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Scientific Article

INFLUENCE OF ANTHROPIC DISTURBANCE IN STRUCTURE OF PLANT POPULATIONS ALONG AN ELEVATION GRADIENT IN CAATINGA REGION

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ABSTRACT

Elevation gradients are useful models for testing how the variation of abiotic factors and anthropogenic disturbance modulate the population structure of plant species. Despite the small range of elevation, mountains in the semi-arid region of Brazil are subject to different levels of anthropic pressure. We investigated whether structural parameters of two species (*Croton blanchetianus* Baill. and *Cenostigma pyramidale* (Tul.) Gagnon & G.P. Lewis) with wide distribution in Caatinga, vary along an elevation gradient. We established 45 plots on three elevation levels. Next, we calculated abundance, percentage of tiller individuals, number of tillers, average diameter, average height, basal area, and above-ground biomass in each plot. Additionally, we recorded six metrics of chronic anthropogenic disturbance (CAD) in each plot. We tested whether species parameters differed between elevation levels and evaluated the influence of CAD on the structural parameters of each species. Abundance, percentage of tiller individuals, and number of tillers were higher at the gradient base for the two species. The metrics of CAD significantly influenced abundance and number of tillers, showing that there is an increase in these parameters in the most disturbing areas. The high capacity for regrowth of dry forest species provides resilience; however, it can contribute to proliferating populations of generalist species tolerant to environments with high rates of CAD. The study highlights relevant observations related to the ecology and distribution of plant populations in the Caatinga, mainly related to elevation gradient recognized as important refuges of biodiversity in this region of Brazil.
Keywords: Population structure; Altitude; Generalist species.

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INFLUÊNCIA DO DISTÚRBIO ANTRÓPICO NA ESTRUTURA DE POPULAÇÕES VEGETAIS AO LONGO DE UM GRADIENTE DE ELEVAÇÃO NA CAATINGA

RESUMO – Gradientes de elevação são modelos úteis para testar como a variação de fatores abióticos e perturbações antrópicas modulam a estrutura populacional de espécies vegetais. Apesar da pequena amplitude de altitude, as serras da região semiárida do Brasil estão sujeitas a diferentes níveis de pressão antrópica. Nós investigamos se os parâmetros estruturais de duas espécies (*Croton blanchetianus* Baill. e *Cenostigma piyramidele* (Tul.) Gagnon & G.P. Lewis) com ampla distribuição na Caatinga variam ao longo de um gradiente de elevação. Estabelecemos 45 parcelas em três níveis de elevação. A seguir foram calculados abundância, porcentagem de indivíduos perfilhados, número de perfilhos, diâmetro médio, altura média, área basal e biomassa aérea em cada parcela. Além disso, registramos seis métricas de Distúrbio Antrópico Crônico (DAC) em cada parcela. Testamos se os parâmetros das espécies diferiam entre os níveis de elevação e avaliamos a influência do DAC nos parâmetros estruturais de cada espécie. A abundância, a porcentagem de indivíduos perfilhados e o número de perfilhos foram maiores na base do gradiente para as duas espécies. As métricas do DAC influenciaram significativamente a abundância e o número de perfilhos, mostrando que há aumento destes parâmetros nas áreas mais perturbadas. A elevada capacidade de regeneração de espécies de florestas secas proporciona resiliência; no entanto, pode contribuir para a proliferação de populações de espécies generalistas tolerantes a ambientes com valores altos de CAD. O estudo destaca observações relevantes relacionadas à ecologia e distribuição das populações de plantas da Caatinga, principalmente relacionadas ao gradiente de elevação reconhecido como importantes refúgios de biodiversidade nesta região do Brasil.

Palavras-Chave: Estrutura populacional; Altitude; Espécies generalistas.

1. INTRODUCTION

Seasonally dry tropical forests (SDTFs) include tall evergreen seasonal forests on moister sites at one extreme of the environmental gradient, to thorn woodlands and cactus scrubs with a lower contribution of grass/herb species at the other end, depending on microclimatic conditions, elevation, soil type, and water availability (Pennington et al., 2018). SDTFs are generally located in environments with low rainfall levels (annual mean total rainfall is less than 750 mm), high temperatures and evapotranspiration exceeding precipitation most of the year (Pennington et al., 2009; Moro et al., 2016).

