Global Ecosystem Dynamics Investigation data enable structural patterns assessment in Amazon rainforest

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1. Introduction

The Amazon rainforest is the most extensive tropical forest in the world and also the most biodiverse (Ter Steege et al. 2013). However, maintaining this biodiversity has been a challenge due to the rising deforestation, predatory exploitation and forest fires, which lead to the loss of ecosystems (Silva Júnior et al. 2020). Thus, efforts have been made by researchers in the search for new forms of sustainable use and monitoring of forest resources (e.g., Paiva et al. 2020).

The Global Ecosystem Dynamics Investigation (GEDI) mission aims to providing high-quality measurements of the vertical structure of tropical and temperate forests around the globe through a huge variety of products, including canopy height, canopy coverage and vertical profile, leaf area index (LAI), topography and biomass (Dubayah et al., 2020). These freely-available data might aid activities on sustainable forest management, such as land cover and use dynamics, distinction of vegetation types and definition of permanent preservation areas. Even though there are other Lidar missions (e.g., ICESat Geoscience Laser Altimeter System), GEDI is the first orbital system primarily designed for structural characterization of forests, with technical features for accurately measuring those with dense and continuous upper canopies, like the Amazon rainforest. Thus, we here aim to explore GEDI data to assess forest structural patterns at National Forest of Purus (NFP), southwestern Amazon, in order to test whether GEDI metrics are a powerful dataset to support actions of sustainable use and conservation.

2. Data and Methods

2.1. Study Area

Our study has been caried out in the National Forest of Purus (NFP), a conservation national park for sustainable use, which stands out for its 256,000 ha of highly conserved tropical forest in the southwestern Amazon (Figure 1).

2.2. Geo-environments mapping

We used as an initial basis the NFP geo-environments units that were manually mapped and characterized by Brandão et al. (2010). First, we map them and other land use and cover features with aid of machine learning algorithm by using the following covariates: nine surface reflectance images from the Sentinel 2A Multi Spectral Instrument visible to shortwave infrared bands (with 20 m spatial-resolution) from 08/15/2019, the calculated Normalized Difference Vegetation Index (NDVI; 20 m), and a surface elevation grid from the Shuttle Radar Topography Mission (SRTM; 30 m). Samples for model training and validation were manually collected for each class, totaling 549 polygons and 9,225 pixels. The following geo-environmental units were identified in the study site: i) Dissected Plateaus with Terra-firme Forest over Latosols and Argisols (DP); ii) Slopes and Ramps with Forests over Argisols (SR); iii) Alluvial Plains with Fluvial Neossols and Gleysols (AP); iv) Anthropized areas with traditional land use; v) River beaches; and vi) Water bodies. The Random Forest algorithm was used to perform the geo-environments mapping using 70% of the samples for training and the remaining (30%) for model validation following Fernandes Filho (2019).

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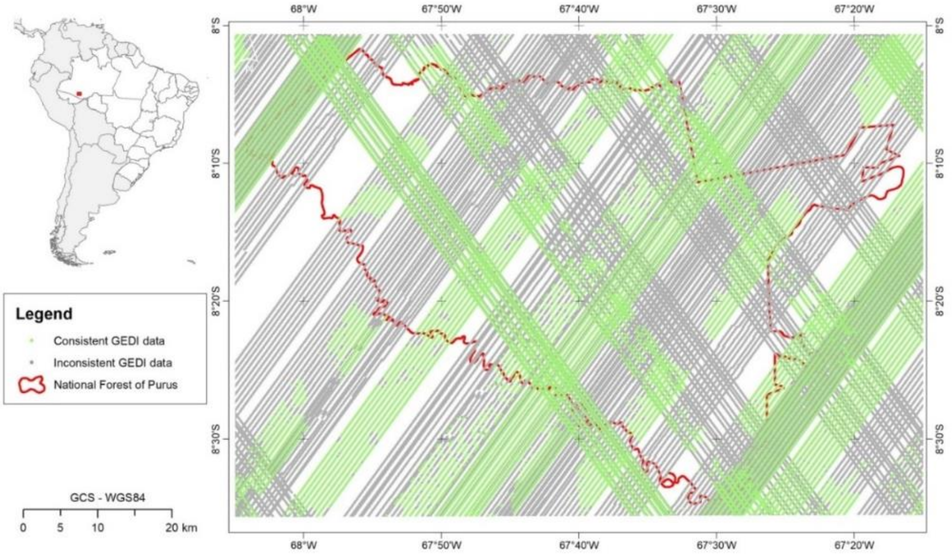

Figure 1: Location of the National Forest of Purus (NFP) in southwestern Amazon and coverage of GEDI data in the NFP and surroundings. In green is the used high-quality GEDI dataset.

