Research, Society and Development, v. 11, n. 5, e29411527880, 2022
(CC BY 4.0) | ISSN 2525-3409 | DOI: http://dx.doi.org/10.33448/rsd-v11i5.27880

Short timescale regeneration in a tropical dry forest in Brazil

Curta escala temporal de regeneração em floresta tropical seca do Brasil

Regeneración a corto plazo en el bosque seco tropical de Brasil

Received: 03/09/2022 | Reviewed: 03/17/2022 | Accept: 03/31/2022 | Published: 04/07/2022

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Abstract
The Tropical dry forests cover large regions of the world and have been extensively altered by human activities. This study was aimed at characterizing and comparing the density, diversity and structural parameters of a human-altered secondary dry within an interval of five years of regeneration. Two hundred plots were established in the forest and two monitoring surveys were carried out, with interval of five years between them. All individuals in each plot with diameter at the ground level ≥ 3 cm were measured. After five years, no differences were observed in the number of species. Total density and mean basal area decreased, as a result of the maturation of the forest and possibly due to a prolonged drought in 2012. In 2008, the total basal area was 10.59 m².ha^{-1}, increasing to 11.01 m².ha^{-1} in 2013. The mean height of the community did not increase significantly, from 3.59 m in 2008 to 3.65 min 2013. The number of individuals in the larger diameter classes reduced between 2008 and 2013, while the opposite was observed for smaller classes. Some structural parameters increased or decreased depending on the group of species analyzed and there was still a group that did not present significant changes. Therefore, age since abandonment can affect the

regeneration process and the resilience of the forest. We realized, the speed in which these alterations occurred in an interval of five years can be considered slow and changes in the recovery process of a 16-year-old forest may not be detected.
Keywords: Semiarid; Caatinga; Natural regeneration; Secondary Forest; Abandoned agricultural field.

Resumo
As florestas tropicais secas cobrem grandes regiões do mundo e foram amplamente alteradas pelas atividades humanas. Este estudo teve como objetivo caracterizar e comparar a densidade, diversidade e parâmetros estruturais de uma floresta seca secundária alterada pelo homem em um intervalo de cinco anos de regeneração. Duzentas parcelas foram implantadas na floresta e foram realizados dois levantamentos de monitoramento, com intervalo de cinco anos entre eles. Todos os indivíduos de cada parcela com diâmetro ao nível do solo ≥3 cm foram medidos. Após cinco anos, não foram observadas diferenças no número de espécies. A densidade total e a área basal média diminuíram, como resultado da maturação da floresta e possivelmente devido a uma estiagem prolongada em 2012. Em 2008, a área basal total era de 10,59 $m^2.ha^{-1}$, aumentando para 11,01 $m^2.ha^{-1}$ em 2013. A altura média da comunidade não aumentou significativamente, de 3,59 m em 2008 para 3,65 min em 2013. O número de indivíduos nas classes de maior diâmetro diminuiu entre 2008 e 2013, enquanto o contrário foi observado nas classes menores. Alguns parâmetros estruturais aumentaram ou diminuíram dependendo do grupo de espécies analisadas e ainda houve um grupo que não apresentou alterações significativas. Portanto, a idade desde o abandono pode afetar o processo de regeneração e a resiliência da floresta. Percebemos que a velocidade com que essas alterações ocorreram em um intervalo de cinco anos pode ser considerada lenta e mudanças no processo de recuperação de uma floresta de 16 anos podem não ser detectadas.
Palavras-chave: Semiárido; Caatinga; Regeneração natural; Floresta Secundária; Campo de agricultura abandonada.

Resumen
Los bosques secos tropicales cubren grandes regiones del mundo y han sido alterados en gran medida por las actividades humanas. Este estudio tuvo como objetivo caracterizar y comparar la densidad, diversidad y parámetros estructurales de un bosque seco secundario alterado por el hombre durante un período de regeneración de cinco años. Se implantaron 200 parcelas en el bosque y se realizaron dos sondeos de seguimiento, con un intervalo de cinco años entre ellos. Se midieron todos los individuos de cada parcela con un diámetro a nivel del suelo ≥3 cm. Después de cinco años, no se observaron diferencias en el número de especies. La densidad total y el área basal media disminuyeron como resultado de la maduración del bosque y posiblemente debido a una sequía prolongada en 2012. En 2008, el área basal total fue de 10,59 m².ha-1, aumentando a 11,01 m².ha-1 en 2013. la altura promedio de la comunidad no aumentó significativamente, de 3,59 m en 2008 a 3,65 min en 2013. El número de individuos en las clases de mayor diámetro disminuyó entre 2008 y 2013, mientras que ocurrió lo contrario en las clases más pequeñas. Algunos parámetros estructurales aumentaron o disminuyeron dependiendo del grupo de especies analizadas y aún hubo un grupo que no mostró cambios significativos. Por lo tanto, la edad desde el abandono puede afectar el proceso de regeneración y la resiliencia del bosque. Nos dimos cuenta de que la velocidad con la que ocurrieron estos cambios en un intervalo de cinco años puede considerarse lenta y es posible que no se detecten cambios en el proceso de recuperación de un bosque de 16 años.
Palabras clave: Semi árido; Caatinga; Regeneración natural; Bosque Secundario; Campo de agricultura abandonado.

