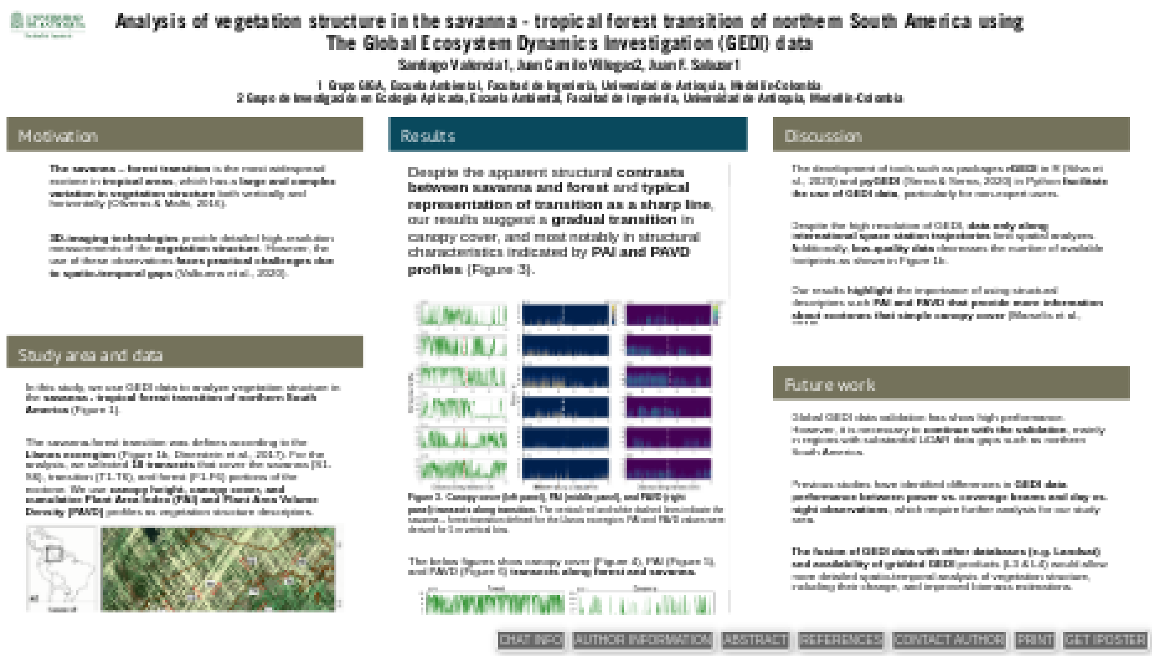
Analysis of vegetation structure in the savanna - tropical forest transition of northern South America using The Global Ecosystem Dynamics Investigation (GEDI) data



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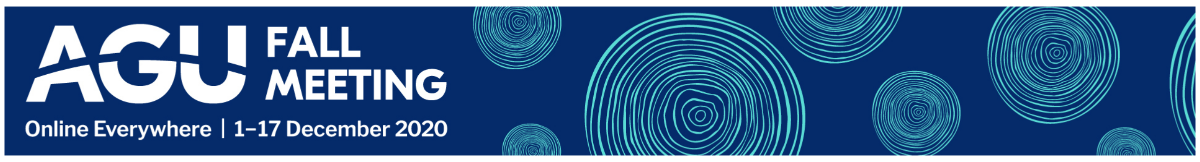

MOTIVATION

- **The savanna – forest transition** is the most widespread ecotone in **tropical areas**, which has a **large and complex variation in vegetation structure** both vertically and horizontally (Oliveras & Malhi, 2016).

- **3D-imaging technologies** provide detailed high-resolution measurements of the **vegetation structure**. However, the use of these observations **faces practical challenges due to spatio-temporal gaps** (Valbuena et al., 2020).

- NASA's Global Ecosystem Dynamics Investigation (GEDI) is the **first quasi-global** (51.6°N-51.6°S) LiDAR (light detection and ranging) observations of 3D vegetation structure at a **footprint resolution of 25 m** (Dubayah et al., 2020).

