Monitoring The Brazilian Savanna with lidar and RGB Sensors Onboard Remotely Piloted Aircraft Systems

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MONITORING THE BRAZILIAN SAVANNA WITH LIDAR AND RGB SENSORS ONBOARD REMOTELY PILOTED AIRCRAFT SYSTEMS

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ABSTRACT

The Cerrado, the most biologically diverse savanna in the world, is threatened by anthropogenic activities, and requires development of effective environmental policies spanning local to global scales. Remotely Piloted Aircraft Systems (RPAS) can dramatically reduce the costs and time of surveys and evaluation of these regions. The objective of this article is to demonstrate the potential of visual (RGB) and Light Detection and Ranging (LIDAR) sensors on RPAS for physical characterization of landscapes in the Cerrado biome. Analyses on vegetation structure were performed, with the number of trees automatically counted. The average height of the trees obtained with the RGB sensor was significantly lower than the obtained by LIDAR, demonstrating the limitation of Structure from Motion data in representing the landscape with denser vegetation. Automatic counting of trees with LIDAR data were equal to 1825 on the whole study area, and 245 inside the ecological study area parcels.

***Index Terms—* LIDAR, SfM, RPAS, Cerrado, Tree metrics**

1. INTRODUCTION

The Brazilian savanna, also known as Cerrado, is spread over a continuous area of 2 million km^2 in the central country, recognized as the most biologically diverse savanna in the world (a conservation hotspot) [1]. However, according to MapBiomas [2] mappings (based on the Landsat 5 and 8 classification, from 1985 to 2017), this biome is extremely endangered, with approximately 50 million hectares (25%) occupied by cultivated pasture (*Brachiaria Brizantha*), 27 million hectares (13.5%) with annual and perennial agriculture (including soybean, sugarcane, corn, cotton, as well as planted forests / eucalyptus, for timber purposes, charcoal), and other 14 million hectares (7%) with mixed use (pasture and perennial agriculture). In addition to the urban areas and water bodies, the worrying 50% conversion rate of the Cerrado was reached in just over five decades [2].

With growing concern about the deleterious effects of climate change, in particular on greenhouse gas emissions from land use and land cover changes, the monitoring and restoration of degraded areas became a global and local need, as a strategy to increase the absorption of CO_2 in native and anthropogenic areas, reducing the emission of this and other gases, such as Methane and Nitrous Oxide [1, 3].

Thus, monitoring and collecting biophysical data in savanna areas (formerly restricted to forest ecosystems) becomes an important challenge, aiming at more accurate assessment of native areas, measuring impacts and generating environmental models for a more efficient use of natural resources in the production of meat and grains. In this way, since the UN-led Climate Conference of 2015 (COP 21), the Brazilian government has been committed to an ambitious goal of restoring 12 million hectares by 2030, with native species, plus 5 million hectares of integrated agricultural systems, combining crop, livestock, and forests [4]. These actions were initiated in 2011, with the "Bonn Challenge" in a commitment to restore 150 million hectares by 2020, and 350 million hectares by 2030 through out the world. Usually, this monitoring of areas in recovery (or farming activities) depends on long fieldwork, aided by satellite data, whose spatial and temporal scales do not always meet the need for analysis, focusing on quantification of volume/biomass, carbon stock and biodiversity.

In this context, Remotely Piloted Aircraft Systems (RPAS), equipped with imager sensors, can dramatically reduce the costs and time of surveys, evaluation of areas in recovery or preservation. One crucial measure, for example, is the counting trees throughout the restoration process. With such information, we can estimate the survival rate of planted seedlings, tree species density, plant spacing, and other metrics.

Specifically in Brazil, RPAS are already used in many applications, such as resource and natural disaster surveys, deforestation control, precision agriculture, management of burned areas, among others. As an autonomous flight platform, equipped with global positioning system (GNSS) and inertial stabilizers, the RPAS has been used to obtain parameters of the vegetation cover, including aspects of its physical and biological structure. Some of this information is estimated by active remote sensing, through airborne laser detection instruments (LIDAR) with recognized accuracy [5], but with high costs in front of the RGB sensors (usual camera with Red, Green and Blue channels), mainly in Brazil.

Thus, our objective in this work, with preliminary analyzes, is to demonstrate the potential of remote sensors (RGB) and LIDAR, onboard fixed-wing and multi-rotor RPAS, respectively, in the physical characterization (mean and maximum canopy height) of native landscapes in the Cerrado biome, with emphasis on research plots installed in the Rio Vermelho Hydrographic Basin, state of Goiás.