1. Introduction

Use Worldwide, forests provide a large variety of products and services to humans (Monteiro, et al., 2006, Lucena, et al., 2008, Peres, et al., 2011, Isaza, et al., 2013). However, the exploitation of these resources has had negative impacts, such as forest fragmentation and habitat loss, affecting biodiversity and promoting the local extinction of species (Wessels, et al., 2011, Zanela, et al., 2012).

Despite that, some areas modified by human activities have the capacity to regenerate, promoting the growth of secondary forests, which are considered the forests of the future (Wijdeven & Kuzee, 2000, Chazdon, 2003, Pereira, et al., 2003). The capacity of forests to regenerate, or their resilience to disturbances, has drawn the attention of many researchers (Sampaio, et al., 1998, Lévesque, et al., 2011, Dupuy, et al., 2012), as this could contribute to recover species diversity and invaluable ecosystem services to humans.

Land use history, type and intensity of human disturbance, and proximity with forests fragments (Nascimento, et al., 2009, Quesada, et al., 2009, Dupuy, et al., 2012, Lopes, et al., 2012, Villalobos, et al., 2013, Souza, et al., 2014) are factors that influence the duration and the process of regeneration. Consequently, questions concerning how forests regenerate and the time necessary for full recovery must be evaluated and answered locally, taking into account the history of the disturbances and the structural and floristic attributes of each area. Seasonally dry tropical forests are thought to be more resilient to anthropogenic disturbances and to recover more rapidly than humid forests due to its lower stature (Murphy & Lugo, 1986, Derroire, et al., 2016) and high proportion of species capable of resprouing (Ky-Dembele, et al., 2007, Madeira, et al., 2009, Busby, et al., 2010, McDonald, et al., 2010, Souza, et al., 2014), which can greatly influence the speed of the recovery and the genetic structure of the newly formed forest.

Nonetheless, despite the recovery potential of seasonally dry tropical forests, the regeneration process can be complex as a result of the biological characteristics of the species involved in the different steps of the successional dynamics, as well as annual local climate variation. Among environmental factors, water availability has been pointed as a key factor to understand the dynamics of seasonally dry ecosystems, because of its effect on plant phenology (e.g. caatinga) (Lima, *et al.*, 2010; Valdez-Hernández, *et al*., 2010; Souza *et al.*, 2021), soil seed bank (Santos, *et al.*, 2013, Silva *et al.* 2013), seed rain (Souza *et al.* 2014), leaf litter (Santos *et al.* 2011), recruitment (Andrade, *et al*., 2007; Silva, *et al.*, 2015), and growth and survival of plants (Araújo, *et al.*, 2007; Villalobos, *et al.*, 2013).

One way to evaluate the regeneration process of a human-altered landscape is by monitoring the floristic composition and structural characteristics of the re-established community (Pereira, *et al.*, 2003; Norden, *et al.*, 2009; Lopes, *et al.*, 2012; Andrade, *et al.*, 2015) using chronosequence trends (Sánchez-Azofeifa, *et al.*, 2005; Chazdon, *et al.*, 2007; Quesada, *et al.*, 2009; Feeley, *et al*., 2011; Lévesque, *et al.*, 2011; Almazán-Núñez, 2012). Forest regeneration studies can be carried out for different periods of time. Short time studies do not encompass the entire successional process but can assess the range of variation of the changes of the attributes of seasonally dry forests and identify general patterns in the recovery of disturbed areas.