- No **studies have previously tested the capacity** of this product to **detect and characterize ecotones and transitions in tropical regions.**

STUDY AREA AND DATA

In this study, we use GEDI data to analyze vegetation structure in the **savanna - tropical forest transition of northern South America** (Figure 1).

The savanna-forest transition was defines according to the **Llanos ecoregion** (Figure 1b, Dinerstein et al., 2017). For the analysis, we selected **18 transects** that cover the savanna (S1-S6), transition (T1-T6), and forest (F1-F6) portions of the ecotone. We use **canopy height, canopy cover, and cumulative Plant Area Index (PAI) and Plant Area Volume Density (PAVD)** profiles as vegetation structure descriptors.

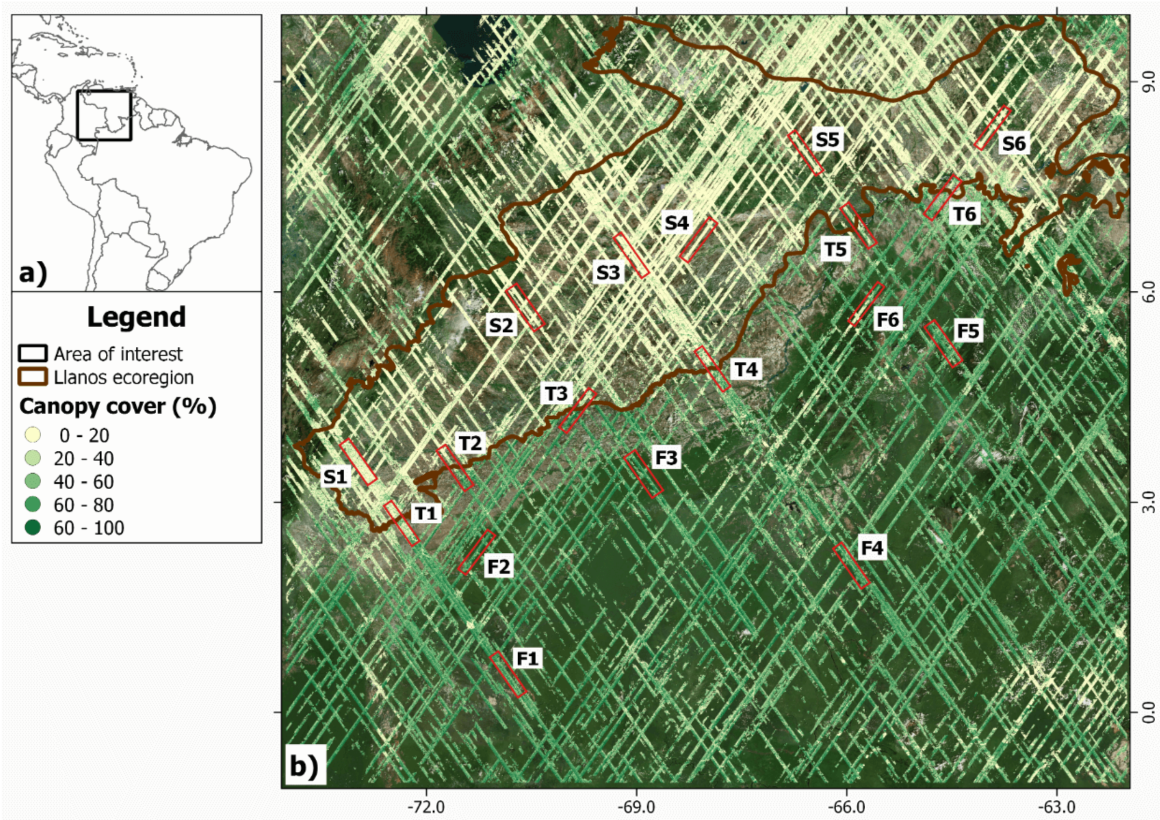

Figure 1. (a) General location of the study area in the northern South America and (b) total available high-quality GEDI data of canopy cover (GEDI2B) over the study area. The brown line represents the limits of Llanos ecoregion (Dinerstein et al., 2017). The red boxes show the selected transect in savanna (S1 to S6), transition (T1 to T6), and forest (F1 to F6). The Google Earth imagery as the background.