SDTFs have a remarkable concentration of endemic species with a diversity of life-forms, as well as functional groups of plants with anatomical, and morphological adaptations to drier conditions (Linares-Palomino et al., 2011). The diversity of life history strategies and plant-animal interactions are perhaps the most neglected biodiversity aspects of dry forest heritage and thus deserve considerable attention. Even in this scenario, SDTFs have become one of the most threatened ecosystems in the world due to massive deforestation, more than 97% of the remaining dry forest area is at risk of several threats (Miles et al., 2006). Tropical dry forests are usually the first frontier for economic development policies, and the degradation and deforestation rates in this ecosystem have been greater than for other types of tropical forests (Silva et al., 2017). The main change driver in dry tropical forests is expanding agricultural land usage, since these forests occupy areas with soils that are excellent for agricultural industries and cattle expansion (Fehlenberg et al., 2017).

Like other SDTFs, the Brazilian Caatinga vegetation hosts a diverse and threatened biota (Leal et al., 2005), supporting one of the most populated semi-arid regions in the world (i.e., 26 inhabitants km2; Medeiros et al., 2012). In addition to climate change, Caatinga dry forests are experiencing increasing levels of habitat loss and fragmentation (i.e., acute disturbances) (Ribeiro et al., 2015; Oliveira et al., 2019), leading to habitat degradation and biological destitution (Ribeiro et al., 2015; Arroyo-Rodríguez et al., 2017). Hunting and overgrazing by stock (goats and cattle) also represent important chronic anthropic disturbance (CAD) drivers in the region (Martorell and Peters, 2005). Human activities have had a pronounced effect on biodiversity patterns. For example, we can refer to decreases in tree species diversity and stem abundance (Méndez-Toribio et al., 2016), and changes in forest structure, species composition and tree phylogenetic diversity and structure (Ribeiro et al., 2016).

As a response to the heterogeneity of abiotic factors, the Caatinga has a variety of environments, including small mountains known as *serras* (Moro et al., 2016), which are considered as natural refuges for the Caatinga woody plant community (Silva et al., 2014; Lopes et al., 2017; Ramos et al., 2020). Studies have shown that lower elevation levels, even in elevation gradients with small amplitude (variation of 500 meters), are more susceptible to anthropogenic disturbance and have fewer woody species richness (Lopes et al., 2017; Ramos et al., 2020). In turn, the highest elevation regions have a greater number of woody species and different floristic composition, as they generally correspond to environments which are inappropriate for agriculture and difficult to access for forest exploitation (Almeida et al., 2020; Ramos et al., 2020).

In addition to the different levels of anthropic disturbance that exist in the elevation gradients of Brazilian semi-arid region, there are other relevant factors in the vegetation structure in these environments. Factors such as slope, soil depth, rock cover, presence of bromeliads, litter stock and composition, and edaphic properties operate at local scales (Lopes et al., 2017; Almeida et al., 2020), promoting increased productivity due to more favorable edaphic and microclimate conditions (Toure et al., 2015; Silva et al., 2019) and interfering in the structure and composition of plant communities (Almeida et al., 2020; Ramos et al., 2020). However, these studies have generally focused on the analysis of floristic composition and plant community diversity measures (Lopes et al., 2017), and little is known (for example) how CAD in such gradients can shape the structure of plant populations. Therefore, environments with a dry climate have become useful models for examining the population structure parameters of plant species with wide distribution.

Variations in the population structure of a species can be conditioned by biotic and abiotic factors (Prado Júnior et al., 2013) and anthropic disturbances (Méndez-Toribio et al., 2016). Anthropic pressures can favor a spread of broadly tolerant generalist species capable of surviving in varying environmental conditions (Rito et al., 2017; Sanaphre-Villanueva et al., 2017). In analyzing the effect of different cutting practices, Figuerôa et al. (2006) identified that *Cenostigma pyramidale*, a very common plant species in several phytosociological surveys in the Caatinga (Moro et al., 2014), is strongly resistant and has high regrowth rates after cutting, regardless of period of the year. Therefore, in areas under intense anthropic disturbance, it is likely that most *C. pyramidale* individuals have many tillers and consequently smaller diameters. In addition, Euphorbiaceae species have been reported to be tolerant and more abundant in anthropogenic environments (Ribeiro-Neto et al., 2016; Ramos et al., 2020).