2.3. GEDI data acquisition and processing

We obtained the GEDI data from the NASA Earth Data collection and processed the level 2B products through the rGEDI package (Silva et al. 2019). Firstly, a selection of the consistent data was carried out by using the data quality indicator (i.e., quality_flag = 1). They totalled 141,560 points at the end of processing, which corresponds to 27% of the total data covering the study area up to 08/31/2020 (Figure 1). The GEDI metrics obtained and evaluated in this study were the Canopy height – rh98 (meters) and the Plant Area Index – PAI (unitless). Those metrics were extracted from each footprint (point) for each mapped geo-environment (DP: 67,248 points; SR: 49,939 points; AP: 24,373 points). To test the hypothesis that the GEDI metrics are effective for distinguishing the forest structure, they were analyzed for the entire database and by geo-environment. In this sense, the Skewness normality test was conducted to verify the distribution of the data and the identity of the different population's distribution function was tested through the Kruskal-Wallis test ($\alpha = 0.05$) and the Dunn's post-hoc test.

3. Results and Discussion

DP showed the highest PAI median value (i.e., PAI = 3.19), followed by SR (3.01) and AP (2.23), with significant differences between the three geo-environments (Figure 2). This result reveals the potential of GEDI-based PAI data to distinguish Amazonian "Terra Firme" (on DP, and SR) from lowland (AP) forests structurally. Canopy height is also a good parameter to discriminate those forests, while AP forests presented a median height of 22.37 m, SR and DP forests stood out for heights of 23.78 and 24.02 m respectively.

Our results indicate an important application of GEDI data for mapping forest structure and diversity across the landscape, as they corroborate previous studies in the Amazon region. Some of them demonstrate variations in the structure and biomass of upland and lowland forests in the Amazon (e.g., Aldana et al., 2017; Bredin et al., 2020). Significant differences in the field-based height of these two forest types was found by Bredin et al. (2020) in the region of the Juruá river. They found taller forests on the upland than on the floodplain. The same was found by Hill et al. (2011) in the Peruvian Amazon from airborne lidar-based estimation. On the other hand, Aldana et al., (2017) found a greater amount of biomass in the floodplain areas in relation to the Terra Firme forests, this difference being related to the greater fertility of the soils in the floodplains. Further studies exploring the GEDI waveforms and other metrics, in addition to soil data, will allow us to better find and understand structural patterns across the studied Amazonian forest, supporting actions for sustainable use and conservation.

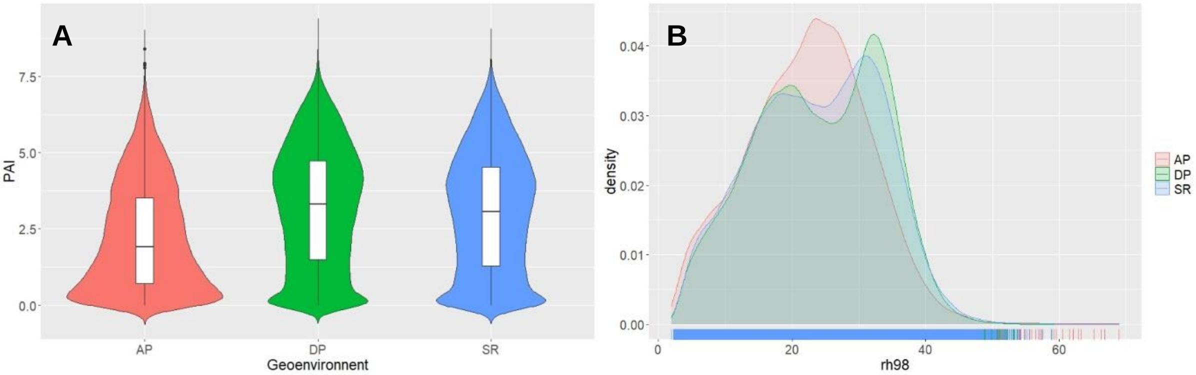

Figure 2: Violin plot of the Plant Area Index - PAI (A) and density plot of the height estimates - rh98 (B) from the forests on Alluvial Plains (AP), Dissected Plateaus (DP), and on Slopes and Ramps (SR).

4. Conclusions

The GEDI data applied to the mapped geo-environmental units showed significant differences between forests that occur in different portions of the terrain by structurally segregating upland from lowland forests mainly. GEDI proved to be a useful tool for assessing the structure of different Amazonian forests and supporting their sustainable use and conservation.

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