As seen in Figure 2, GEDI data consists of 8 beam ground transects. In this study, we obtained data only for **one full power beam** (beam0101) excluding low-quality data. We download, extract, and process data with the **rGEDI package in R** (Silva et al., 2020).

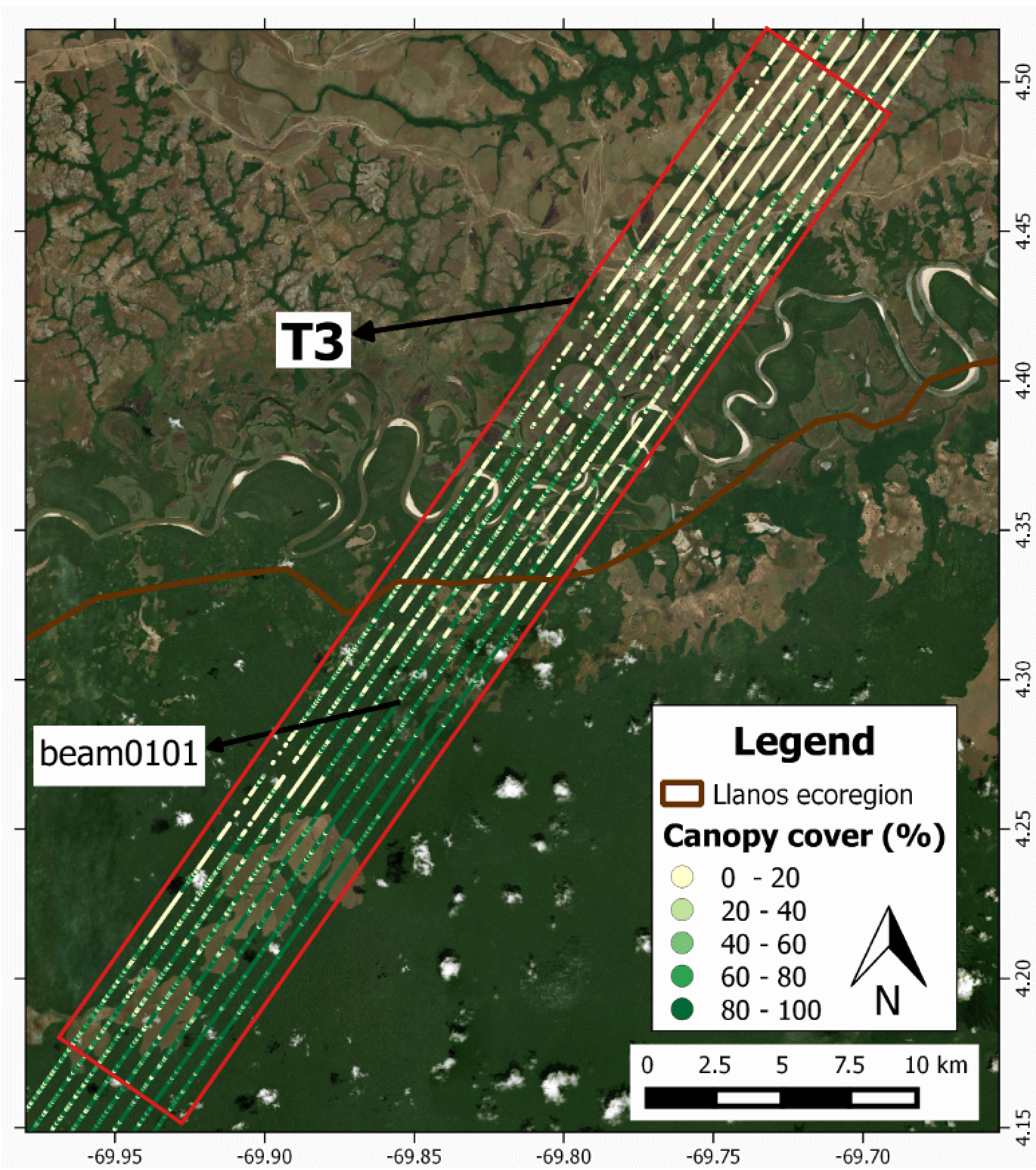

Figure 2. Example of 8 beam ground transect. Red rows indicate the selected beam in this study and the brown line represents the limits of Llanos ecoregion (Dinerstein et al., 2017). The Google Earth imagery as the background.

RESULTS