From this perspective, understanding the responses in the plant population structures in semi-arid ecosystems, mainly located in environmental gradients with anthropogenic disturbances, is extremely important to aid in the recovery of degraded areas and to implement conservation programs, such as the creation of new environmental protection areas (EPA) (Banda et al., 2016). Thus, herein we investigated whether anthropic disturbances drive changes in plant population structure parameters (diameter, height, tillering and biomass) in an elevation gradient in the semi-arid region of Brazil. To do so, we selected the *Croton blanchetianus* and *C. pyramidale* species, which are frequent in Caatinga dry tropical forests, with the objective to answer the following questions: What is the spatial distribution pattern of these two species along an elevation gradient? Do the structural variables of both species change along an elevation gradient? We hypothesized that the greatest abundance and tillering is located in lower elevations coinciding with the matrix surrounding the serra formed by a disturbed shrubby Caatinga.

2. MATERIAL AND METHODS

2.1 Study site

The predominant vegetation formation in the Northeast region of Brazil is characterized by a seasonally dry forest (Pennington et al., 2009) known as Caatinga. This formation presents small-sized trees and shrubs with small and deciduous leaves and with adaptation mechanisms to drought, such as the presence of thorns (Pennington et al., 2018). The Caatinga represents a mosaic of

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physiognomies conditioned to variations in relief, precipitation and soils (Moro et al., 2016). The rainy season in most of Caatinga dry forest lasts between three and five months. The rains are irregular, with annual mean total precipitation below 750 mm, and potential evapotranspiration can reach more than double the rainfall due to high temperatures of around 27°C. The regional climate is Bswh’ (warm semi-arid) according to the updated Köppen-Geiger climate classification (Alvares et al., 2013).

The topography in the Caatinga is relatively uniform with altitudes varying around 400 m, but some highlands, such as the Chapada Diamantina, Borborema and smaller mountains (*serras*) scattered throughout the Caatinga can reach over 1000-1200 m (Moro et al., 2016; Silva and Souza, 2018). According to Ab’Saber (1974), the mountains may have been formed during the Tertiary period through erosive processes and currently occur as isolated areas in the middle of the lower surrounding matrix.

For this study, we selected an elevation gradient (*Serra de Bodocongó* - 7º 27’ 6” S, 35º 59’ 41” W) with an altitude ranging from 400 to 680 m asl, located in the Planalto da Borborema, State of Paraíba, in the Northeast of Brazil (Figure 1).

