SOIL - PLANT RELATIONSHIP IN A CERRADÃO IN SOUTHERN TOCANTINS STATE, BRAZIL.

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INTRODUCTION

In the past 40 years more than 50% of the Cerrado biome has been transformed in agricultural land (mostly soy and sugar cane) and pastures (Klink & Machado 2005). This Brazilian biome comprises the world's richest tropical savanna, surpassing 12 thousand vascular plant species (Mendonça *et al.*, 2008). Even though the Cerrado is classified as a world hotspot, with great biodiversity and extremely threatened, conservation initiatives are scarce with only 2,2% of the biome under protected areas leaving 20% of the endemic and threatened species unprotected (Klink & Machado 2005).

The different savanna, forest and grassland physiognomies of this biome are distributed not necessarily following a gradient, but constituting land mosaics in a heterogeneous landscape (Silva *et al.*, 2006). In this complex landscape the cerradão phytophysiognomy, a type of low xeromorphic forest, embodies the mixed nature of different vegetations presenting a sorted flora of savanna and forest species. Therefore cerradão fragments have different origins: natural patches within a heterogeneous landscape with a permeable savanna matrix; isolated fragments in intensified areas of land use (Oliveira - Filho & Ratter 2002, Felfili *et al.*, 2004).

Recent studies have showed two types of cerradão that vary in relation to soil fertility: mesotrophic facies cerradão and distrophic facies cerradão. Distrophic cerradão occurs in upland and well drained soils, more common in the biome's core area. These soils generally have acid pH (4 - 4.8) high aluminum saturation (> 50%) and low amounts of nutrients (Ca, Mg, K and P). Furley & Ratter (1988) described some distrophic communities as having typical species such as Hirtella glandulos, Emmotum nitens and Sclerolobium paniculatum. However there still is much to learn regarding the association of cerradão species and soil properties.

Currently cerradão is among the lesser studied vegetation types of the Cerrado biome, partly because of its limited natural distribution and partly because of the fast and growing land use change, scarcely represented in protected areas and farms legal reserve. Also cerradão can have a key role in conservation initiatives because of its mixed flora of savanna (cerrado stricto sensu) and forest (gallery forest, deciduous and semideciduous forests etc.) species. Many questions regarding cerradão remain unanswered such as what are its main determinants; its relation with environmental factors (soil, climate, altitude etc.); diversity patterns and floristic connections; structural variation and patterns in the biome. What soil properties influence cerradão species distribution is the question that this paper pursues.

OBJECTIVES

The main goal is to analyze the species distribution in relation to soil chemical and textural properties in a cerradão fragment.

MATERIAL AND METHODS

The study area is located in the Rio da Conceição municipality, Tocantins State (11o26'46.32"S e 47o6'25.56"W). The fragment chosen is about 230 ha in size, within Ecologic Unit 1B (Silva *et al.*, 2006) a region with altitude varying from 300 - 700m, plain surface with well drained soils. This region is a mosaic of open and dense savanna woodland (cerrado stricto sensu), intercalated by cerradão and dry forests. Floristically this region is in the confluence of two Cerrado biome floristic provinces: CW and N&NE (Ratter *et al.*, 2003).

For data collection of vegetation one hectare was sampled consisting of ten 20 x 50m randomly placed plots in the cerradão fragment (Felfili *et al.*, 2005). All individuals with more than 5cm basal diameter (Db30 5 cm) where measured, as suggested by the Manual de Parcelas Permanentes dos Biomas Cerrado e Pantanal (Felfili *et al.*, 2005). Tree height was measured using a graded telescopic measuring stick.

Curtis & MacIntosh (1950) formulas where applied for structure and composition analysis: density (DR), fre-

quency (FR), dominance (DoR), Cover Value (CV) and Importance Value (IV).

Five soil samples at 0 - 20cm depth where systematically collected in each plot, that mixed together rendered one compound soil sample for each plot. The following soil properties where analyzed: pH, potencial acidity (H+Al), Al3+, Ca2+, Mg2+, P+, K+, soil organic matter, and soil texture (% of sand, loam and clay).

