remote Sensing data; Map Pilot software for flying the P4Pro and Mission Planner software for flying the F550; a Spectra Precision SP60 for collecting precise coordinates of the Ground Control Points (GCP); Agisoft Metashape for generating the Digital Surface Model (DSM), the Digital Terrain Model (DTM) and the Canopy Height Model (CHM); R for assessing the RPA images; and QGIS for creating the layouts.

2.3. Methods

All flights were in compliance with Brazil's RPAs laws [7]. The P4Pro flight had 80 meters height above the ground, generated around 2 centimeters Ground Sampling Distance (GSD) and the front and side overlap between photos were equal to, respectively, 90% and 80%. Six Ground Control Points were used. The F550 flew at 80 meters in height, generated around 8 centimeters GSD and the photos had only front overlap, which was equal to 50% approximately.

To assess the canopy cover, the two classes trees and non-trees were mapped through four different methods: (1) CHM, which is the difference between the DSM and the DTM; (2) Modified Photochemical Reflectance Index (MPRI), where MPRI=(R-G)/(R+G); (3) Normalized Difference Vegetation

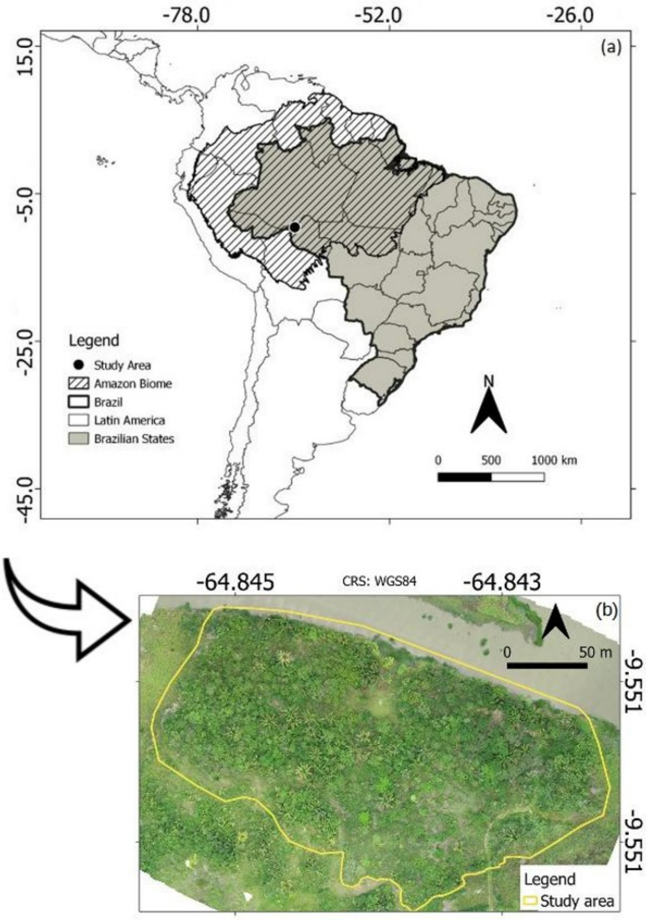

Figure 1: The study area was a Forest Restoration site in the Amazon: (a) located at the Porto Velho Municipality, Rondonia state, Brazil; and (b) illustrated by the RGB orthomosaic.

Index (NDVI), where NDVI=(NIR-R)/(NIR+R); and (4) the values of the Near Infra-Red band (NIR), which ranges from 0 to 255 (8bits of radiometric resolution). For better readability, from here on these four methods are going to be referred to as CHM, MPRI, NDVI and NIR, while the Near Infra-Red band is going to be referred to as Nir band.

Both the CHM and the MPRI methods were obtained using the RGB sensor onboard the P4Pro. The NDVI method was obtained using the NIR band from the multispectral sensor and the Red band from the RGB sensor, which was possible due to the GCP on the different images (the red band of the multispectral sensor had some technical problems and could not be used). Finally, the NIR method was obtained using the Nir band of the multispectral sensor. The canopy cover on each method was then obtained by defining a threshold value, which was equal to: (1) CHM > 30cm; (2) MPRI > 0.2; (3) NDVI > 0.2; (4) and NIR > 160. As can be seen, only the CHM method has an associated metric unit.

The accuracy was assessed using reference data that consisted of two hundred points: one hundred for the class trees and one hundred for the class non-trees. Confusion Matrices for the four methods were then generated. A correlation matrix including the reference data and the four canopy cover methods was also generated to evaluate not only the accuracy but also the similarities between the different results.

3. RESULTS

Canopy cover was equal to 0.55, 0.21, 0.39 and 0.37 according to CHM, MPRI, NDVI and NIR methods, respectively. Figure 2 shows these results over the orthomosaic that was presented in Figure 1.