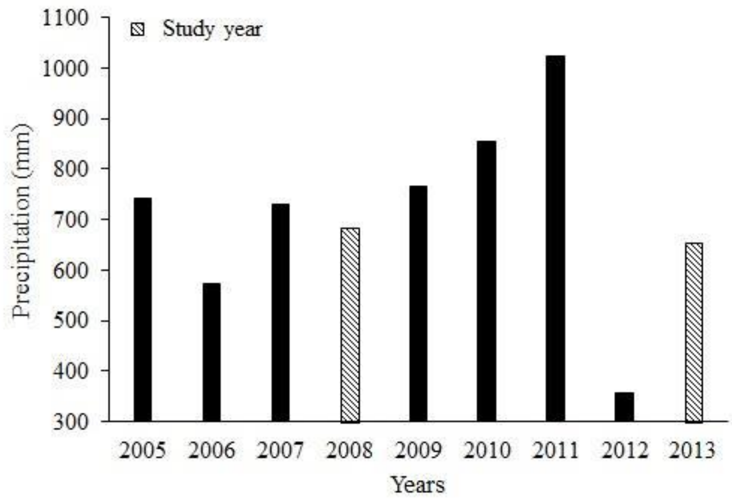
Despite local differences in natural recovery and regeneration process of human-altered forests, in dry environments, studies have shown that: a) richness, stature, and basal area of species are higher in older forests (Lévesque, *et al.*, 2011; Dupuy, *et al.*, 2012; Villalobos, *et al.*, 2013) b) individual density is lower in older forests (Sampaio, *et al.*, 1998; Dupuy, *et al.*, 2012) c) no species appears to be characteristic to the floristic composition of each successional stage (Dupuy, *et al.*, 2012).

Assuming that the structure of a forest community can function as an indicator of the effects of human disturbance, this study was aimed at evaluating the recovery rate of a secondary dry forest after five years of abandonment this study intends to measure the speed of recovery of a secondary forest, ascertaining whether within five years of regeneration the forest presents changes in these indicators. Using permanent plots in an area of secondary dry forest that allows the monitoring of regeneration at different times, we try to understand: (1) if the density of the regenerating tree community decreases and (2) diversity and structural parameters increase in a range of five years of regeneration.

2. Methodology

Description and history of the study area. - The area is located in the experimental station of the Agronomic Institute of Pernambuco (IPA- Instituto Agronômico de Pernambuco) (8˚14'18" S - 35˚55'20" W, 535 m above sea level), Caruaru, Pernambuco, Brazil. The climate is semiarid, BSh (Köppen, 1948) with mean annual precipitation of 710 mm concentrated between March and August and mean temperature of 22.7 ˚C. Although the seasons are well defined, occasional rains can be observed in the dry season, short-term droughts may occur during the rainy season, and seasons may be accelerated and delayed. Total rainfall for the years when this study was conducted are presented in Figure 1.

Figure 1. Inter-annual variation of total precipitation in the study area, Caruaru, PE, Brazil.



Source: Authors.

The experimental station was established in 1959, and comprised an area of 190 ha that were gradually reduced to a 35 ha fragment as studies on cattle ranching and farming practices were conducted. In 1994, 3 ha of the original forest were cleared for the cultivation of *Opuntia ficus-indica* (Mill.); no fire or pesticides were used in the soil preparation. This fragment is adjacent to an area of native vegetation and approximately three meters from of an unpaved road. After six months, the crop was abandoned with no further human interference, and this area of regenerating secondary tropical dry forest was selected for this study.

The soil of the secondary tropical dry forest is classified as Yellow Podzolic tb eutrophic, abrupt, moderate, sandy loam texture (Alcoforado-Filho, *et al*., 2003). The pH of the soil is 5.2, the mean values of coarse sand, fine sand, silt, and clay are: 41, 26, 22 and 11%, respectively, and moisture contents at 0.3 and 15 atm are 22.37 and 13.29%. The nutrients P, Na, and K were 6.78, 23.6, 104 ppm and Ca, Mg, H and Al are 1.02, 0.37, 3.17, 0.34 $cmol_c$ dm^{-3}, respectively.

Data collection.-In 2008, 200 5x10m permanent plots were established in a 1 ha of secondary dry forest. The plots were scattered in five columns and 30 rows, 3 meters from one another and 1 meter from the fragment border. During the 2008 and 2013 rainy seasons (Fig. 1), all individuals inside the plots with a stem diameter at ground level (DGL) ≤ 3 cm were tagged and measured. Plant height was measured using a graduated pole, while stem diameter was determined with a digital caliper (Rodal, *et al.*, 1992). The circumference of larger individuals was obtained with a measuring tape. In case of plants with stems branched at ground level, all branches were individually measured and the sum of the basal area of each branch was used to calculate a single measurement of diameter. The plots were monitored monthly in order to collect samples of reproductive material for species identification.

Herbarium specimens were prepared using the collected material, according to standard techniques for drying and mounting vouchers, which were later deposited in the Prof. Vasconcelos Sobrinho Herbarium (PEUFR). Taxonomic identifications were carried out by comparison with vouchers deposited in the PEUFR and Dárdano de Andrade Lima Herbarium (IPA), using taxonomic keys and specific literature. The botanical classification followed APG III (APG, 2009) and the species names were verified in the database of the Rio de Janeiro Botanical Garden – www.jbrj.gov.br.

Data analysis.- The following phytosociological parameters were calculated to characterize the structure of the vegetation in the regenerating forest: mean density, basal area, height, and diameter, using the software Fitopac 2.1 (Shepherd, 1995). Community richness and structure (mean density, height, and diameter) and between each population, between 2008 and 2013 were compared with an ANOVA and the Tukey test (HSD at 5%) using the software Statistic 6.0.

