

Evaluation of Vegetation after Four Years in a Caatinga Fragment in the State of Sergipe, Brazil

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Abstract

The comparison of vegetation at two different moments allows for recognizing the stability of plant communities. The structure and floristic composition of a Caatinga fragment in the municipality of Poço Verde, state of Sergipe, were evaluated after four years (2011-2015). Sampling was performed through 30 plots of 20 m × 20 m, considering individuals with circumference at breast height ≥ 6 cm. Despite the increase in density (0.79%) and basal area (4.82%), changes in floristic composition, in Shannon-Wiener diversity (from 3.33 nats.ind⁻¹ to 3.30 nats.ind⁻¹) and in Pielou equability (from 0.78 to 0.80) were small. None of the structural parameters evaluated (richness, density, basal area, importance value and Shannon-Wiener diversity) significantly differed between evaluation periods. The vegetation remained stable over time, tolerating current anthropization levels and enabling the use of its natural resources through planned management.

Keywords: floristic survey, phytosociology, stability.

1. INTRODUCTION AND OBJECTIVES

Studies comparing vegetation at different times can detect floristic and structural variations in populations and plant communities, supporting the understanding of factors that affect changes in these communities (e.g., Carvalho et al., 2010; Cavalcanti et al., 2009; Mews, Marimon, Pinto et al., 2011). In addition, these studies allow for inferences about vegetation dynamics; short-term assessments are more sensitive in detecting changes in a community (Braga & Rezende, 2007).

Adopting a temporal scale in structural and floristic evaluations enables recognizing the stability of plant communities; changes in the community are inevitably continuous and time-dependent (Condit et al., 1992). Data obtained from these evaluations are fundamental to subsidize conservation actions and programs for the recovery of degraded areas, providing subsidies for the sustainable vegetation management (Cavalcanti et al., 2009; Mews, Marimon, Maracahipes et al. 2011; Rolim et al., 1999).

In Brazil, publications comparing vegetation composition and/or structure between two distinct periods were carried out in Cerrado areas (e.g., Mews, Marimon, Pinto et al., 2011; Silva Neto et al., 2017), gallery forests (e.g., Braga & Rezende, 2007; Guimarães et al., 2008), ombrophilous forests and/or montanes (e.g., Chagas et al., 2001; Gomes et al., 2003; Oliveira Filho et al., 2007; Schaaf et al., 2005) and seasonal and semideciduous forests (e.g., Mews, Marimon, Maracahipes et al., 2011; Nascimento et al., 1999; Paula et al., 2002; Silva & Araujo, 2009). Despite the existence of publications for Brazilian seasonally dry tropical forests (SDTF) (e.g., Werneck & Franceschinelli, 2004), studies of this type are scarce for the Caatinga biome (Cavalcanti et al., 2009), which contributes to the little knowledge about its dynamics (Pereira et al., 2001).

In Caatinga, anthropization and climatic variations are the main responsible for vegetation changes (Alves, 2009; Cavalcanti et al., 2009). In this biome, disturbed environments have shown declines in diversity (Kauffman et al., 1993), richness, basal area and plant distribution in diameter classes and an increase in

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mortality rates of individuals (Cavalcanti & Rodal, 2010; Pereira et al., 2001; Santos et al., 2009). In addition, longer drought periods have caused higher mortality rates on individuals' ingress, as well as decreases in density, diameter and height of these individuals (Albuquerque, 1999; Cavalcanti et al., 2009).

Given the importance of temporal evaluations to understand the functioning of plant communities (Condit et al., 1992; Libano & Felfili, 2006) and the absence of data for Caatinga communities (Cavalcanti et al., 2009), this study was carried out with the objective of assessing the structure and the floristic composition after a four-years period (2011-2015) in a Caatinga fragment in the municipality of Poço Verde, state of Sergipe. It is expected that factors observed in the study area, such as anthropization and interannual climatic variability, cause structural and floristic changes in the vegetation between evaluation moments.

2. MATERIALS AND METHODS

2.1. Study area

The study was conducted on a 71.42-hectare Hypoxero-philic Caatinga fragment, located in the settlement of Santa

Maria da Lage (10°44'31"S and 38°05'53"W), in the municipality of Poço Verde, mid-southern region of Sergipe, Brazil (Figure 1). This fragment is characterized by dense and dry forest vegetation, with closed sub-forest, presenting the record of 170 species, 129 genera and 46 families (Ferreira et al., 2013).