Despite the apparent structural **contrasts between savanna and forest** and **typical representation of transition as a sharp line**, our results suggest a **gradual transition** in canopy cover, and most notably in structural characteristics indicated by **PAI and PAVD profiles** (Figure 3).

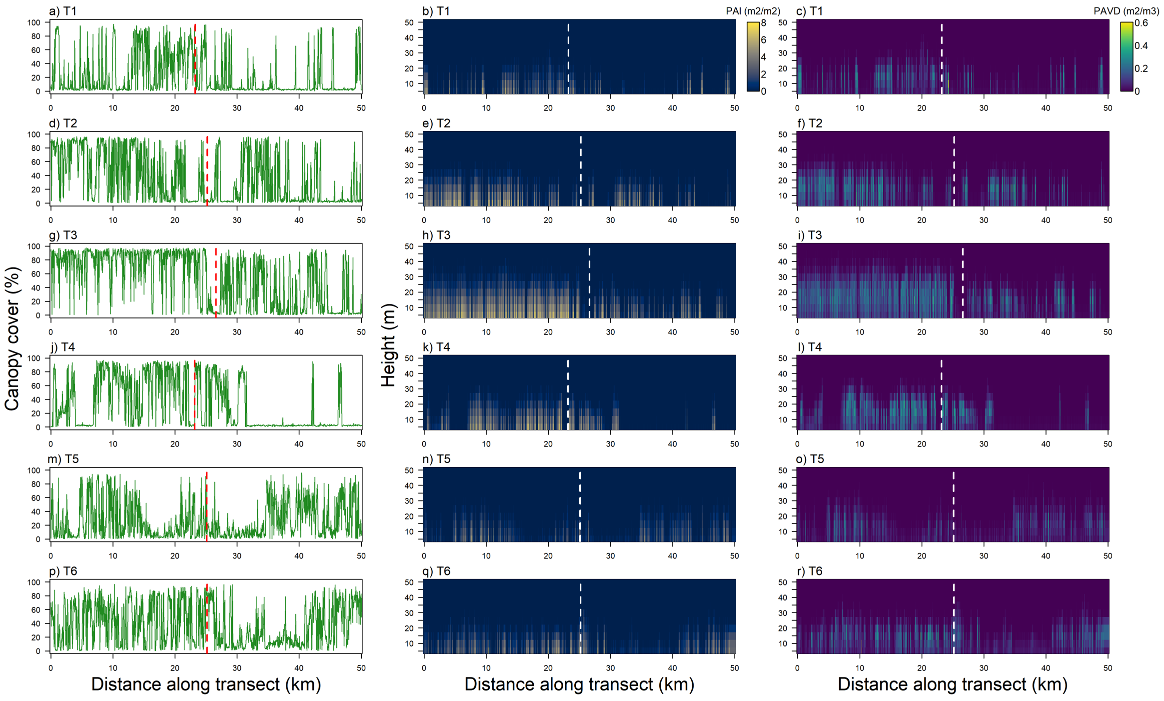

Figure 3. Canopy cover (left panel), PAI (middle panel), and PAVD (right panel) transects along transition. The vertical red and white dashed lines indicate the savanna – forest transition defined for the Llanos ecoregion. PAI and PAVD values were derived for 5 m vertical bins.

