Universidade Federal do Paraná
Setor de Ciências Agrárias
Pós-graduação em Engenharia Florestal
Revista Floresta

NATURAL REGENERATION DYNAMICS IN CAATINGA TREE SUBMITTED TO FOREST MANAGEMENT

Ana Flávia Costa Santos[1], Alessandro de Paula[2], Patrícia Anjos Bittencourt Barreto-Garcia[3], Michele Martins Corrêa[4], Jennifer Rafaela Bombonatti[5]

[1]Universidade Estadual do Sudoeste da Bahia, Programa de Pós-graduação em Ciências Florestais, Vitória da Conquista, Ba, Brasil – csanaflavia@outlook.com
[2]Universidade Estadual do Sudoeste da Bahia, Departamento de Engenharia Agrícola e Solos, Vitória da Conquista, Ba, Brasil - apaula@uesb.edu.br
[3]Universidade Estadual do Sudoeste da Bahia, Departamento de Engenharia Agrícola e Solos, Vitória da Conquista, Ba, Brasil - patriciabarreto@uesb.edu.br
[4]Universidade Estadual do Sudoeste da Bahia, Departamento de Ciências Naturais, Vitória da Conquista, Ba, Brasil – mcorrea@uesb.edu.br
[5]Universidade Estadual do Sudoeste da Bahia, Programa de Pós-graduação em Ciências Florestais, Vitória da Conquista, Ba, Brasil – jrbflorestal@gmail.com

Received for publication: 09/05/2022 – Accepted for publication: 17/01/2023

Resumo

Dinâmica da regeneração natural em Caatinga arbórea submetida a manejo florestal. Este estudo visou avaliar a dinâmica da regeneração natural em Caatinga sujeita a diferentes técnicas de manejo. O trabalho foi realizado na Floresta Nacional de Contendas do Sincorá, sendo a cobertura vegetal predominante a Savana-estépica Florestada. A área de estudo consistiu em parcelas fixas plotadas em 2015. Os tratamentos foram: Testemunha; corte raso; corte seletivo por diâmetro mínimo à altura do peito ≥ 5 cm; e corte seletivo por espécies. Os parâmetros fitossociológicos foram estimados para cada espécie. O Índice de Diversidade Shannon-Weaver e o Índice de Expansão Florística (FEI) foram calculados e o método Ward foi utilizado para a análise da similaridade florística. Foram amostrados um total de 453 indivíduos, distribuídos em 31 espécies. *Combretum monetaria* foi destacada em todos os tratamentos e parâmetros fitossociológicos. O dendrograma mostra que existe similaridade florística entre os anos 2015 e 2020. O tratamento CC obteve a maioria das espécies com FEI positivo no período de 2015 a 2017, com um resultado semelhante aos outros tratamentos em 2020. Não houve diferença estatística entre os tratamentos em relação à diversidade, após cinco anos de intervenção. A rebrota por toco foi muito importante no início da regeneração. A semelhança florística entre 2015 e 2020 mostra uma recuperação cinco anos após a instalação do experimento. As técnicas de manejo não tiveram um impacto negativo sobre a riqueza florística da regeneração natural, demonstrando que a área recupera bem mesmo com as interferências feitas na área.
Palavras-chave: Savana estépica, Índice de Expansão Florística, Fitossociologia.

Abstract

This study aimed to evaluate the natural regeneration dynamics in Caatinga subjected to different forest management practices. The work was carried out in the Contendas do Sincorá National Forest, with the predominant vegetation cover being forested steppe savanna. The study area consisted of fixed plots plotted in 2015. The treatments were: control (Con); clear cutting (CC); selective cutting by minimum diameter at breast height ≥ 5 cm; and selective cutting by species. The phytosociological parameters were estimated for each species. The Shannon-Weaver Diversity Index and the Floristic Expansion Index (FEI) were calculated and the Ward method was used for the floristic similarity analysis. A total of 453 individuals were sampled, distributed in 31 species and five morpho-species. *Combretum monetaria* was highlighted in all treatments and phytosociological parameters. The similarity dendrogram shows that there is floristic similarity between the years 2015 and 2020. The CC treatment obtained the most species with positive FEI in the period from 2015 to 2017, with a result similar to the other treatments in 2020. It is concluded that there was no statistical difference between treatments in relation to diversity after five years of intervention. Stump regrowth was very important at the beginning of regeneration. The floristic similarity between 2015 and 2020 shows a recovery five years after the experiment installation. Management practices did not have a negative impact on the floristic richness of natural regeneration, demonstrating that the area recovers well even with the interference made in the area.
Keywords: Steppe savanna, Floristic Expansion Index, Phytosociology.