In the fragment under study, past records point to the extraction of medium-impact vegetation inside and around this fragment (Fernandes et al., 2015; Ferreira et al., 2013). Currently, anthropic impacts are restricted to the selective extraction of wood, animal husbandry (causing herbivory and overgrazing) and to fires (personal observation).

The study area, located in the backcountry pediplane, presents dissected surfaces, residual mountains at an altitude of 273 meters (Sergipe, 2014) and Planosol, Halomorphic and Regosol soils (Sergipe, 1997).

The climate of the region is characterized as As type, according to the Köppen climatic classification (Alvares et al., 2013; Sergipe, 2011). The average annual temperature is 23.7°C, with average annual precipitation of 780 mm (Sergipe, 1997, 2011).

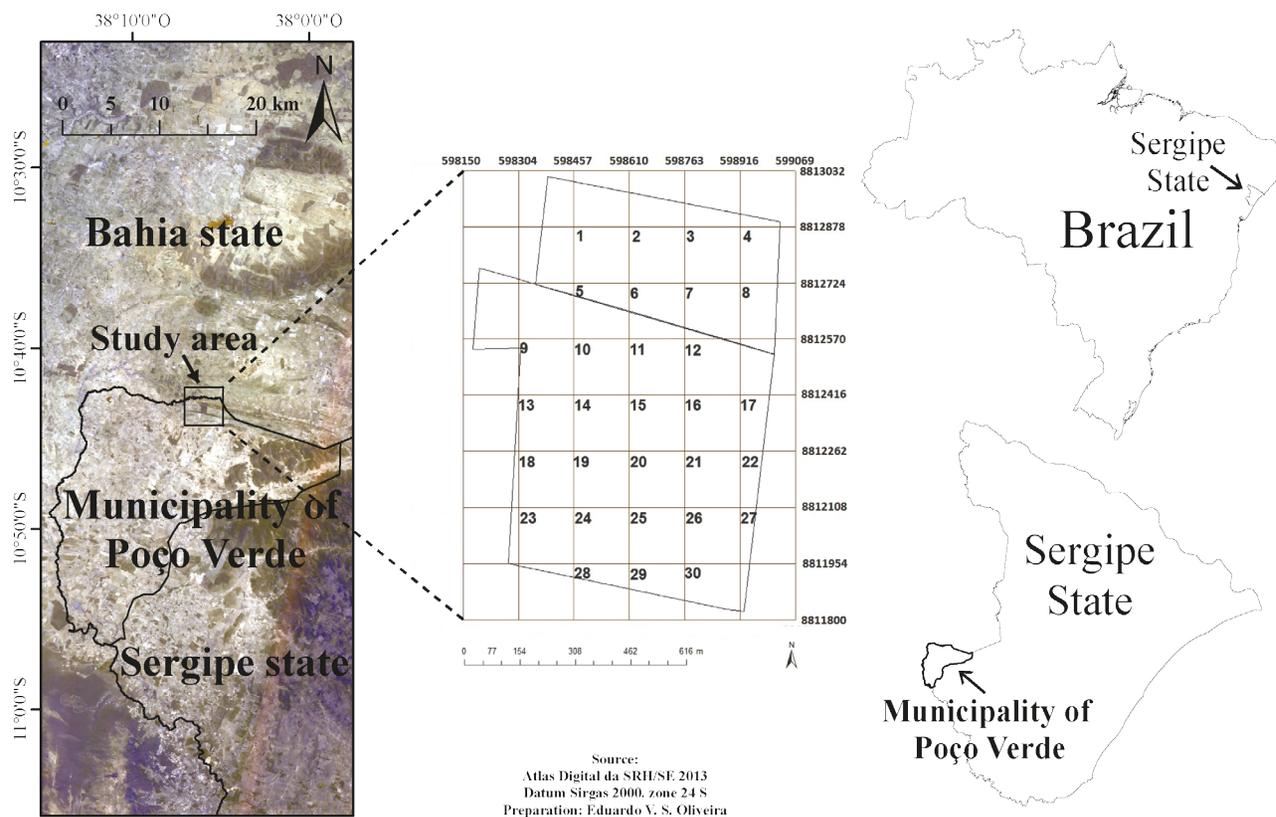


Figure 1. Location of the study area and distribution of georeferenced plots for the Caatinga fragment in the municipality of Poço Verde, Sergipe, Brazil.