The below figures show canopy cover (Figure 4), PAI (Figure 5), and PAVD (Figure 6) **transects along forest and savanna.**

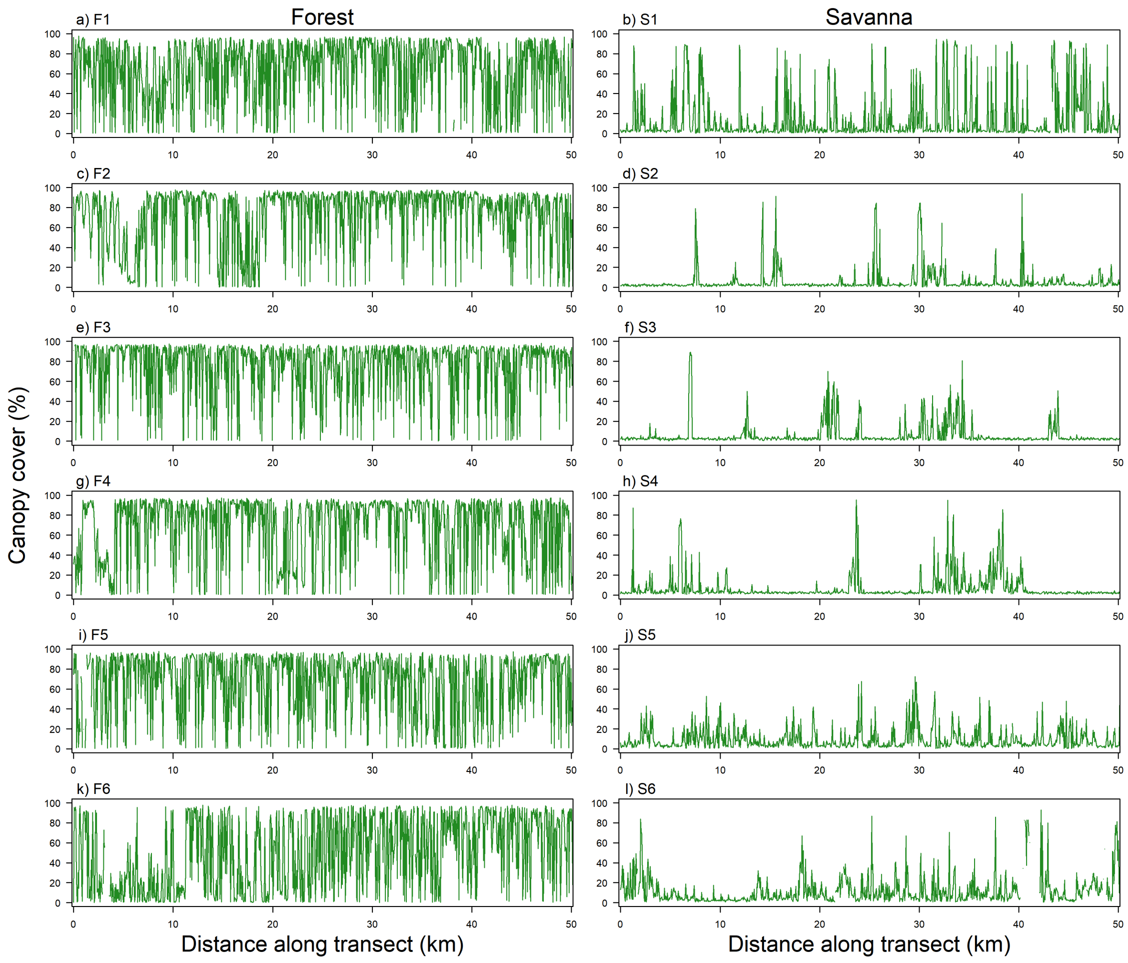

Figure 4. Canopy cover transects along forest (left panel, F1 to F6) and savanna (right panel, S1 to S6).