Floral composition of the 200 plots in each year was compared with a nonmetric multidimensional scaling (NMDS) using the Bray–Curtis dissimilarity matrix, based on species density. ANOSIM was used to examine the groups formed with NMDS using the software Primer-E 6.0 (Clarke & Gorley, 2006).

3. Results

The total density of the studied area was 3,306 ind./ha in 2008 and 2,890 ind./ha in 2013. The mean density of the community was significantly higher in 2008 (Fig. 2). *Croton blanchetianus, Cordia trichotoma, Lonchocarpus sericeus, Piptadenia stipulacea*, *Acacia paniculata*, *Poincianella pyramidalis,* and *Mimosa arenosa* were the species with the highest density values regardless of year.

Although not included in the analysis, a large number of standing dead trees with DGL≥3 was observed. In 2008, 229 dead individuals were recorded (6.4% of trees with DGL≥3), of which only 19 (8.2% of standing dead trees in 2008) were recorded in 2013. Of all live individuals tagged in 2008, 77 (2.3%) were considered dead in the 2013 survey.

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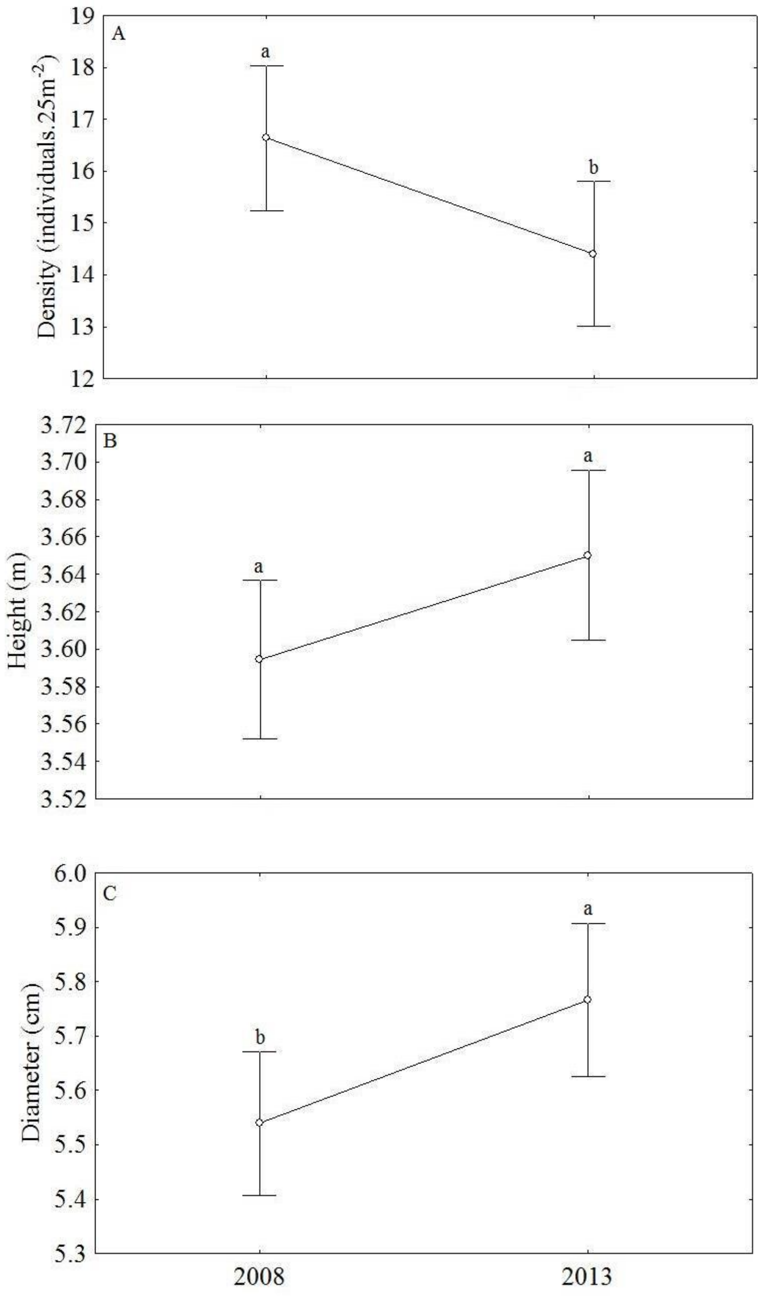
Figure. 2. Differences in mean density (A), height (B) and diameter (C) of plants per plot in 2008 and 2013 (Different letters between years in density, height, and diameter indicate significant difference according to the Tukey test HSD at 5%).