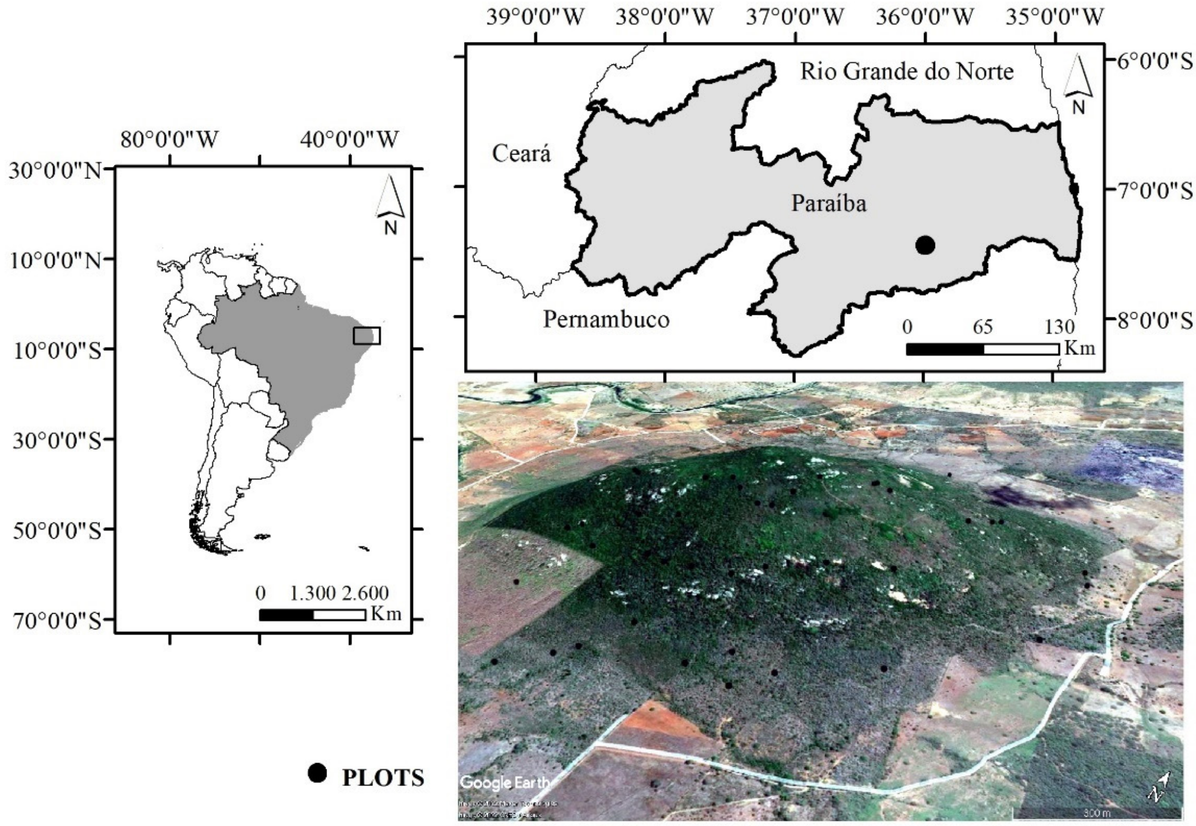

Figure 1 – Study area; Elevation gradient (Serra de Bodocongó) located in the State of Paraíba, Northeastern Brazil. Dark circles represent vegetation sampling plots.

Figura 1 – Área de estudo; Gradiente de elevação (Serra de Bodocongó) localizado no Estado da Paraíba, Nordeste do Brasil. Os círculos escuros representam parcelas de amostragem de vegetação.

We selected this serra because it is easily accessible and it represents a typical elevation gradient of Brazilian semi-arid region. The region has an average annual temperature of 23.4ºC and an average annual rainfall of 446 mm, with a maximum in the period March-May (Fick and Hijmans, 2017). The region around the serra encompasses a series of dry forest fragments created by extensive farming. These fragments are marked by the presence of trails left by grazing animals and local inhabitants collecting forest resources. The vegetation is better developed and species diversity is higher between mid-altitude and the upper reaches, with the presence of taxa typical of more humid areas (Lopes et al., 2017). The elevation gradient is also characterized by a higher rock cover, steep slopes and presence of bromeliads, all of which contribute to micro-habitat formation (Almeida et al., 2020). The prevailing soils in the study areas are Leptosols and Luvisols (Santos et al., 2011).

2.2 Selected species

Croton blanchetianus and *C. pyramidale* are among the most frequent species in phytosociological and floristic surveys of the Caatinga (Moro et al., 2014). *Croton blanchetianus* is popularly known as "*marmeleiro*" and belongs to the Euphorbiaceae. It presents a tree/shrub habit, autochorous dispersion and flowering in the rainy season. *Marmeleiro* is considered a potential species for restoring degraded areas due to its great capacity for regrowth and rapid growth (Figuerôa et al., 2006). *Cenostigma pyramidale* is an arboreal plant (3–12 m) belonging to the Fabaceae. It is an endemic species of Brazil which occurs in the North (Amazonas) and Northeast regions (Alagoas, Bahia, Ceará, Maranhão, Paraíba, Pernambuco, Piauí and, Sergipe), in the phytogeographic domains of the Amazon and Caatinga (Matos et al., 2019). It performs autochorous dispersion and blooms and bears fruit in February and March. It is also listed as one of the preferred species for wood use (Pedrosa et al., 2022).

2.3 Species structure

Fieldwork was conducted from 2013 to 2015. Vegetation was surveyed in 45 200-m² plots (50 × 4 m), evenly distributed among three altitudinal belts: Level 1 (low belt, 400–500 m a.s.l.) - L1; Level 2 (mid belt, 501–600 m a.s.l.) – L2; and Level 3 (high belt, 601–660 m a.s.l.) – L3, with 15 plots for each altitude, totaling 0.9 ha. The distinction of elevation belts was based on previous studies (Silva et al., 2014; Lopes et al., 2017; Ramos et al., 2020), who reported floristic and structural differences between them.

We included all live individuals of two populations ≥ 1 m in height, and with stem diameter at ground level (DGL) ≥ 3 cm in sampling the vegetation, as these values characterize adult plants in this vegetation (Rodal et al., 2013). The DGL was measured individually in the case of individuals who had multiple tillers (Rodal et al., 2013). Individual heights were measured with a 12–m measuring rod. Species were identified in the field whenever possible; otherwise, we collected specimens to be identified by specialised literature or through comparison with vouchers kept at the herbarium of the *Universidade Estadual de Paraíba*. Species names and synonymies were verified in the data banks of the Flora do Brasil and Reflora. Species were classified into families following (APG, 2016).