2.2. Data collection

Initially, annual precipitation, temperature and mean maximum temperature data for the study region were obtained for the period from 1960 to 2007 (historical average) and from 2008 to 2015, using online databases (INMET, c2016; Sergipe, c2016).

The evaluation of vegetation structure and composition was performed by comparing two surveys performed in 2011 (t_0) and 2015 (t_1), and the same plots and methodology were used in both surveys. In t_0 , plots were installed according to the fixed area method, and 30 square plots of 20 m × 20 m (400 m²) were randomly distributed (Figure 1), which is the recommended size for inventory standardization in Caatinga (RMFC, 2005). In t_1 , after relocating the demarcated plots in t_0 , each plot was re-sampled (further details on the methodology in Oliveira et al., 2018).

In both surveys all individuals present inside the plots (including columnar cacti), with height above 1.30 m and circumference at breast height (CBH) greater than or equal to 6 cm were measured using a tape measure. Fertile and/or vegetative samples were collected from individuals not identified in the field and referred to the Herbarium of the Federal University of Sergipe (ASE). After herborization (according to Mori et al., 1985), the collected material was identified by comparison with exsiccates present in the collection of the ASE herbarium, considering a floristic listing published for the study area (Ferreira et al., 2013).

2.3. Data analysis

For the survey of the current horizontal structure (t_1), the classical phytosociological parameters (Mueller-Dombois & Ellenberg, 1974) were estimated: density, frequency, dominance and importance value (IV). These calculations were performed with the aid of the Fitopac 2.2 software (Shepherd, 2010). Shannon-Wiener diversity index (H'), Pielou-J equability (Magurran, 2004) and the floristic similarity using the Sørensen index (the latter between the two samplings – t_1 and t_0) were also calculated by means of the Past 2.17 software (Hammer et al., 2013). The total increment in basal area was calculated by subtracting the values found between t_1 and t_0 ; the annual rate of this parameter was obtained by dividing its total increment by four. For the analysis of the diametric structure, individuals were distributed into diameter classes, using the class intervals calculated with formulas present in Spiegel (1976).

2.4. Statistical analyses

After verifying data normality using the Shapiro-Wilk test, statistical differences ($\alpha = 0.05$) between the two periods (t_0 and t_1) were evaluated for richness, absolute density and basal area; all of these using the paired t test (Vieira, 1980; Zar, 2010). Differences in the proportion of IV for the three species with higher value of this index were tested using the McNemar's chi-square test (χ^2) (Elzinga et al., 1998). The diversity index (H') was compared between the two periods by the Hutcheson's t test (Magurran, 2004). Except for the last test, carried out in the Past 2.17 software (Hammer et al., 2013), all the others were performed with the aid of the R software (R Development Core Team, 2013).

3. RESULTS

In the analysis period, the study region presented precipitation values below previous values and historical average. An annual increase in precipitation was observed between 2011 and 2014, with a marked reduction in 2015 (Figure 2). The mean temperature and mean maximum temperature values were above the historical average. Except for 2014 and 2015, temperature remained relatively constant in the study period in relation to the previous year (2010), although with higher average maximum temperature variation (Figure 2).

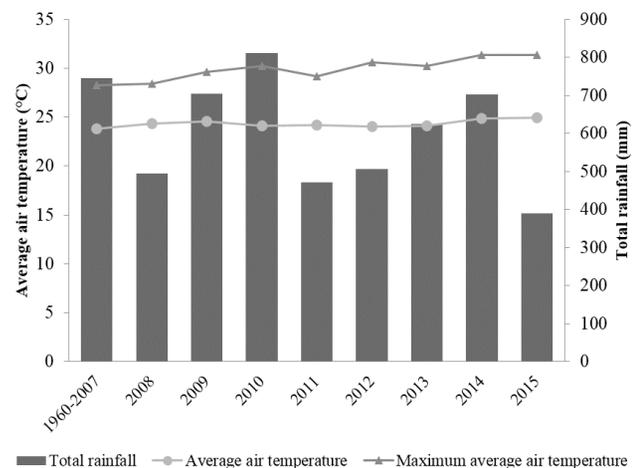


Figure 2. Historical average (1960-2007), total annual rainfall, average temperature and average maximum annual temperature observed for the study region in the municipality of Poço Verde, Sergipe, Brazil.