INTRODUCTION

The Caatinga is an exclusively Brazilian biome which is composed of seasonally dry tropical forest (SDTF) cores which cover most of the semi-arid region of Northeast Brazil. This biome plays an important role in the region's economy, as its natural resources are directly and indirectly used to generate energy for both industry and households and to obtain non-timber forest products.

The Caatinga is probably the least known botanically and the most undervalued among the Brazilian biomes given the frequent inadequate exploitation of its resources and the high proportion of areas deforested for

livestock (MAIA *et al.*, 2017). The adoption of techniques which enable legally exploiting native vegetation in this biome becomes necessary to contribute to its conservation, allied to the local socioeconomic development. Thus, a viable alternative for the semi-arid region is sustainable forest management, which is provided for in Art. 3, item VII, of Law No. 12,651, of May 25, 2012.

Despite this, even if carried out with technical criteria, forest management can change the composition of woody species and the natural regeneration capacity of the vegetation. The level of these changes is related to the techniques applied, whose choice should provide the best recovery of the ecosystem, favoring its regeneration (LUCENA *et al.*, 2017, LIMA-JÚNIOR *et al.*, 2015). The main forest management practices adopted in the Caatinga are clear cutting and selective cutting by minimum diameter or by species, but little is known about which would be the most appropriate to preserve the biome's characteristics.

Understanding some parameters such as diversity, richness and regeneration of Caatinga species is essential to understand the level of interference caused by different management practices in recovering structure and floristic composition. In addition, knowledge of the floristic and structural characteristics of regenerating vegetation contributes to understanding community dynamics and helps to predict the direction of ecological succession (ÁVILLA *et al.*, 2016). Given the scarcity of information on the regeneration of the Caatinga, especially when subjected to forest management, knowledge about this mechanism can be the starting point for understanding the behavior and development of the forest. This information is essential to propose management practices which are sustainable from an economic and environmental point of view, since it provides information about the species which may compose its future stock.

Thus, this study aimed to evaluate the natural regeneration dynamics in Caatinga subjected to different forest management practices with a view to offering subsidies to actions aimed at sustainability and recovery of this ecosystem. The hypothesis of this study is that management practices impact on the floristic richness of natural regeneration.

MATERIAL AND METHODS

Study area

The work was developed in a sustainable use conservation unit of the of Contendas do Sincorá (FLONA), which is located in the municipality of Contendas do Sincorá in the state of Bahia, Brazil (Figure 1). It is situated between two elevations, with one to the east and the other to the west; FLONA is in a depression region with small relief undulations, between 380 and 400 m in altitude. The region has a semi-arid climate (BSwh) according to the Koppen classification, characterized as hot and with scarce and irregular rains concentrated in the summer. The average annual total rainfall is 596 mm, with the wettest period from November to April. The predominant vegetation cover in FLONA is forested steppe savanna, which is fundamentally structured in two strata: one is superior with a predominance of periodically deciduous nanophanerophytes and more or less densely populated by generally thick trunks and a grassy-woody lower stratum, usually discontinuous and of little physiognomic expression (IBGE, 2012).

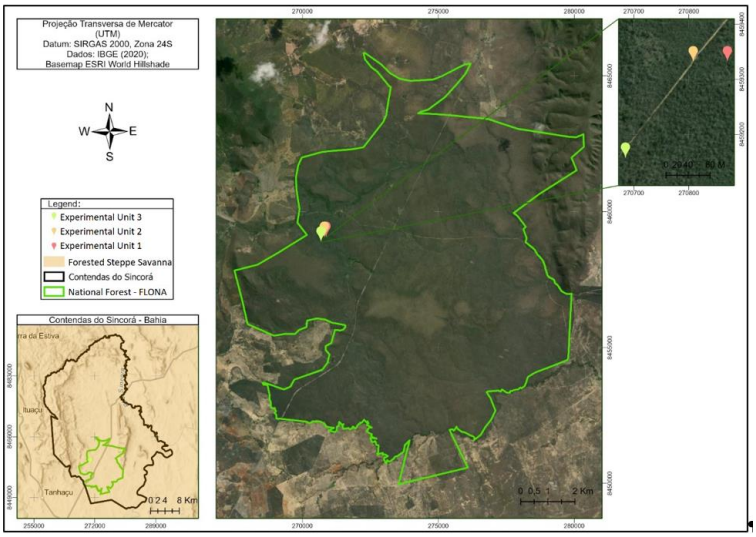

Figure 1. Location map of the study area in Contendas do Sincorá National Forest, Bahia, Brazil.
Figura 1. Mapa de localização da área de estudo na Floresta Nacional das Contendas do Sincorá, Bahia, Brasil.