2. MATERIALS AND METHODS

2.1. Study area and Experimental design

The study area is located in the Rio Vermelho Hydrographic Basin (RVHB), located in the Center-West portion of the state of Goiás (municipality of Itapirapuã), Brazil, with an area of 10,824 km² [6], as shown in Fig. 1. RVHB is located in areas of Cerrado largely occupied by cultivated pastures, as well as in remnant vegetation class composed of grassland, savanna formations and forest formation. The climate in the region is of semi-humid tropical type, with a dry season between April and September, and another rainy season, between October and March, with average monthly rainfall varying from 1,400 to 1,600 mm in the rainy months. The average monthly temperature varies between 23 and 28 ºC [6].

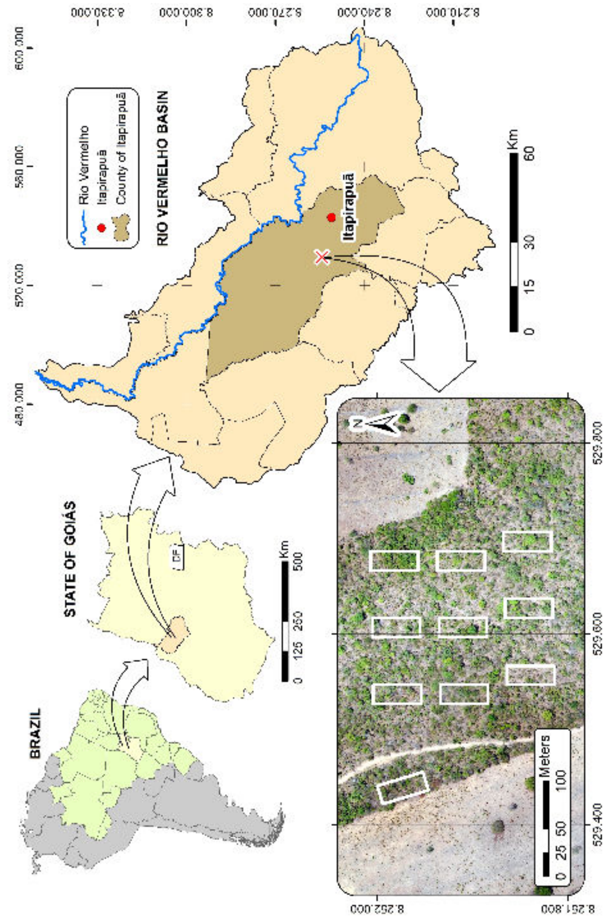

Fig. 1. Location of the study area in Goiás state (Rio Vermelho Hydrographic Basin), Brazil, highlighting the 10 ecological samples overflown with eBee/SODA and Matrice 600 Pro/LIDAR system.

The research has been conducted on a transect 50 km long and 200 m wide, positioned in the East-West direction of the basin (high and medium portion), which has been monitored with some regularity: 1) Aircraft with LIDAR sensor (August 2015); 2) Multi-rotor RPAS with LIDAR sensor (August 2017); 3) Fixed-wing RPAS with RGB sensor (September 2017).

2.3. Database and Analysis Procedures

The data used in this work were obtained from two unmanned aerial surveys on the 10 ecological plots (Fig. 1). The first set of information was obtained in August 2017, with the GatorEye system (www.gatoreye.org - University of Florida) [7], composed by the Phoenix LIDAR sensor suite, onboard the DJI Matrice 600 Pro hexacopter multi-rotor RPAS, with L1/L2 dual-frequency GNSS (PPK mode -

Post Processing Kinematic). This system consists of a Velodyne VLP-16 dual-return laser scanner head, capable of 600,000 returns per second, with Phoenix live and post-processing software. The second set of data was obtained in September 2017, with RGB SODA camera (24 MP), onboard the fixed-wing Sensefly RPAS, model eBee RTK/PPK, L1/L2 dual-frequency GNSS (PPK mode - Post Processing Kinematic), with which were obtained aerophotogrammetric mosaics with 10 cm spatial resolution. The longitudinal and lateral overlap was of 60% in order to ensure a good cloud of altimetric points. Fig. 2 illustrates the two sets of instrument.

Fig. 2. (A) Sensefly fixed-wing eBee RTK Plus + SODA camera; (B) DJI Matrice 600 Pro + LIDAR system, both used in the experimental site, in July/August 2017.

The data obtained by the Sensefly eBee/SODA system were processed in the PIX4D Mapper software. The other analyzes about vegetation structure were performed in ArcGIS software (Spatial Analyst - Zonal statistics Tools). LIDAR data processing was performed using the LAStools software [8]. First, from the raw 3D LiDAR point cloud, we classified the ground returns and generated the digital terrain model (DTM) with 0.5 m resolution. Then, from the raw LIDAR cloud, we performed a spurious-return filter and generated the raster digital surface model (DSM), also with 0.5 m resolution. Finally, with DTM and DSM, we removed the lower and upper spurious data from the raw LIDAR point cloud, and generated the normalized LIDAR point cloud and the Canopy Height Model (CHM) with 0.5 m resolution.