After four years, there was a 0.74% increase in density, from 2,700.8 to 2,720.8 individuals.ha⁻¹, but it was not significant (df = 29, t = 0.54, p > 0.58). The basal area had an increase of 0.62 m².ha⁻¹ (4.82%) and annual of 0.16 m².ha⁻¹ (1.21%), from 12.86 m².ha⁻¹ to 13.48 m².ha⁻¹, but the difference was

not significant (df = 29, t = 0.98, p > 0.33). The variations of density and basal area were lower than those observed in a Caatinga area with evaluation period similar to that of this study; and in relation to other SDTF areas, variations observed were lower or similar (Table 1).

Table 1. Relative variations of density and basal area in seasonally dry tropical forests, including the Caatinga fragment in the municipality of Poço Verde, Sergipe, Brazil.

Reference	Study site	Period (years)	Density (%)	Basal area (%)
Werneck & Franceschinelli (2004)	Minas Gerais, Brazil	4	-10	1.5
Marín et al. (2005)	Carazo, Nicaragua	7	-13 ^{nS}	1.2 ^S
Venkateswaran & Parthasarathy (2005)	Puducherry, India	10	0.6	-8
Cavalcanti et al. (2009)*	Pernambuco, Brazil	5	13.5 ^S	7.5 ^{nS}
This study*	Sergipe, Brazil	4	0.7^{nS}	4.8^{nS}

*: studies carried out in Caatinga; S: Significant; nS: not significant (only studies with statistical test).

In both surveys, the majority of individuals are concentrated in the three small diameter classes; thin individuals (< 14 cm) continue predominating in the community, as well as a reduced number of individuals in the larger diameter classes. However, there is a trend of diameter increase for individuals in the intermediate classes at t₁ (Figure 3). An increase in the number of individuals in the first diameter class (115 or 6%) and decrease in the second (92 or 13%) and third was observed (33 or 13%), probably due to the growth of individuals of the latter two classes (Figure 3).

The difference in the Shannon-Wiener (H') diversity indexes between evaluation periods was not significant

(df = 6463.2; t = -0.91; p > 0.35), as well as for richness (df = 29; t = 0.41; p > 0.28). These indexes, as well as the Pielou equability (J), remained stable after four years (Figure 4). In addition, no significant changes in floristic composition were observed between evaluation periods. Only four species were not found in the current survey (t₁): *Senegalia* sp., *Solanum* sp., *Handroanthus impetiginosus* (Mart. ex DC.) Mattos and an indeterminate species. In turn, two species were unique in the current survey (t₁): *Vasconcellea quercifolia* A.St.-Hil. and *Clusia dardanoi* G. Mariz & Maguire (Figure 4).