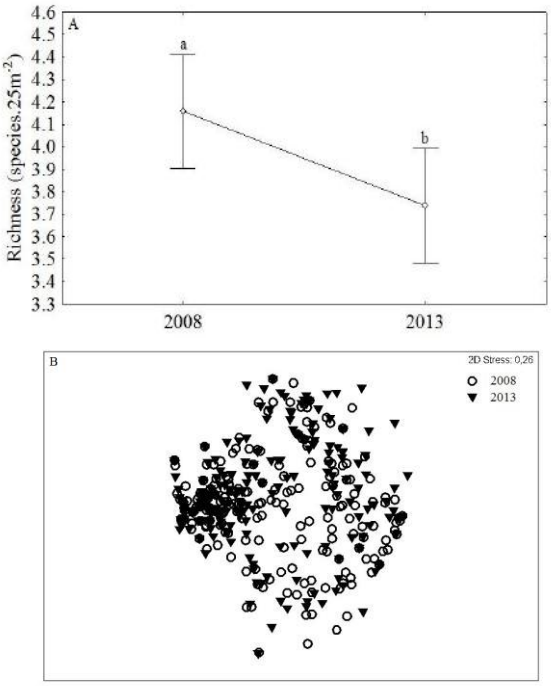


Source: Authors.

1In 2008, 35 species were identified, comprising 16 families. The most represented families were Fabaceae (10), Euphorbiaceae (5) and Anacardiaceae (3). Other families were represented by only one or two species. In 2013, 34 species of 17 families were found, with prevalence of species of Fabaceae (9), Euphorbiaceae (5), and Anacardiaceae (3). No consistent pattern was observed regarding species richness in the plots between the years, while mean richness was significantly higher in 2008 (Fig. 3A).

Two species were not found in 2013, both represented by one single individual in 2008: *Cordia curassavica* and Fabaceae 2. ANOSIM revealed a significant difference (R global = 0.033 and p<0.01) associated to species abundance in the community structure between years, which was reflected in the NMDS ordination (Fig. 3B).

Figure 3. Differences in mean richness per plot in an interval of 5 years (A) and ordination of floristic diversity (B) with non-metric multidimensional scaling (NMDS) in a tropical dry forest, Brazil (Different letters between years indicate a significant difference in mean richness according to the Tukey test HSD at 5%).



Source: Authors.

Mean height, diameter, and basal area differed between survey years. Although the mean height of the community increased from 3.52 m (2008) to 3.65 m (2013), this difference was not significant (Table 1). When examining species separately, some had a significant increase in mean height, while others decreased or remained unaltered (Table 1).

The mean diameter of the structure of the plant community in the secondary forest in 2013 was significantly larger than that obtained for 2008 (Fig. 2). Of all species in common between 2008 and 2013, seven had significantly different mean diameter. *Croton blanchetianus* and *Piptadenia stipulacea* had smaller mean diameter, while *Cordia trichotoma*, Fabaceae 1, *Guapira laxa*, *Lonchocarpus sericeus* and *Schinopsis brasiliensis*, the mean diameter in 2013 was larger (Table 1).

Table 1. Temporal variation in mean density (individuals.25m^{-2}) mean height (m) and mean diameter (cm) of populations in 2008 and in 2013 in an area of seasonally dry tropical forest, Brazil. Values in bold indicate a significant difference (p<0.05) according to GLM (generalized linear model – ANOVA).