The study area consists of fixed plots that were installed in 2015. The experiment consists of three experimental units (EU), each one composed of by 16 plots of 5 x 5 m, where the treatments were randomly distributed with four replications each. The treatments performed were: control (Con) - which consists of unmanaged Caatinga; clearcutting (CC) – with the removal of all trees and shrubs, regardless of size or species (100% reduction in basal area); selective cutting by minimum diameter (SCDBH) – cutting of all trees with diameter at breast height (DBH) greater than or equal to 5 cm (60% reduction in basal area); and selective cutting by species (SCS) – with cutting of three species (*Commiphora leptophloeos* Mart.) J.B. Gillet, *Jatropha molissima* (Pohl) Baill. and *Pseudobombax simplicifolium* A. Robyns) selected due to their higher population density (15% reduction of the basal area) (Figure 2). All individuals removed from the area were cut at 10 cm from the ground to evaluate the regrowth mechanism of strains.

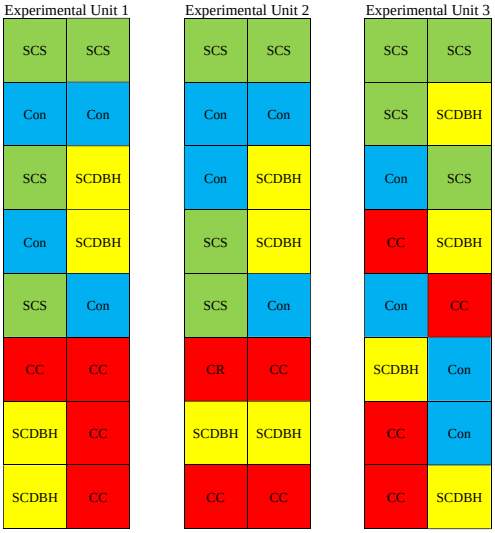

Figure 2. Experimental design, installed in the Contendas do Sincorá National Forest, Bahia, Brazil.
Figura 2. Desenho experimental, instalado na Floresta Nacional das Contendas do Sincorá, Bahia, Brasil.

Phytosociological survey

Naturally regenerating individuals were considered those with height equal to or greater than 0.5 m. The species and height class of each stem of these individuals were recorded according to the Management Network protocol, as follows: C1 - height class from 0.5 to 1.0 m; and C2 - height class above 1.0 m up to DBH = 6.0 cm. Whether the regeneration originated from stump regrowth was also recorded.

Species identification was performed by collecting botanical material, consulting specialized literature and comparing them with specimens available at the Herbarium on the campus of Vitória da Conquista – BA, Brazil (HUESBVC).

Data analysis

The phytosociological parameters for each species were estimated using the FITOPAC 2.1 software (SHEPHERD, 2010). The absolute and relative density and frequency parameters were used to obtain the Natural Regeneration Relative Size Class (NRRSCi) and Total Natural Regeneration (TNR) indices. Floristic diversity was evaluated using the Shannon-Weaver Index (H') (SHANNON; WEAVER, 1964).

The density and number of individuals from regrowth values were submitted to the non-parametric analysis of Kruskal-Wallis and later to the test of multiple comparisons of Dunn to verify the occurrence of the interference of treatments in the floristic composition and phytosociological structure of the natural regeneration, as long as there was a significant difference between the sample means. Analysis of variance (ANOVA) was performed, followed by the Student's t-test for the H' values. Shannon diversity comparison was performed between two samples at a time.

The existence of floristic similarity between the sampling years was analyzed by the Ward method (hierarchical agglomeration) (VALETIM, 2012) using qualitative and quantitative data. This analysis was performed using the Past 4.02 software program (HAMMER *et al.*, 2001).

The Floristic Expansion Index (FEI) was also calculated, as obtained through the natural regeneration rate weighted by the relative abundance of the species. The result verified in the natural regeneration rate (NRr) only evaluates fluctuations in the abundance of the species (mortality and growth), implying that the forest is well conserved. However, the species that colonize the gaps are not always the same that formed it before the opening, making the dynamic regeneration balance found in this analysis only quantitative. It is possible to quantify the

floristic variation over time through the FEI, considering an increase or decrease in the representativeness of the species in relation to the total floristic composition of the stand (JARDIM, 1988). The defined categories classify the species in nominal groups by a qualitative analysis, represented as:

$$FEI = NRr * ABrel$$

on what FEI = Floristic Expansion Index, $NRr = \left[\left(\frac{A1}{A0}\right) - 1\right].100$ = Natural Regeneration rate, A1 = final absolute abundance (2020 sampling), A0 = initial absolute abundance (2015 sampling) and ABrel = final relative abundance of each species = $\frac{A1}{\sqrt{A1}}$.