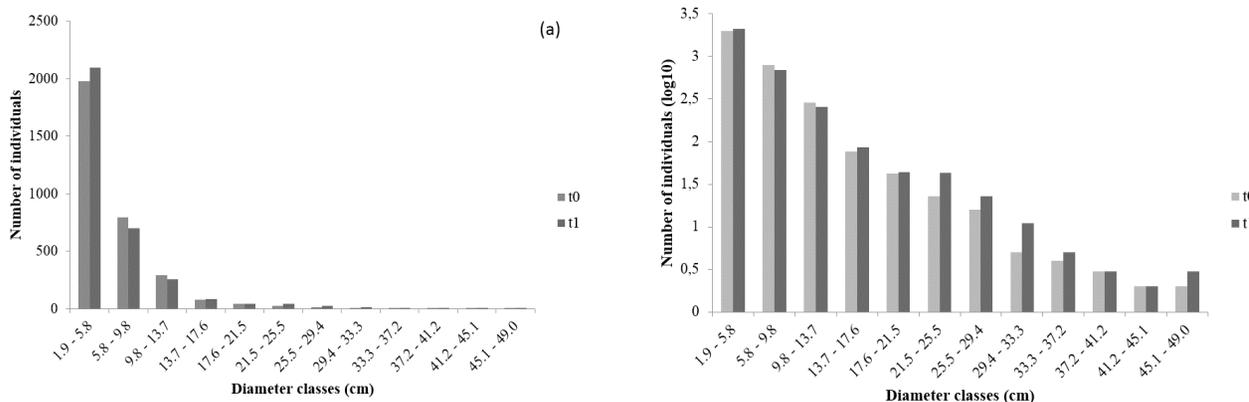


Figure 3. Distribution of number of individuals (a) and number of logarithmized individuals (b) by diameter classes between evaluation periods (t₀ and t₁) for the Caatinga fragment in the municipality of Poço Verde, Sergipe, Brazil.

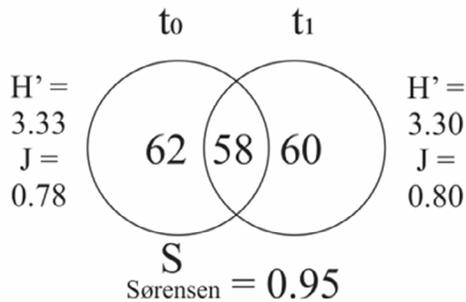


Figure 4. Venn diagram of floristic indexes evaluated for the analyzed period (t_0 and t_1) in the Caatinga fragment in the municipality of Poço Verde, Sergipe, Brazil, including Shannon-Wiener diversity (H'), Pielou equability (J), number of unique and common species in each period and temporal floristic similarity (Sørensen coefficient).

Fabaceae and Euphorbiaceae families remained the most abundant (17 and 10 species, respectively), with higher number of individuals (802 and 930, respectively) and, consequently, those with the highest relative IV (18.7% and 12.9% respectively) between evaluation periods. The number of families remained the same between the two evaluation periods (22). Two families (Bignoniaceae and Solanaceae) disappeared and two new ones (Caricaceae and Clusiaceae) were included. Apart from these families, the order for specific richness remained the same between the two evaluation periods. Regarding the ordering of families by number of individuals, small changes were observed and only Malvaceae, Cactaceae and Rubiaceae families increased in importance.

Alterations in the community structure were restricted to the density and absolute frequency of some species, which caused small changes in the IV parameter. Some species increased in density (*Poincianella pyramidalis* (Tul.) L.P. Queiroz, *Psidium schenckianum* Kiaersk. and *Mimosa acutistipula* (Mart.) Benth.), while others decreased (*Myracrodruon urundeuva* Allemão and *Commiphora leptophloeos* (Mart.) J.B. Gillett). However, because changes were small (ranging from two to eleven individuals), no major changes in the ordering of the species by IV were observed. Only for the species *Guettarda angelica* Mart. ex Müll. Arg. more significant changes were observed, with an increase in IV, probably due to the recruitment of individuals, since its density increased fourfold. *Psidium schenckianum* Kiaersk. (Myrtaceae), *Cedrela odorata* L. (Meliaceae) and *Poincianella pyramidalis* (Tul.) L.P. Queiroz (Fabaceae) continue to be the species with the highest relative IV, accounting for 28.15% of IV in the entire community. No significant differences were observed for the IV of *P. schenckianum* ($df = 1$; $\chi^2 = 2.10$; $p > 0.14$), *C. odorata* ($df = 1$; $\chi^2 = 0.30$; $p > 0.58$) and *P. pyramidalis* ($df = 1$; $\chi^2 = 2.10$; $p > 0.14$) between evaluation periods.

4. DISCUSSION

In studies carried out in Brazilian SDTF, temporal changes in vegetation composition and structure are mainly related to the history of the evaluated area. Changes in quantitative parameters such as richness, H' , J , basal area and/or coverage, density and phytosociological indexes by species, and qualitative, such as species and family composition, were influenced by factors such as presence and anthropization level and the regeneration time (Cavalcanti et al., 2009; Fernandes et al., 2015; Silva et al., 2009; Werneck & Franceschinelli, 2004; Werneck et al., 2000).