Canonical Correspondence Analysis (CCA) (ter Braak 1986), a direct gradient analysis ordination method, was carried out to verify the soil - vegetation relationship using CANOCO for Windows version 4.5 software (ter Braak & Smilauer 1999). The species matrix consists of the total species density at each sample plot, log transformed. The environmental variables matrix consists of chemical and textural soil properties, square - root transformed. Soil variables with inflation factor larger than 20 where eliminated form the analysis because of its redundant explanatory power (ter Braak & Smilauer 1999) and to reduce data noise and misinterpretations with auto - correlated variables. This correction tries to avoid errors related to the arc effect of the second axis (Kent & Coker 1992). The ordination axes significance was tested using Monte Carlo permutations (ter Braak 1995).

RESULTS AND DISCUSSION

A total of 650 trees where sampled, with 12,83 m2/ha basal area, distributed in 77 species, 58 genera and 33 families. Tree density and basal area are among the lowest values found for cerradão communities using the same sampling methods, comparable only with a study in Alto Paraiso (716 trees/ha and 16,67 m2/ha) (Felfili *et al.*, 2007). However the latter mentioned area occurs in an area of elevated altitude (ca 1500m) and shallow soils. Even though cerradão has a wide structural variation, in some cases being defined as an open forest (Furley 1999), it seems that fragmentation and degradation process has taken a toll on the study area. Also the region is dominated by a mosaic of open and dense savanna woodlands in witch cerradão is scarce and structurally close to the dense savanna woodlands. Species richness is within the upper limit for other areas, showing a greater resilience of the fragment regarding this parameter.

Fabaceae (12), Myrtaceae (7) and Vochysiaceae (5) are the richest families while Byrsonima (4), Myrcia (4) Diospyros (3) e Qualea (3) are the richest genera. Fabaceae and Myrtaceae are commonly the richest families in the savanna and forest formations of the Cerrado bioma and in other regions as well (i.e. Atlantic Coastal Forest). Vochysiaceae is one of the most important families in the Cerrado biome, presenting high abundance levels through species of Qualea and Vochysia, and with an important ecological role of aluminum accumulation in the acid Cerrado soils (Haridasan, 1987)

The species with highest Importance Value are: Copaifera langsdorffii, Qualea grandiflora, Tapirira guianensis, Caryocar brasiliense, Emmotum nitens, Magonia pubescens, Curatella americana, Terminalia argêntea, Xylopia aromatica, Ouratea hexasperma and Sclerolobium paniculatum. These

species are fairly common in distrophic cerradão communities comprised of cerrado stricto sensu (savanna woodland) species such as Q. grandiflora, C. americana C. brasiliense and O. hexasperma, species commonly found in gallery and dry forests such as C. langsdorffi and T. guianensis and species common in forest and savanna formations that present high abundance patterns in cerradão communities such as S. paniculatum, E. nitens and M. pubescens (Felfili *et al.*, 994, Mendonça *et al.*, 008).

The soil sampled in the study area presented low levels of Ca and Mg, base saturation lower than 50% (considered distrophic) and high Al saturation (> 50%, considered alic). Soil texture varied from Clay (plots 1,2,5,6 and 7 with more than 40% of clay) and Sandy - Clay (plots 3,4,8,9 and 10 with more tha 45% of sand). Therefore the sampled area is a typical distrophic cerradão on well drained oxisoils of the Cerrado core area.

Eigenvalues for the first two axes of the Canonical Correspondence Analysis (CCA) are 0.341 and 0.245 respectively. These eigenvalues, considered low, indicate a short gradient (ter Brack 1995), where species abundance changes among the plots and not a typical species turnover situation. This result is confirmed by the high floristic similarity among sampled plots (Sorensen Index) but low structural (quantitative) similarity (Czekanowski index), that takes account of species abundance, showing internal heterogeneity of the cerradão fragment (Solórzano *et al.*, 2009).

The Monte Carlo test (with 499 permutations), revealed that the axes gradients are significantly different of a random process (F = 1.359 and p = 0.01) and that the CCA can significantly explain the soil - vegetation relationship. The first two axes explain conjunctly 54% of the species - environment relation variance and just 34% of the species data variance (1st axis = 19.8 and 2nd axis = 14.2) showing considerable amount of noise interfering in the data set, a large portion of the variance uncounted for. Low amount of explained variation are common in other papers (Espírito - Santo *et al.*, 2002; Dalanesi *et al.*, 2004) and doesn't affect the significance of vegetation - soil relation (ter Brack 1995) because of high species - environment correlations on the four main axes: 0.999; 0.975; 0.969; 0.987.