The horizontal structure of species populations was characterized by the analyses of the following parameters: abundance (A), percentage of individuals with multiple stems per plot (T, tillering), number of tillers (N), average diameter (D, in cm), average height (H, in meters), basal area (BA, in m²/ ha) and total above-ground biomass (AGB, in ton/ ha). AGB was calculated using an allometric equation for Caatinga vegetation (Biomass kg = 0.0644*DGL(cm)2.3948), as proposed by Sampaio and Silva (2005). We used the total values calculated in each plot for A, T, N, BA and AGB parameters, while we used the average between individuals per plot for D and H.

2.4 Explanatory variables

We recorded six metrics in each plot, described as being important indicators of chronic anthropogenic disturbance in Dry Tropical Forests (Arnan et al., 2018), which were obtained from satellite images using the ArcGIS 10.2.2 free 60-day trial software program. We calculated metrics related to human activities based on disturbances which refer to marks of land use by people. We quantified the proximity to the nearest house (PNH), proximity to the nearest road (PNR), and proximity to the exploited area (PEA), such as the reciprocal distance from the center of the plot to the residence, the nearest road, and the area which has clear marks of land use and occupation, respectively, as well as trail density (TRAN). Land use (LUSE) was measured within a 50m radius buffer from the center of the plot. Land use (LUSE) refers to the percentage of land cover dedicated to agriculture, pasture, residences and buildings, and is used as a disturbance measure. At this point, we manually drew polygons with these specific land use types by visually assessing

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satellite images and then calculated the fraction of area around the plot that was inside the 50m buffer used for these purposes.

Next, we integrated the PNR, PEA and PNH measures into a single measure through a Principal Components Analysis (PCA). We use the first axis of PCA to calculate the Human Activity Index (HAI). All metrics were highly correlated with the first two axes of the PCA, which explained 95%.

2.5 Data analyses

First, we analyzed whether the population structure parameters (A, T, N, D, H, BA and AGB) differed between the L1, L2 and L3 elevation levels in order to test our hypothesis. We tested the data normality using the Shapiro-Wilk test ($p>0.05$) and we used the Kruskal-Wallis non-parametric analysis and Dunn's post hoc test with Bonferroni correction ($p<0.05$) in the data analysis.

We additionally established the population size structure. The diameter and height data were distributed from the calculation of the Sturges algorithm as determined by the A/K formula with the amplitude of the diameter values and K being the number of class intervals. The frequency distribution of individuals in each class was represented in histograms for both species and at each elevation level.

We used Generalized Linear Models (GLM) using the GLM function of the R program to assess the influence of anthropogenic disturbances on the structure parameters of each species. We tested the correlation between all variables to avoid multicollinearity problems between explanatory variables. For this, we used the 0.70 correlation threshold to address the collinearity between the explanatory variables. All analysis were performed using the R version 3.6.0 program (R Core Team, 2019).

3. RESULTS

A total of 842 individuals were sampled, specifically 529 of *C. blanchetianus* and 313 of *C. pyramidale*. We identified that the two species analyzed showed greater abundance (A), number of tillers (N) and percentage of multi-stemmed individuals (T) at lower elevation levels. These parameters decrease sharply as the elevation increases (Table 1). For example, 30 *C. blanchetianus* individuals were sampled in median values at L1 (400-500 m). This sample number then decreased to 1.5 ind/plot in L2 (501–600 m). *C. pyramidale* and *C. blanchetianus* presented 36% and 17% tiller individuals in L1, respectively. Table 1 shows values of structural variables in the three elevation levels.

On the other hand, mean height (H), basal area (BA), average diameter (D) and total above-ground biomass (AGB) showed different variations depending on the species analyzed (Table 1). *Croton blanchetianus* individuals did not differ in variables H, D and AGB. However, there was an increase in the basal area (Table 1). Moreover, there was a decrease in the average diameter of *C. pyramidale* individuals along the gradient. There was also a reduction in BA and AGB, which are simultaneously influenced by abundance and diameter.