	Densidade			**Altura**			**Diâmetro**		
Espécie	**2008**	**2013**	**ANOVA**	**2008**	**2013**	**ANOVA**	**2008**	**2013**	**ANOVA**
Acacia paniculata Willd.	2,8	2,2	$F_{(1, 126)}$=1,98	3,3	2,5	**$F_{(1, 326)}$=40,38**	5,4	7	$F_{(1, 326)}$=12,98
Allophylus quercifolius Radlk.	1	1	-	2,9	3	-	7,8	5,8	-
Anacardium occidentale L.	1	1	-	3,7	3	-	20,7	13	-
Bauhinia cheilantha (Bong.) Steud.	1,6	1,8	$F_{(1, 9)}$=0,04	4,9	4,6	$F_{(1, 17)}$=0,26	5	6	$F_{(1, 17)}$=0,76
Capparis flexuosa (L.) L.	1,8	1,3	$F_{(1, 47)}$=1,23	2,9	3,2	$F_{(1, 66)}$=1,11	4,3	4,5	$F_{(1, 66)}$=0,41
Capparis jacobinae Moric. ex Eichler	1,5	1,4	$F_{(1, 9)}$=0,09	2,8	2,5	$F_{(1, 13)}$=0,75	6,9	6,9	$F_{(1, 13)}$=0,001
Cereus jamacaru DC.	2	2	-	2,6	3,4	$F_{(1, 14)}$=2,99	12,4	10,4	$F_{(1, 14)}$=0,26
Commiphora leptophloeos (Mart.) J.B. Gillett	1,1	1,1	$F_{(1, 17)}$=0,001	3,8	4,4	$F_{(1, 19)}$=2,00	9,8	15,6	$F_{(1, 19)}$=1,48
Cordia curassavica (Jacq.) Roem. & Schult.	1	-	-	3	-	-	4,5	-	-
Cordia trichotoma (Vell.)	7,8	7,2	$F_{(1, 82)}$=0,05	2,9	3,4	**$F_{(1, 625)}$=18,67**	3,8	4,3	**$F_{(1, 625)}$=4,10**
Coutarea hexandra (Jacq.) K. Schum.	2	3	-	4,5	4,3	-	9,2	5,1	-
Croton rhamnifolius Willd.	1,6	1,3	$F_{(1, 50)}$=0,77	2,7	2,6	$F_{(1, 75)}$=0,15	4,1	4,6	$F_{(1, 75)}$=1,70
Eugenia uvalha Cambess.	3	3	-	2,7	3,6	**$F_{(1, 29)}$=11,29**	3,9	4,1	$F_{(1, 29)}$=0,11
Fabaceae 1	4	3,8	$F_{(1, 9)}$=0,004	2,2	3,1	**$F_{(1, 41)}$=28,59**	3,9	4,8	**$F_{(1, 41)}$=4,45**
Fabaceae 2	1	-	-	1,8	-	-	8,2	-	-
Guapira laxa (Netto) Furlan	2,6	2,3	$F_{(1, 53)}$=0,18	3,2	3,8	**$F_{(1, 133)}$=11,02**	4,8	5,8	**$F_{(1, 133)}$=6,91**
Jatropha mollissima (Pohl) Baill.	1,2	1,2	-	4,1	4,6	$F_{(1, 12)}$=0,87	6,1	4,8	$F_{(1, 12)}$=1,25
Lantana camara L.	1,8	1,25	$F_{(1, 21)}$=1,19	3,2	3	$F_{(1, 35)}$=0,25	9	7	$F_{(1, 35)}$=1,28
Lippia americana L.	1,87	1,37	$F_{(1, 46)}$=1,77	2,2	1,4	**$F_{(1, 74)}$=17,12**	5,4	6,1	$F_{(1, 74)}$=1,14
Lonchocarpus sericeus M.J. Silva & A. M. G. Azevedo	19,6	19,4	$F_{(1, 23)}$=0,002	3,8	4,3	**$F_{(1, 486)}$=20,72**	4,5	5,1	**$F_{(1, 486)}$=11,15**
Malvaceae 1	-	1	-	-	2,5	-	-	6,3	-
Continuação da tabela 1									
	Densidade	**Altura**	**Diâmetro**	4,3	7	-	8,1	8	-
Espécie	**2008**	**2013**	**ANOVA**	**2008**	**2013**	**ANOVA**	**2008**	**2013**	**ANOVA**
Myracrodruon urundeuva Allemao	1,48	1,43	$F_{(1, 59)}$=0,06	4,2	5,1	**$F_{(1, 85)}$=9,11**	7,6	8,3	$F_{(1, 85)}$=0,65
Pilosocereus gounellei F. Ritter	2	2	-	3,6	3,5	$F_{(1, 10)}$=0,02	9,5	9,8	$F_{(1, 10)}$=0,05

Piptadenia colubrina (Vell.) Brenan	2,02	1,94	$F_{(1, 72)}$=0,08	5,7	6,4	$F_{(1, 145)}$=3,15	14,8	13,3	$F_{(1, 145)}$=0,89
Piptadenia stipulacea (Benth.) Ducke	2,37	2,48	$F_{(1, 208)}$=0,10	4,6	4	**$F_{(1, 516)}$=34,23**	6,4	5,7	**$F_{(1, 516)}$=6,43**
Poincianella pyramidalis (Tul.) L.P.Queiroz	2,55	2,4	$F_{(1, 137)}$=0,11	3,7	4,2	$F_{(1, 343)}$=11,77	4,9	5,1	$F_{(1, 343)}$=0,56
Pseudobombax marginatum (A. St.-Hil.,Juss. & Cambess.) A. Robyns	1	1	-	2,9	4,3	-	5,4	7,1	-
Ptilochaeta bahiensis Turcz.	1,3	1,3	-	3,6	3,8	$F_{(1, 24)}$=0,66	4,9	5,4	$F_{(1, 24)}$=0,71
Sapium lanceolatum (Mull. Arg.) Huber	1	1	-	2,3	3,5	-	7,2	4,9	-
Schinopsis brasiliensis Engl.	1,81	1,81	$F_{(1, 105)}$=0,001	4,1	5,3	**$F_{(1, 191)}$=36,38**	6,8	9,9	**$F_{(1, 191)}$=17,80**
Sebastiania jacobinensis (Mull. Arg.)Mull. Arg.	1	1	-	3,5	5,5	-	6	15	-
Senna spectabilis (DC.) H.S. Irwin & Barneby	4,83	4,16	$F_{(1, 10)}$=0,08	3,1	3,3	$F_{(1, 52)}$=2,06	6,8	11,6	$F_{(1, 52)}$=10,13
Ziziphus joazeiro Mart.	2	2	-	5	4,1	$F_{(1, 4)}$=2,49	8,3	12,4	$F_{(1, 4)}$=0,70

