**Understanding the origin and the landscape dynamics of white-sand vegetation in Amazonia**

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**Introduction**

The white-sand vegetation system, also known by the general terms *Campinarana* in Brazil, *Varillal* in Colombia, and *Wallaba* in Guyana, is distributed on sandy and nutrient-poor soils all over the Amazon. The vegetation structure varies from open grassland to dense forest (Prance 1996) as a mosaic scattered on the landscape. In Central Amazonia, this vegetation type occupies small and fragmented areas surrounded by non-flooded terra-ﬁrme forest (Anderson 1981). However, in the Negro’s river basin, extensive plains are ﬂooded due to poor drainage of sandy soils (spodzols; superﬁcial rock beds) and water inﬁltration of periodically ﬂooded river margins (Ab’saber 2002).

Open vegetation types in Amazonia (e.g. savannas and grasslands) have received much attention from researchers, as they have been considered refuge ecosystems related to Late Pleistocene and Holocene dry periods (Absy et al. 1991). Across the Amazon, sandy soils can arise by different processes (e.g. local acid hydrolysis or in situ leaching, tectonic subsidence of low lands, paleochannels and deposits caused by river dynamics) within different geological units and over distinct time scales. As a result, white-sand ecosystems throughout the Amazon are not the same in terms of vegetation structure, floristic composition, flooding period, and patch size. Indeed, the white-sand flora is unique, and many species are geographically endemic.

A full understanding of the process in which white-sand landscapes have emerged is lacking, and it is still the subject of debate. Where pollen preservation is low, such as in areas with a predominance of sand deposition, δ13C of organic matter and phytoliths has been used for reconstructing vegetation patterns of many other tropical and subtropical areas. Here, we aimed to answer these questions by investigating how vegetation shifts occurred during the past 10,000 years in a forest–grassland mosaic of white-sand ecosystems. I will use soil organic matter carbon isotope and phytolith ratios as a proxy for changes in C3/C4 plant (tree/grass) relative abundance to quantify and date forest expansion across a vegetation gradient spanning: forests, forest patches, and grasslands. The long-term equilibrium of the different portions of this vegetation gradient is not well understood, which makes it difficult to test hypotheses regarding the importance of landscape dynamics in Amazonia.

**Study area**

The field research was conducted at Viruá National Park, located in the county of Caracaraí, Roraima State, Brazil (01°46′34″ N, 61°02′06″ W). According to Koppen classiﬁcation, mean annual temperature is around 26 °C and mean annual rainfall is 1900 mm, with a dry season from November to April, during which monthly precipitation is <50 mm. The park area is approximately 227 000 ha, mostly lowlands (<150 m a.s.l.) with some residual hills of ca. 250 m a.s.l. The lowlands are usually dominated by poorly drained white-sand soils, and on the hills soils are clayish and lateritic. The vegetation at Viruá National Park includes white-sand forests and savannas, Igapó forests, and dense rain forest (terra-ﬁrme forests) on the isolated hills. In the wet season, all plains become ﬂooded. During the dry season, soil moisture is minimal, and savannas are frequently burned due to the increase in human activities around the park.

**Sampling design**

We will divide the vegetation gradient into the following classes: forest, forest border, large patch, small patch, and grassland. Transects were placed perpendicularly to forest–grassland. A plot (10 x 10 m) will be placed every 10 m along each transect, totaling 12 plots per transect (10 into the forest island and two into the grassland). Likewise, we will establish plots at seven large patches and ﬁve small patches. The area of large patches ranged from 1,700 to 3,000 m2 (closed canopy), whereas small patches were less than 1,200 m2 with partially open canopy and few large trees. All patches were surrounded by grassland matrix. To look for spatial patterns in patch formation, we will place plots at four borders; 10 m from each of these borders into the patch; and at the center of the patch, totaling nine plots per patch. The distance between borders ranged roughly from 34 to 91 m according to patch size. Aside from the grassland plots placed along transects (near the forest borders), we will established ﬁve grassland plots far from the forest limits.

Within each of these 10 x 10 m plots, we will describe the vegetation structure and sample soil. At each plot, we will determine total canopy cover, tree density, basal area, and grass cover. Canopy cover will be measured at the center of the plots using a concave spherical densiometer (measurements were taken at 1 m height). We will perform four canopy measurements at the center of each plot and use the average value as the canopy cover of the plot. Total basal area will be determined with the help of a metric tape. For this and for tree density calculations only trees with more than 5 cm of circumference at breast height will be included. A smaller plot (1 x 1 m) will be placed at the center of each larger (10 x 10 m) plot and the total grass cover was visually estimated.

At the center of each of the 10 x 10 m plots described above, samples from the superﬁcial soil (0–5 cm depth) and down to 1 m depth (10 x 10 cm increments), or until bedrock is reached, will be taken using a soil borer. This procedure was performed for all vegetation gradient. These soil samples will be taken for two fundamental reasons. First, to determine past shifts in vegetation, and second, to investigate possible associations between edaphic properties and the current vegetation gradient. These two lines of investigation involve different analytical procedures, which are described below.

**Data analysis**

We will correlate structural parameters of the present day vegetation with superﬁcial SOM δ13C to deﬁne the isotopic signature and pytolith composition of each portion of the vegetation gradient: forest, forest border, large patch, small patch, isolated tree, and grassland. Using these signatures, we elaborated ﬁgures that show shifts in vegetation (SOM δ13C) in different depths of soil proﬁles. We prepared two different ﬁgures that show past shifts in vegetation featuring both border dynamics and forest patches formation, conferring color labels (gray scale) that are equivalent to the range of the SOM δ13C that deﬁnes the signature of each portion of the vegetation gradient. These results are presented as shifts in vegetation through time. Soil depth was converted into a time scale by using the relationship found between depth and SOM age, determined through14C activity analysis, using our results and those of two other independent studies. Carbon isotope ratios of the soil organic matter (SOM) will be determined at the Laboratory of Stable Isotope at the Lawrence National Laboratory, Berkeley and the pytolith extraction will be performed at the Archeological Facility, UC Berkeley.

**Expected Results and Significance of Proposed Research**

I expect to verify if patches of white-sand forests are expanding or contracting over savanna and grassland areas. In addition, it will be possible discuss if biotic and abiotic factors are constraining dynamic process involved in shaping the modern white-sand ecosystems. My previous studies have shown that forest species can be established into savannas and grasslands (Damasco et al. 2013). As a complementation, we will be able to detect if plant dispersal processes could generate new forest islands over the landscape mosaic of white-sand areas. In addition, expecting the decreasing of rainfall regime over climate change, we will suggest a substitution of open grasslands by forests physiognomies in the future. This proposal will generate novel contributions regarding the origin and dynamic of Amazonian white-sand vegetation and will help us to predict possible future Amazonian scenarios under climate changes. In so doing, we will gain new insight into the processes that result in the maintenance of biodiversity in the Amazon basin, home to the world’s most species-rich ecosystems.