Regarding the diameter distribution, there was a higher frequency of individuals in the first diameter class for all species and at all elevation levels (Figure 2). In L1, 61.2% of *C. pyramidale* individuals and 70.4% of *C. blanchetianus* were sampled in the smallest diameter class (3–6 cm). The frequency of individuals for both species in the first class was still larger at higher levels (L2 and L3), but with much lower values than those recorded in L1. For example, *C. pyramidale* and *C. blanchetianus* represented 46.4 and 54.2% of the individuals in the 6 cm class in L2.

There was a higher frequency of individuals in the lower classes (2 and 4 m) regarding the hypsometric distribution (Figure 2) for both species, but only at the L1. In percentage numbers, we observed that 63.9 and 81.2% of *C. pyramidale* and *C. blanchetianus* individuals, respectively, were registered in the first two classes. *C. pyramidale* individuals were distributed among the intermediate height classes in L2, while there was a higher frequency of *C. blanchetianus* individuals in the lower height classes.

Considering the explanation percentages given by the generalized linear models, the metrics of human activities had a negative influence on the abundance of *C. pyramidale* and *C. blanchetianus*. The average diameter

Table 1 – Median values of structural parameters along an elevation gradient, Paraíba, Northeastern Brazil. H: average height, BA: basal area, D: average diameter, AGB: total above-ground biomass, A: abundance, N: number of tillers, T: percentage of individuals with multiple steams per plot (200 m2). L1: 400-500 m a.s.l., L2: 501-600 m a.s.l., L3: 601-660 m a.s.l. Different letters indicate statistical difference (P < 0.05).

Tabela 1 – Valores medianos dos parâmetros estruturais ao longo de um gradiente de elevação, Paraíba, Nordeste do Brasil. H: altura média, BA: área basal, D: diâmetro médio, AGB: biomassa aérea total, A: abundância, N: número de perfilhos, T: porcentagem de indivíduos com múltiplos vapores por parcela (200 m2). L1: 400-500 m acima do nível do mar, L2: 501-600 m acima do nível do mar, L3: 601-660 m acima do nível do mar. Letras diferentes indicam diferença estatística (P < 0,05).

Species	Elevation Level	H (m)	BA (m²/ha)	D (cm)	AGB (ton/ha)	A	N	T
Croton blanchetianus	L1	3.34a	4.43a	5.51a	9.05a	30a	37a	17a
	L2	4.25a	0.29b	7.04a	1.27a	1,5b	2b	0b
	L3	4.02a	0.92b	6.46a	4.63a	2b	3,5b	0b
Cenostigma pyramidale	L1	3.76a	4.57a	7.66a	9.91a	15a	28a	36a
	L2	6.0a	0.60b	5.93a	4.64a	3b	4b	0ab
	L3	3.0a	0.08c	4.5b	0.12b	1c	1c	0b