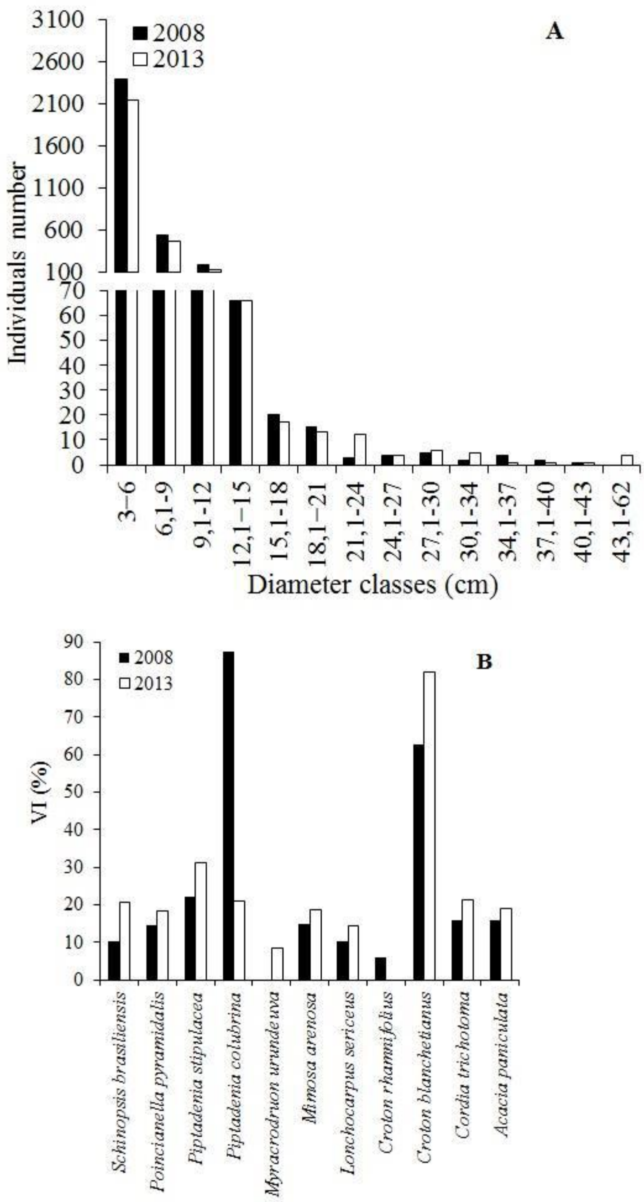
Source: Authors.

The number of individuals in the larger classes of diameter decreased from 2008 to 2013, while the inverse was observed in smaller classes (Fig. 4A).

In 2008, the total basal area was 10.59 $m^2.ha^{-1}$, increasing to 11.01 $m^2.ha^{-1}$ in 2013. Increase in basal area was observed for 11 species.

The four species with higher IV remained the same in the two years: *Croton blanchetianus*, *Piptadenia stipulaceae*, *Cordia trichotoma*, and *Piptadenia colubrina*, although the values varied and the order of importance changed among them (Fig. 4). Changes in the IV values of the main species are presented in Figure 4.

Figure 4. Distribution of individuals per class of diameter (A) and species with the highest importance values (B) in 2008 and 2013 in a tropical dry forest, Brazil



Source: Authors.

4. Discussion

The changes in community structure observed in five years was due to the decrease in density and increase in mean diameter of individuals, since the short-term regeneration was not enough to observe the arrival of new species and to observe an increase in mean height of individuals. Thus, our findings suggest that as regeneration advances, species richness and forest height increase.

The successional process may lead to a reduction in density in some populations (Lebrija-Trejos, *et al.*, 2008; Dupuy, *et al.*, 2012), as observed in the present study. In addition, studies on changes after human disturbance followed by abandonment have reported that a reduction in species richness and density can be indicators of maturation (Carreto &

Almazán, 2004; Gallardo-Cruz, *et al.*, 2005). This may explain the changes in richness and density observed in our study. Although five years is considered a relatively short period of time, the natural recovery of the forest is still taking place.