Aiming to count the number of trees automatically, the watershed algorithm was applied on the CHM, using the rLidar package, on the R command platform software [9]. The watershed algorithm was applied in the whole study area and then only the trees within the ecological parcels were clipped.

3. RESULTS AND DISCUSSION

The Fig. 3 illustrates the preliminary data of this research, which compares the tree structure of ecological plots, installed in a native Cerrado area (RVHB), based on the Canopy Height Model generated with the RPAS eBee and Matrice 600 Pro, equipped with multispectral sensor SODA (RGB standard) and LIDAR, respectively. The Table 1 brings the metrics on height and number of trees in the 10 plots analyzed, generated with both systems.

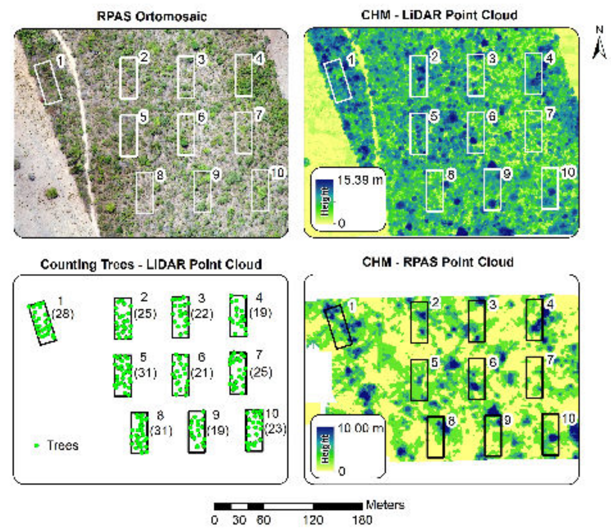

Fig 3. Figures in clockwise direction: (1) Location of the plots on the ortomosaic RGB generated with eBee / SODA system. (2 and 3) Comparison of Canopy Height Model (CHM) generated with Matrice 600 Pro / LIDAR system and eBee / SODA system. (4) location / counting of trees based on the LIDAR data.

Table 1. Metrics of height and number of trees in the 10 plots analyzed, generated with RPAS - LIDAR and RGB systems (July and August 2017, respectively).

Plots	Max. Height		Min. Height		Average Height		Number of Trees
	LIDAR	RPAS	LIDAR	RPAS	LIDAR	RPAS	LIDAR
1	12.45	5.00	0.55	0.00	7.51	1.67	28
2	12.88	5.00	0.17	0.00	6.99	1.12	25
3	11.94	5.00	0.14	0.00	5.17	1.08	22
4	12.51	5.00	0.26	0.00	6.89	1.25	19
5	12.73	3.00	0.15	0.00	6.75	0.99	31
6	13.27	6.00	0.10	0.00	5.80	1.21	21
7	9.86	3.00	0.04	0.00	4.81	0.47	25
8	11.89	4.00	0.16	0.00	5.02	0,71	31
9	13.45	7.00	0.15	0.00	6.94	0.90	19
10	11.97	5.00	0.26	0.00	6.38	1.17	23

It can be noticed that the average height of the trees obtained with the RGB sensor is significantly lower than the average obtained with LIDAR (Table 1), demonstrating the limitation of optical data (Structure from Motion - SfM) in representing the landscape with denser vegetation (in this case, a savanna with shrub and tree/forest physiognomies). Once LIDAR collects information below the canopy and SfM doesn't, CHM are more susceptible to huge differences between these two mapping methods on such circumstances. Still in Table 1, when observing the points with maximum height of the vegetation, the difference between the systems is around 7 meters. In this case, and although the RGB sensor data is underestimated, visually the taller trees were marked by both systems (Fig. 3). In general, the automatic counting of trees (with LIDAR data) were equal to 1825 on the whole study area, and 245 inside the ten ecological parcels (Fig. 3 and Table 1), indicating the capacity of this sensor, as well as the RPAS system as a whole, in monitoring/mapping native areas, or in forest restoration.

4. CONCLUSIONS

Environmental monitoring of native or forest restoration areas can be performed by RPAS, since it provides higher resolution data on both LIDAR and RGB sensors technologies.

As expected, data from RGB camera generated inaccurate CHM when compared to LIDAR, because the study area presented few gaps over the canopy. Consequently, tree metrics obtained by SfM were inaccurate when compared to LIDAR. This fact reinforced LIDAR technology as a tool for measuring, managing and monitoring forested areas automatically. Despite generating inaccurate metrics automatically, the RGB sensor generated a high-resolution data that can be used for photointerpretation evaluation of the trees (including species analysis).

As Cerrado's forested areas present more quantity of gaps between trees, next steps of this study should evaluate methods for automatically obtaining CHM more accurately on this important Brazilian biome, considering field inventory data from the ecological parcels. Future studies should also evaluate if RGB/SfM generates canopy tree metrics as accurate as LIDAR's on highly dense forested areas, such as the Amazon (not considering in this case the trees below the canopy).

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