Considering that temporal variations in vegetation are associated with the intensity of the anthropic action, it is believed that the results found in the fragment indicate little anthropization (Bhat et al., 2000; Cavalcanti & Rodal, 2010; Cavalcanti et al., 2009; Condit et al., 1992; Pereira et al., 2001; Sampaio et al., 1993; Silva et al., 2004). The temporal maintenance of all quantitative parameters analyzed and the minimal changes in the structure of some species and in the floristic composition allow inferring that the vegetation remained stable after four years.

In Caatinga anthropization may not exceed the resilience capacity of the vegetation; low anthropization levels allow for rapid recovery of plants, maintaining vegetation stability against periodic disturbances (Holanda et al., 2015; Sampaio et al., 1993). Knowing the factors that contribute to the stability of the Caatinga vegetation provides subsidies for rational exploration models (Maia et al., 2003; Pereira et al., 2001). Thus, the sustainable use of natural resources of the study fragment is possible through planned forest management, guaranteeing source of income for the local population. The direct use of natural resources by local populations without affecting ecosystem support capacity constitutes an excellent conservation strategy (Brasil, 2008; Diegues, 2001).

The stability observed in this study reflects differences between evaluation periods and does not mean that the community remained static over time, since changes constantly occur in time and space (Pinto & Hay, 2005). For example, fluctuations in community structure and composition may have occurred in response to climatic variability observed for the period. The alternation of annual precipitation exerts a strong influence on the forest dynamics, causing fluctuations in the balance between mortality and recruitment (Carvalho & Felfili, 2011).

The distribution of individuals per diameter class in both evaluation periods follows the inverted "J" pattern, considered characteristic of native forests (Oliveira et al., 2013). Although a large number of small and thin individuals may indicate the occurrence of past disturbances (Nunes et al., 2003),

the observed tendency in the growth of the individuals' diameter in intermediate classes in t_1 may indicate successional evolution (Chagas et al., 2001, Paula et al., 2002).

In the study fragment, records indicate that the vegetation cutting is selective, prioritizing trees of better quality wood, such as *Myracrodruon urundeuva* Allemão and *Handroanthus impetiginosus* (Mart. Ex DC) Mattos (Carvalho, 2003; Peixoto et al., 2002; Silva et al., 2014) and those easy to handle, such as *Commiphora leptophloeos* (Mart.) J.B. Gillett (Carvalho, 2009). It is believed that the extraction of individuals of these three species was the main reason for the temporal decrease in the density of *M. urundeuva* and *C. leptophloeos* and the disappearance of *H. impetiginosus*. The latter could be considered locally rare due to the low population density (Rambaldi & Oliveira, 2003), which made it very inclined to local extinction (Primack & Rodrigues, 2001).

In the study area, *Guettarda angelica* Mart. ex Müll. Arg was not found in the sub-forest, only developing in edges and/or clearings, probably because it preferred to colonize these environments. Therefore, it is believed that the extraction of wood from canopy species may have allowed a better development of individuals due to the greater light input, which would justify their temporal increases in density and IV.

Also, *Guettarda angelica* can be considered an example of a "winning species", that is, the one that benefits from the anthropization of landscapes, rapidly proliferating in these environments. In contrast, *Myracrodruon urundeuva* and *Handroanthus impetiginosus* can be considered as examples of "losing species", due to the selective cutting of wood by the local population, causing population reduction, consequently leading to their disappearance (Tabarelli et al., 2012).

The current state of knowledge does not yet allow understanding whether the Caatinga biome is more stable over time than other plant formations. In addition to factors such as the time scale of investigation and presence and intensity of disturbances, the time of the disorder in relation to the investigation should also be considered as determinant for the detection of stability in temporal evaluation studies. Continuous vegetation monitoring over the evaluation period, i.e., four years, is advisable because it improves the ability to infer about the dynamic processes of the vegetation (Braga & Rezende, 2007; Mognon et al., 2012).

5. CONCLUSIONS

Although the occurrence of possible fluctuations in the community in response to climatic variability observed during the evaluation period is not ruled out, the vegetation under study remained stable over time, tolerating current

anthropization levels. Public policies that provide planned management of the study area by the local population should be established, thus becoming an alternative for the conservation of this remnant. Continued monitoring of the area is necessary, and further studies focusing on population dynamics are recommended.

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