As expected, **the savannas have low canopy cover** (S1 to S6, Figure 4). However, **high canopy cover values along the savanna transects**, mainly associated **riparian forest** (Figure 2), fundamental for biodiversity in these systems.

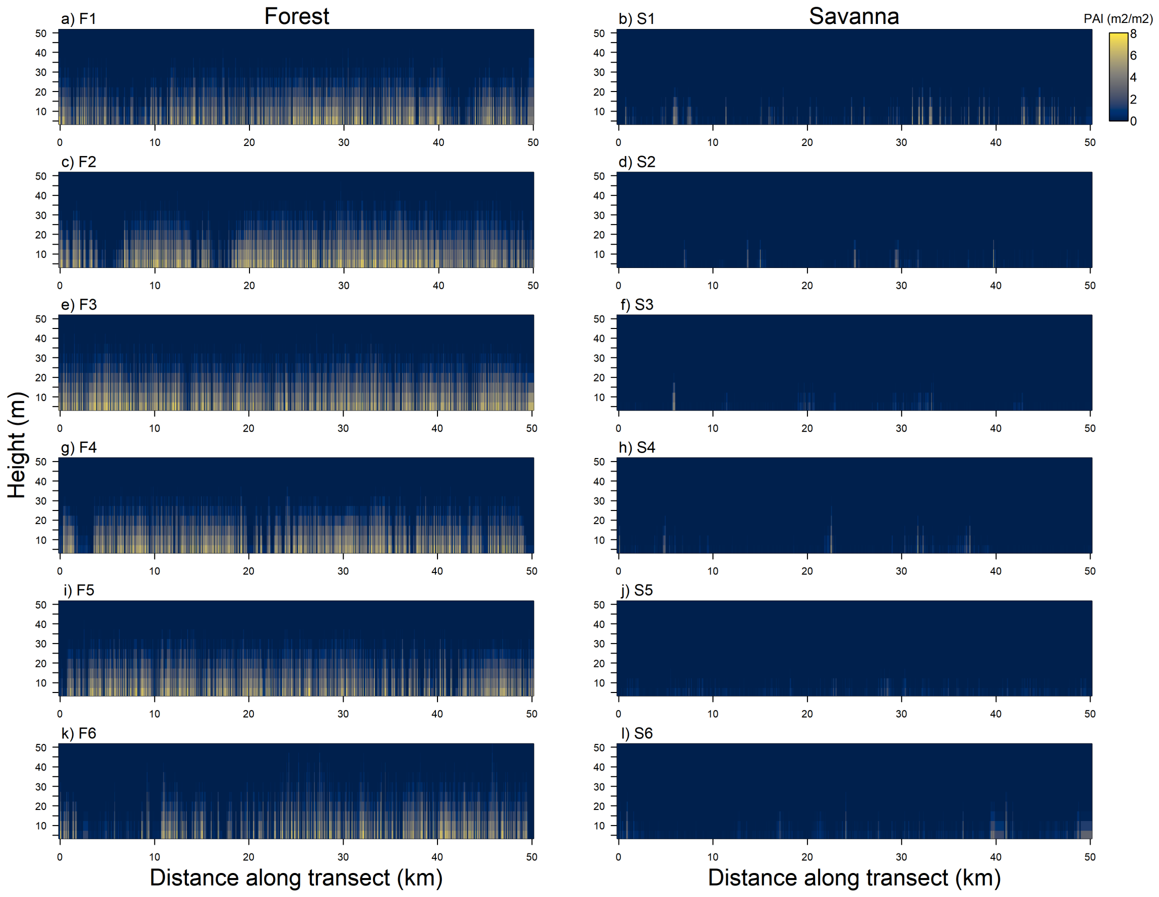

Figure 5. PAI vertical profile as a function of canopy height transect along forest (left panel, F1 to F6) and savanna (right panel, S1 to S6). PAI values were derived for 5 m vertical bins.