The reduction in density observed after five years can be an indication of forest maturation, due to the successional process (Sampaio, *et al.*, 1998; Dupuy, *et al.*, 2012) or environmental stochasticity, specially regarding variations in annual and interannual rainfall. The population dynamics of the area can be strongly influenced by climate seasonality and the occurrence of occasional droughts in the rainy season or erratic rains in the dry season can increase mortality and reduce the size of the population (Araújo, *et al.*, 2007; Silva, *et al.*, 2015). Also, years of intense droughts or rains can influence the recruitment of individuals in the following years (Villalobos, *et al.*, 2013).

The modest change observed in the structure of the community during a five-year interval, despite the basically unaltered set of species, reflects the abundance of populations. Small variations in community structure throughout years are described in the literature as indicators of species stability, suggesting that the area is no longer in early stages of the successional process (Lévesque, *et al.*, 2011; Dupuy, *et al.*, 2012; Villalobos, et al., 2013). Nonetheless, it should be pointed out that the study area is located near a mature forest, which might have affected the arrival of diaspores, accelerating the regeneration process (Cook, *et al.*, 2005; Lopes, *et al.*, 2012; Souza, *et al.*, 2014).

The history, type of human disturbance (clearing, burn, slash and burn, chemicals, and pesticides) (Van Bloem, *et al.*, 2005; Lopes, *et al.*, 2012; Miller, 2013), as well as seasonality and local climate (Villalobos, *et al.*, 2011; Lopes, *et al.*, 2012; Santos, *et al.*, 2013) can affect the recovery process and time of a human-altered area. Even in areas with a single disturbance event and the proximity to a source of diaspores, the recovery time of the forest may be long, as reported by Lopes *et al.*, (2012) for the regeneration of the same area monitored in this study. These authors concluded that 16 years were not enough for the young forest to reach maturity based on community structure and species composition.

During the time interval between 2008 and 2013, a severe drought occurred in 2012, in which the area received half of the mean rainfall for the area (Fig. 1). The reduction in density observed in our study might be a result of this strong event, halting the recovery of the forest. Some studies have reported that prolonged droughts can affect the regeneration of disturbed areas, slowing the successional process. The reduction in density and structure of the community caused by these climate events may increase the representation of more drought resistant species (Feeley, *et al.*, 2011; Villalobos, *et al.*, 2013). These results indicate that tropical dry forests can take longer to regenerate due to irregular rains and prolonged droughts, delaying the successional process.

The difference in species composition in plots, combined with the large reduction in total density in the area, suggests that some species tend to disappear from the area, such as *Acacia paniculata*, *Lantana camara* and *Lippia americana*, as time of abandonment increases, while some species tend to be characteristic of a successional stage.

The mean height, diameter, and basal area of individuals increased in 2013. Other studies on disturbed forests reported that these indicators increased along with time of abandonment and density reduction (Dupuy, *et al.*, 2012). The increase in mean diameter in 2008 was concentrated in individuals of larger classes, since mortality is usually higher among individuals of smaller classes (Lévesque, *et al.*, 2011).

Most studies on the resilience of human-altered dry forests indicate that longer time of abandonment of an area is reflected in increase in total basal area, mean diameter, and mean height (Sánchez-Azofeifa, *et al.*, de 2005; Quesada, *et al.*, 2009; Feeley, *et al.*, 2011; Lévesque, *et al.*, 2011; Almazán-Núñez, 2012).

The most important species in the young forest in 2013 still are very distinct from those with higher VI established in the nearby mature forest. According to Alcoforado-Filho *et al.*, (2003), the ten most important species in this mature forest were *Poincianella pyramidalis, Schinopsis brasiliensis, Solanum sp., Bauhinia cheilantha, Maprounea cf. guianensis, Piptadenia colubrina, Eugenia uvalha, Mimosa malacocentra, Piptadenia stipulacea, Commiphora leptophloeos*, and

Pithecelobium parviflorum and many of them were not considerably important in the young forest, suggesting that full maturity has not been reached, as reported by Lopes *et al.*, (2012).

The present study observed small changes in five years in species composition and richness in the sampled plots. The structural parameters changed positively or negatively in one group of species, while no significant alterations were observed in another group.

5. Conclusion

The time of abandonment affects the regeneration process and the resilience of the forest, but the speed of changes within five years may be considered slow and prominent changes may not be observed in the recovery of a 16-year-old forest. In addition, an atypical climate event (severe drought in 2012) likely affected the successional process, delaying the regeneration of this secondary dry forest.

Acknowledgments

The authors thank PRPPG/UFRPE, CNPq (productivity grant 303505/2018-8), Facepe, and Capes for their financial support in carrying out the research and granting a scholarship to some authors. We thank the researchers of the Northeast Laboratory of Plant Ecology and Ecosystems (LEVEN) for their support and suggestions during the execution of this project.

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