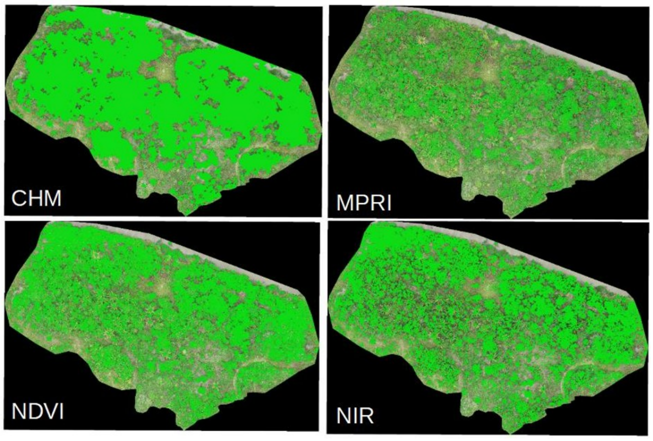

Figure 2: The automatic canopy cover results obtained by the CHM, MPRI, NDVI and NIR methods.

3.1. Results accuracy

The CHM method was the only one that presented all accuracy values greater than 0.9. Figure 3 shows the Overall Accuracy and the Kappa results, while Figure 4 shows the confusion matrix of each method. Figure 5 shows the correlation matrix between the reference data and the four methods.

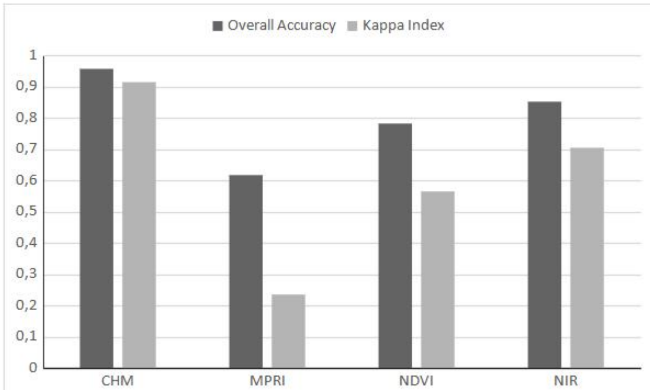

Figure 3: Overall Accuracy and Kappa Index of the four canopy cover methods evaluated in this study.

4. DISCUSSION

CHM method was the most accurate and the only one considered robust because all of its accuracy values were greater than 0.9. This result reinforces the low-cost RPA potential to monitor FR and reinforces that the point cloud data is a relevant database for FR projects [8]. Although only light detection and ranging (LiDAR) sensors generate accurate DTMs in closed-canopy conditions [5, 6, 9], the

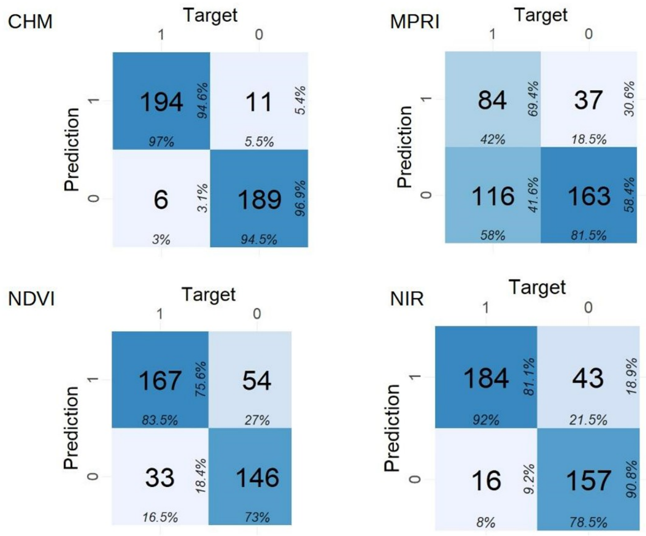

Figure 4: Confusion matrices of the four canopy cover methods evaluated in this study.