The **PAI and PAVD** profiles show that footprints in **savanna with similar canopy cover to the forest (> 80%), have lower canopy height and structural complexity**, typical of savannas.

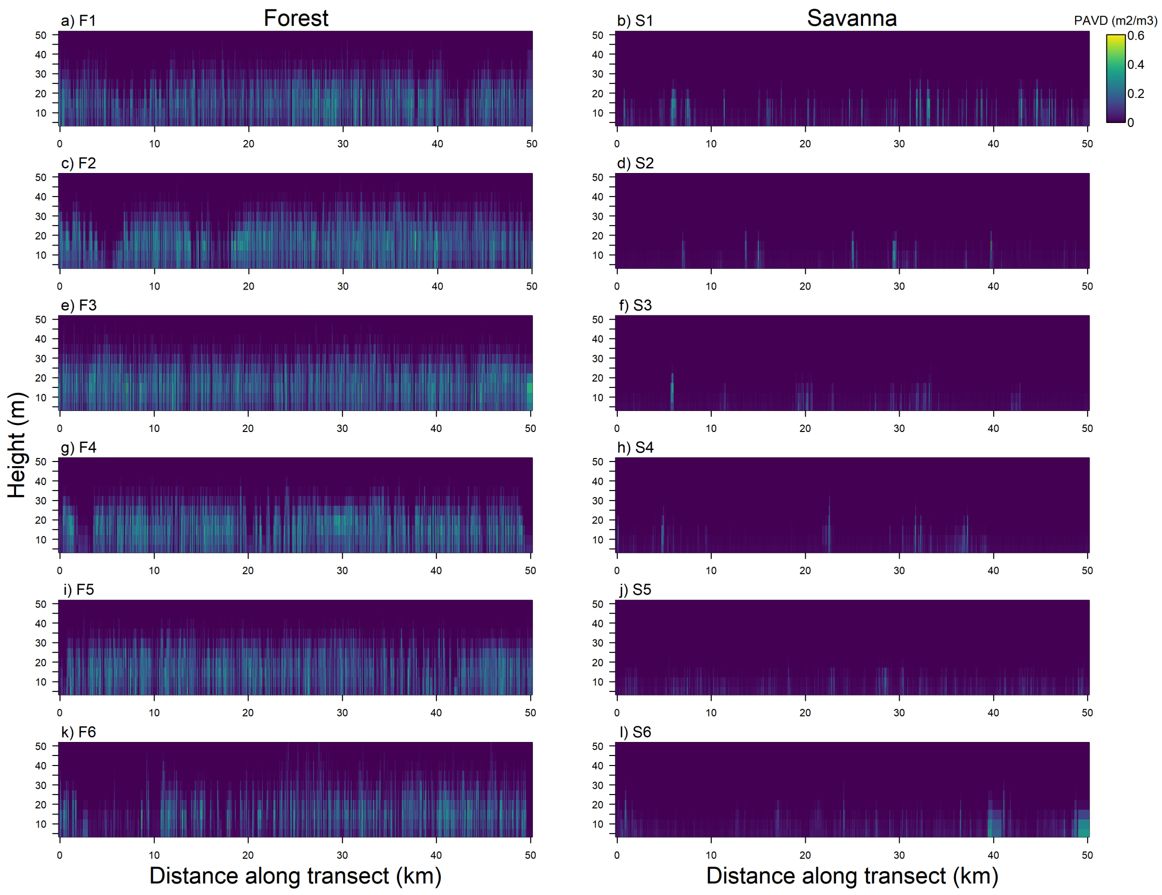

Figure 6. PAVD vertical profile as a function of canopy height transect along forest (left panel, F1 to F6) and savanna (right panel, S1 to S6). PAVD values were derived for 5 m vertical bins.