Out of all the soil variables measured, only five where chosen, comprising high correlations with the first two axes: Clay, Sand, Al, Ca and Mg. The other variables had high inflation factors and highly redundant with other variables, or simply had no correlation with any axis. Mg, Ca, Al and Clay are positively correlated to the firs axis and Sand negatively correlated to the first axis with respective values of 0.93, 0.91, 0.55, 0.65 and - 0.72. Clay is negatively correlated to the second axis (- 0.69). This shows that the first axis has stronger correlations being responsible for most of the relations between species, samples and soil properties.

The CCA clearly shows the separation of plot 1 from the rest, positively correlated to the first axis and related to the Ca and Mg vectors and positively correlated to the second axis related to the Al vector. Some typically aluminum accumulator species such as Vochysia haenkeana are associated to this condition. Other typical forest species are related to the fertility gradient of the first axis such as Protium heptaphyllum, Myrsine guianensis, Sclerolobium au-

reum and species common to cerradão but not exclusively such as Bowdichia virgilioides and Machaerium acutifolium. Some forest species like, Dilodendron bipinatum, Licania apetala, Matayba guianensis, Tabebuia roseo - alba and Tetragastris balsamifera are related to the Clay vector, positively related to the fertility gradient of axis 1 and negatively related to the 2nd axis, in opposition to Sand variable, separating plots 2 and 5 from the rest. Therefore the CCA shows a clear separation of forest species related to a higher fertility (Ca and Mg concentrations) and in some cases related to a higher clay content (and indirectly to higher soil moisture). Close to the center but still on the positive side of the first axis are some forest species but also considered generalists such as Copaifera langsdorffii, Xylopia aromatica and Tapirira guianensis, confirming their indifferentiated aspect.

Most part of the species and samples are on the first axis negative side and close to the center. This region of the multi - dimentional space is related to the Sand variable. However these species are of different conditions: biome widespread generalists (i.e. occurs in all of the Cerrado biome); typical cerrado stricto sensu (savanna woodland) species. Some of the wide spread generalists are very common in cerradão communities such as Magonia pubescens, Astronium fraxinifolium, Emmotum nitens and Roupala Montana located close to the center of the second axis negative portion and opposite to the Al vector. Thus species that even though don't demand higher nutrient levels aren't associated with Al content. Widespread biome generalist species like Curatella americana, Qualea grandiflora and Qualea parviflora (Ratter *et al.*, 2003) have a wide distribution among many vegetation physiognomies (Mendonça *et al.*, 2008) and commonly present in cerradão inventories. Simultaneously typical savanna woodland species like Caryocar brasilense Ouratea hexasperma, Hancornia speciosa, Connarus suberosus and Miconia ferruginata are related to a higher sand content, indicating a lower demand in soil moisture and higher tolerance to drier conditions.

CONCLUSION

The CCA results show that even though there was some data interference due to noise and part of the variance unexplained, the first two canonical axes rendered significant correlations. These correlations separated typical forest species from the rest of the species, associated with a higher Ca and Mg concentration and higher clay content (indirectly indicative of higher soil moisture). Many species stayed in the center of the axes denoting an indifferentiation in relation to the soil variables. These species are comprised of widespread generalists and typical savanna woodland species. The CCA confirms an increasingly accepted tendency of the cerradão: comprise typical forest and savanna species and also generalists. However when the cerradão community is analyzed as a whole some empty spaces need to be filled for a better comprehension of the processes that determine its species distribution. This study showed some tendencies, but doesn't clarify if a niche compartmentation related to environmental variable occurs or if a neutral pattern can be established in witch species have an indifferentiated be-

havior towards environmental variables, such as the case of generalist species. In this case some questions arise that still have to be answered: 1) Can cerradão be divided into guilds according to species typical occurrence to a vegetation type (i.e. forest, savanna or generalist)? Does the unified theory of biogeography and biodiversity apply to cerradão communities?

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