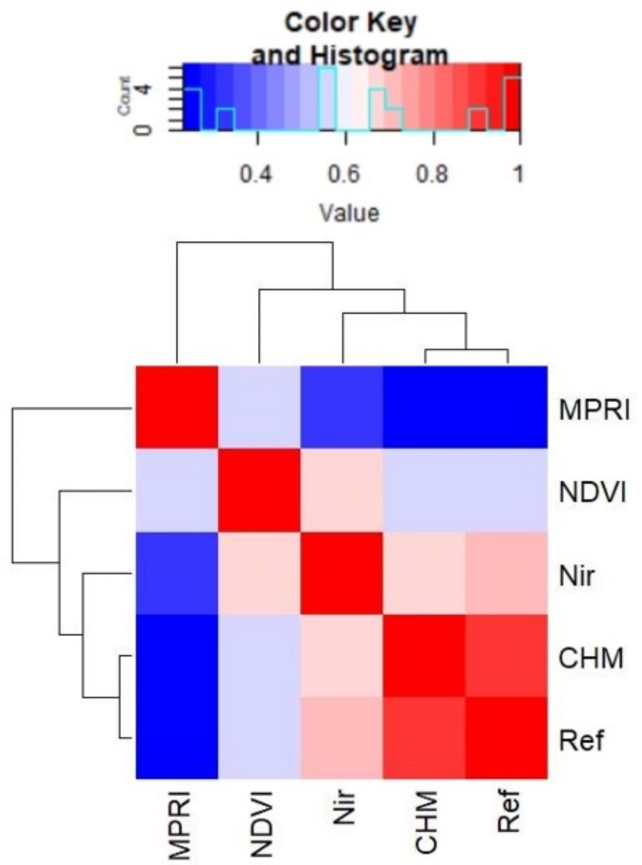

Figure 5: Correlation matrix between the reference data and the four canopy cover methods evaluated in this study.

results of this work reinforce the relevance of the protocol that uses low-cost RPA to monitor canopy cover [8].

The correlation matrix reinforces the robustness of the CHM method because it was the only one significantly correlated to the reference data. The MPRI method presented poor accuracy values and low correlation to the reference data because trees and grasses presented a lot of confusion due to similar spectral responses. NDVI and NIR methods presented a medium correlation between each other, which reinforces, along with the confusion matrices, that NIR presented a better performance in general.

When considering the vegetation indexes, the NDVI and the NIR methods presented more accurate results when compared to MPRI, which was somehow expected because MPRI uses the bands of the visible spectrum. NIR was also a bit more accurate than NDVI, but in this work, the red band was obtained from a different sensor, which may have degraded a bit the NDVI results. Even so, these results reinforce that multispectral sensors are capable of detecting the photosynthetic activity of the vegetation, which may consist an interesting research field for FR and Remote Sensing.

When using the image provided by the multispectral sensor, it was possible to notice different radiometric responses on the crowns of the trees. The response to the Near Infra-Red band was greater on the top of the trees than on the borders of the crowns. It may have occurred due to sunlight angle conditions, which shall be confirmed in future works, but such greater photosynthetic activity on the top of the trees is a typical self-thinning situation, where a fast vertical growth stimulates a long stem due to light competition between the trees, which also increases biomass production. Future studies therefore should assess the multispectral sensor potential to detect the different ecological succession dynamics between different FR management, as trees and biomass production are different between natural regeneration, direct sowing and seedling planting. Besides detecting different ecological succession dynamics, the potential of the multispectral sensor to discriminate different tree species must also be assessed in the future.

The RPA flights were conducted at the beginning of the rainy season and the multispectral sensor could detect different spectral responses between grasses and trees, while it was not possible when using only the RGB sensor. Future works must assess such spectral responses' separability between trees and grasses in the dry season and also in different light conditions of the same season.

Despite some benefits such as presenting different spectral responses between trees and grasses, the multispectral sensor that was used in this work increased not only the costs of hardware acquisition but also the time demanded for the fieldwork and for image processing. However, there are some multispectral sensors that are a bit more expensive than RGB sensors and also have similar image processing routines (when compared to RGB sensors). Thus, for scientific research, multispectral sensors may be interesting because it presents more potential to assess different patterns of ecological succession as mentioned in a previous paragraph, which may consist of an interesting research branch for upscaling FR. Even so, for researchers who don't have any RPA, the multispectral sensor may be interesting after the acquisition of an RPA coupled with an RGB sensor.

5. CONCLUSIONS

RPA presented a high potential to map canopy cover automatically. The method that used the point cloud data of the RGB sensor presented the most accurate result. Results considering spectral responses require the Near Infra-Red band to have some accuracy, but a proper multispectral sensor must be used to avoid increasing the costs of fieldwork and image processing. A user-friendly multispectral sensor may fit well such requirements, as the one that was used in this work was difficult to operate in the field and collected data that was more difficult to process.

The RGB sensors onboard RPA are cheaper and more user-friendly in general (it takes less time for training) when compared to some multispectral sensors. However, for scientific research, multispectral sensors onboard RPA may present more innovative perspectives because it detects photosynthetic activities more accurately, which has more potential to innovate the upscaling of FR monitoring. Future works must compare the results between RGB sensors and other multispectral sensors, especially the ones that are more user-friendly. Such comparisons must also involve other FR areas.

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