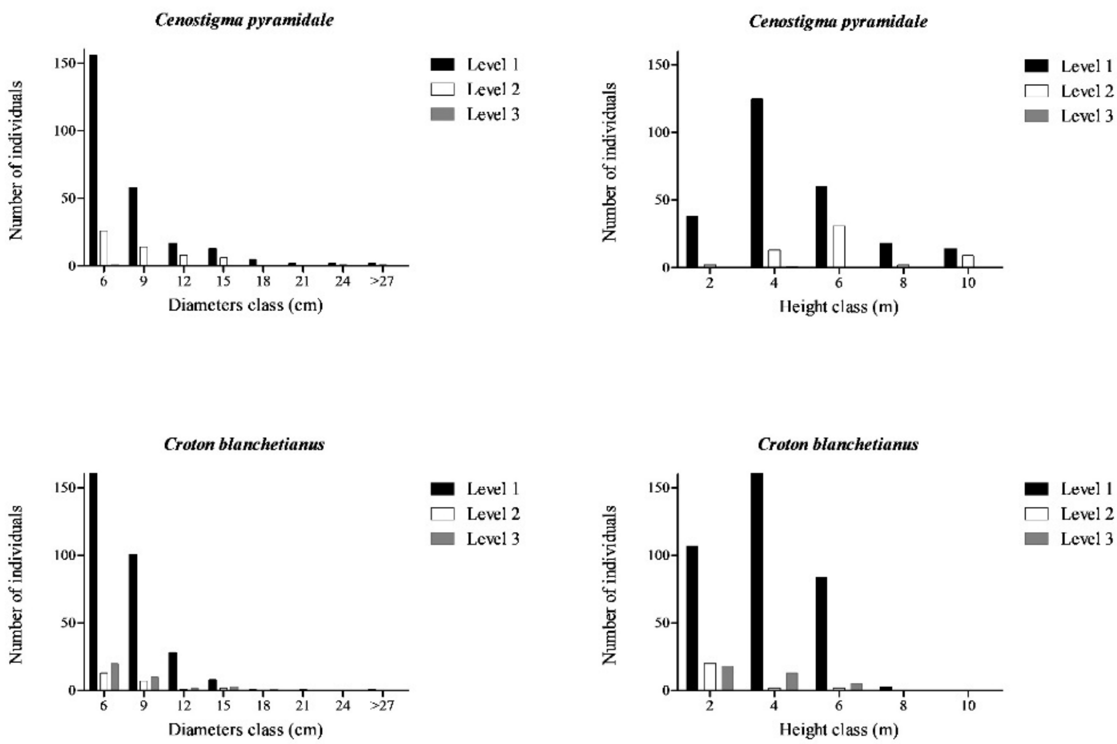

Figure 2 – Diametric and hypsometric distribution of individuals of both species; Diametric (left) and hypsometric (right) distribution of individuals of *Croton blanchetianus* and *Cenostigma pyramidale* along an elevation gradient, Paraíba, Northeastern Brazil.

Figura 2 – Distribuição diamétrica e hipsométrica dos indivíduos de ambas as espécies; Distribuição diamétrica (esquerda) e hipsométrica (direita) de indivíduos de *Croton blanchetianus* e Cenostigma piramidale ao longo de um gradiente de elevação, Paraíba, Nordeste do Brasil.

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and number of tillers of *C. pyramidale* were only negatively influenced by HAI, while the number of tillers of *C. blanchetianus* was influenced by the density of human trails (TRAN) (Table 2).

Table 2 – Results of GLM models used to test the relationship between predictors of chronic anthropogenic disturbances and structural parameters of two plant species from the Caatinga along an elevation gradient, Paraíba, Northeastern Brazil. TRANS: density of human trails, LUSE: land use, HAI: Human Activity Index. Significance of codes: 0 '***' 0.001 '**' 0.01 '*'

Tabela 2 – Resultados dos modelos GLM utilizados para testar a relação entre preditores de distúrbios antropogênicos crônicos e parâmetros estruturais de duas espécies de plantas da Caatinga ao longo de um gradiente de elevação, Paraíba, Nordeste do Brasil. TRANS: densidade de trilhas humanas, LUSE: uso do solo, HAI: Índice de Atividade Humana. Significado dos códigos: 0 '***' 0,001 '**' 0,01 '*'

Response variable	Predictors	t-value	intercept
Cenostigma pyramidale			
Abundance (A)	HAI	-16.689***	6.32***
	LUSE	-2.209*	
Number of tillers (N)	HAI	-1.834*	0.05
Croton blanchetianus			
Abundance (A)	HAI	-5.443***	5.826***
	LUSE	-12.242***	
Number of tillers (N)	TRAN	13.738***	
	TRAN	2.14*	-0.169

4. DISCUSSION

The results presented herein provide substantial information for understanding the elevation gradients of the Brazilian semi-arid region, which are fundamental environments for understanding the dynamics of Caatinga vegetation, as well as the geomorphological and pedological processes which underlie this ecosystem. Our results confirmed our hypothesis that both species show greater abundance and tillering at the lower elevation levels and that anthropic disturbances are important factors in the structure of *Croton blanchetianus* and *Cenostigma pyramidale*. The plant community at higher elevation levels is less susceptible to pressures from human use and can sustain species which are more sensitive to environmental disturbances (Silva et al., 2014; Lopes et al., 2017). Therefore, the increase in other species in these higher areas may have caused a decrease in the abundance of species analyzed in this study by competition, which are much more frequent in areas under anthropogenic disturbance (Moro et al., 2014).

We identified about 30 *C. blanchetianus* individuals in median values per plot in the lower elevations, which demonstrates the ability of this species to thrive in areas under intense use. Studies have shown that *C. blanchetianus* and *C. pyramidale* reach a high density after long exploitation periods (Araujo et al., 2010). In addition, some Euphorbiaceae species, such as *C. blanchetianus*, possess a set of characteristics which guarantee their success in colonizing degraded Caatinga areas (Rito et al., 2017).