These differences between canopy cover and vertical profiles are also observed in the forest, where **canopy cover shows high homogeneity,** while **PAVD and PAI highlight variations in canopy height and complexity structural** along and between transects.

The **PAVD profiles** also indicate that savanna and forest have a **greater density of vegetation** in heights between 0-10 m, and 15-25 m, respectively.

DISCUSSION

The development of tools such as packages **rGEDI** in R (Silva et al., 2020) and **pyGEDI** (Serna & Serna, 2020) in Python **facilitate the use of GEDI data**, particularly for non-expert users.

Despite the high resolution of GEDI, **data only along international space station trajectories** limit spatial analyzes. Additionally, **low-quality data** decreases the number of available footprints as shown in Figure 1b.

Our results **highlight** the importance of using structural descriptors such **PAI and PAVD that provide more information about ecotones that simple canopy cover** (Marselis et al., 2018).

Our results support that **transition shows *many shades of green*** depending on the local biophysical factors (e.g. climate, soil, fire) and human-related disturbances (e.g. deforestation, degradation) (Oliveras & Malhi, 2016; Stark et al., 2020).

Multiple studies have highlighted that although **canopy cover** is useful in many cases, it can lead to **underestimating the structural complexity** of the vegetation. For example, **open biomes**, as savannas with typically low canopy cover, has been **wrongly classified** as **degraded forest** and priority areas for **restauration** (Silveira et al., 2020) solely based on a canopy cover criteria.

Our results support that the **savanna-forest transition in tropical regions** can be described as a **grassland - forest continuum** (Breshears, 2006), which contrasts with the **typical representation as a simple line in maps** (Marques et al., 2020). Considering a **transition zone instead of a line** is key to understand the **impacts of environmental change** (e.g. deforestation, degradation, fire) and **related ecosystems process** (Stark et al., 2020).

FUTURE WORK

Global GEDI data validation has show high performance. However, it is necessary to **continue with the validation**, mainly in regions with substantial LiDAR data gaps such as northern South America.

Previous studies have identified differences in **GEDI data performance between power vs. coverage beams and day vs. night observations**, which require further analysis for our study area.

The fusion of GEDI data with other databases (e.g. Landsat) and availability of gridded GEDI products (L3 & L4) would allow more detailed spatio-temporal analysis of vegetation structure, including their change, and improved biomass estimations.

Acknowledgment

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ABSTRACT

The savanna - forest transition in the tropics has a large and complex variation in vegetation structure both vertically and horizontally. 3D-imaging technologies provide detailed high-resolution measurements of the vegetation structure. However, the use of these observations globally faces practical challenges due to spatio-temporal gaps and operational restrictions, mainly in tropical regions. NASA's Global Ecosystem Dynamics Investigation (GEDI) is the first quasi-global (51.6°N-51.6°S) LiDAR (light detection and ranging) observations of 3D vegetation structure at a footprint resolution of 25 m. Here we use GEDI data (GEDI02_Bv001) to analyze vegetation structure in the savanna - tropical forest transition of northern South America, using canopy height, canopy cover, and vertical profiles of Plant Area Index (PAI) and Plant Area Volume Density (PAVD) as vegetation structure descriptors. Despite contrasts between savanna (open-canopy) and forest (closed-canopy), our results show a gradual variation along the transition in canopy height, canopy cover, total PAI, and maximum PAVD. Our results support that the savanna- forest transition in tropical regions can be described as a grassland - forest continuum. Results also indicate that GEDI data allow a better characterization of vegetation lower than 5 m in height, mainly in savanna, an improvement from other global databases (e.g. MODIS). Further, our study illustrates the potential of GEDI data to advance in the characterization of large-scale patterns of vegetation structure in tropics, key for supporting biogeography, and macroecology studies relevant in the phase of current ecosystem changes.

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