Low elevation regions are under more intense chronic disturbance processes, including grazing by domestic herbivores and selective logging typical of the matrix surrounding the Brazilian semi-arid mountains (Lopes et al., 2017), which may be associated with greater tillering present at these elevation levels. Although almost all angiosperm woody plants have the ability to sprout studies have shown that the predominance of regrowth behavior is related to the level of vegetation disturbance, specifically with the vegetation structure of Brazilian Caatinga (Barros et al., 2021). Such an attribute is quite common in seasonally dry tropical forests (SDTFs) when compared to other tropical forests (Vanderlei et al., 2022). Despite these generalizations, regrowth ability varies according to the disturbance intensity, frequency and type, as well as between species (Vanderlei et al., 2021).

The Caatinga has a history of forestry exploitation, which over time has culminated in biological and phylogenetic simplification, changes in the dynamics of regeneration, phenology, seed dispersal, and dominance of species with generalist characteristics in favorable environments such as *C. blanchetianus* and C pyramidale (Ribeiro-Neto et al., 2016). The GLM results suggest that there is a greater abundance of *C. pyramidale* and *C. blanchetianus* in the plots closest to homes (PNH), roads (PNR) and exploited areas (PEA). In the case of *C. blanchetianus*, the positive effect of number of trails on abundance and number of tillers reinforces the success that this species obtains in anthropized areas, since these trails are considered important metrics of chronic anthropic disturbance. The diametric structure in the form of an inverted J (Fig. 2) at the lowest elevations is considered to be a typical trend of regenerating forests, indicating the positive balance between recruitment and mortality (Vanderlei et al., 2021), and confirms that these regions are under a more intensive anthropic pressure (Lopes et al., 2017).

The few existing studies specifically for Caatinga have pointed out that woody species respond differently to cutting and/or fire practices (Sampaio et al., 1993, Figuerôa et al., 2006). According to Figuerôa et al. (2006), the average regrowth percentage reaches 90.6, 57.4, 72.4 and 62.6% for the *C. pyramidale*, Mimosa ophthalmocentra Mart. ex Benth., *Mimosa tenuiflora* (Willd) Poir. and Croton sonderianus Muell. Arg. species, respectively, under different cutting practices and at different times of the year. Despite the differences, there is a strong impact of CAD on common Caatinga specie populations. In addition to the anthropic influence, it is worth mentioning that regrowth can also be a response to other events such as attacks by insects and pathogens, herbivory and decreased water availability (Vanderlei et al., 2021).

The parameters such as basal area and biomass were strongly influenced by the greater abundance of populations of both species in L1, meaning that an environment of greater anthropic disturbance favors the establishment of studied species (Lopes et al., 2017). However, differently from what we predicted, the elevation did not influence the average height and diameter of individuals in both populations. As tillering decreased along the gradient, it would be expected that the resources captured by the plants in L2 and L3 would be used to increase height and diameter. However, it is worth mentioning that plant growth does not only depend on the individual's genetic makeup, but is also conditioned to the availability of resources, external pressures to the plant (herbivory) and intra and interspecific interactions (Waller, 1986). In an elevation gradient in the semi-arid region, Almeida et al. (2020) already demonstrated that there is a positive correlation between elevation and litter (Kg), which can reflect in greater soil acidity, less availability of nutrients for plants at higher elevations, and consequently less ability to perform photosynthesis. Insect predation and competition can be important in regulating plant growth but have not yet been investigated in elevation gradients in the Caatinga. We hope that future studies will address these relationships and their effects on the population structure of Caatinga species in anthropic and edaphic gradients.

5. CONCLUSION

Higher abundance values of studied species were found in conditions of greater anthropogenic disturbances such as those in lower elevation regions, as well as greater tillering of individuals. The high regrowth capacity leads to success of these species in impacted Caatinga environments and can contribute to establishing dominant populations in disturbed conditions. This proliferation of species can substantially modify the community composition. However, we still do not know the effects of this increase in populations on species composition and ecological functions for the Caatinga. Finally, we believe that our study adds important observations related to the ecology and distribution patterns of plant population of Caatinga, mainly related to the land elevations recognized as important refuges of biodiversity in this region of Brazil.

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AUTHOR CONTRIBUTIONS

LOPES SF was responsible for conducting the experiment, data analysis and writing of manuscript. RAMOS MB, ALMEIDA HA and ALMEIDA GR conducting the experiment, data analysis and assisted in writing. SILVA FKG and PINTO AS contributed with the data analysis and writing of manuscript.

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