Table 1 indicates how the FEI results and NRr% can be interpreted in relation to the behavior of the species in the stand, presenting six possibilities.

Table 1. Categories of Floristic Expansion Index (FEI) results and the relationship with species behavior groups.
Tabela 1. Categorias de resultados do Índice de Expansão Florística (FEI) e a relação com os grupos de comportamento das espécies.

Categories	Interpretation
Positive FEI	Species occupied the spaces left by other species.
Negative FEI	Species reduced their floristic representation.
NRr=100% and low FEI	Species considered new or rare in the area.
Low FEI	Species with a tendency to be replaced over time by species with higher FEI.
FEI = 0 and A1 = 0	Elimination of the species from the forest structure.
FEI = 0 and NRr = 0	Stable in the stand and responsible for maintaining the structural physiognomy of the forest.

RESULTS

A total of 453 individuals were sampled in 2020, distributed in 18 families, 29 genera, 31 species and five morpho-species. The treatments that showed the highest richness were Con and CC, with 23 and 22, respectively (Table 2).

The families with the highest number of species were Fabaceae (8) and Euphorbiaceae (4), totaling 34%. The *Handroanthus chrysotrichus* (Mart. ex DC.) Mattos, *Combretum monetaria* Mart., *Bauhinia cheilantha* (Bong.) Steud., *Pseudobombax simplicifolium* A.Robyns, *Senegalia piauhiensis* (Benth.) Seigler, *Coursetia rostrata* Benth., *Mimosa tenuiflora* (Willd.) Poir. and *Senegalia lewisii* (Bocage & Miotto) L.P.Queiroz species were present in all treatments. *Manihot carthagenensis* (Jacq.) Müll.Arg. and *Coccoloba schwackeana* Lindau were only present in CC. Other exclusive species were *Metternichia principis* J.C.Mikan and *Licania rigida* Benth., found only in Con.

Table 2. Floristic listing of natural regeneration in arboreal Caatinga subjected to forest management in the Contendas do Sincorá National Forest - BA, Brazil.
Tabela 2. Listagem florística da regeneração natural em Caatinga arbórea submetida ao manejo florestal na Floresta Nacional Contendas do Sincorá - BA, Brasil.

Family	Species	Con	CC	SCDBH	SCS
Anacardiaceae	*Astronium urundeuva* (M.Allemão) Engl.	X		X	X
	Spondias tuberosa Arruda	X	X		X
Annonaceae	*Annona vepretorum* Mart.		X	X	X
Bignoniaceae	*Handroanthus chrysotrichus* (Mart. ex DC.) Mattos	X	X	X	X
	Handroanthus impetiginosus (Mart. ex DC.) Mattos	X	X	X	
Boraginaceae	*Cordia incognita* Gottschling & J.S.Mill.	X	X	X	X
Capparaceae	*Colicodendron yco* Mart.	X		X	
Chrysobalanaceae	*Licania rigida* Benth.	X			
Combretaceae	*Combretum monetaria* Mart.	X	X	X	X
Erythroxylaceae	*Erythroxylum pungens* O.E.Schulz	X	X		
Euphorbiaceae	*Cnidoscolus bahianus* (Ule) Pax & K.Hoffm.	X			X
	Croton conduplicatus Kunth	X	X		X
	Manihot carthagenensis (Jacq.) Müll.Arg.		X		

	Sebastiania macrocarpa Müll.Arg.	X	X	X	
Fabaceae	*Bauhinia cheilantha* (Bong.) Steud.	X	X	X	X
	Caesalpinia pyramidalis Tul.	X		X	
	Calliandra spinosa Ducke	X	X		X
	Cenostigma pluviosum (DC.) Gagnon & G.P.Lewis			X	
	Coursetia rostrata Benth.	X	X	X	X
	Mimosa tenuiflora (Willd.) Poir.	X	X	X	X
	Pseudobombax simplicifolium A.Robyns	X	X	X	X
	Senegalia piauhiensis (Benth.) Seigler	X	X	X	X
Undetermined	Undet 1		X		
	Undet 2		X		
	Undet 3		X		
	Undet 4			X	
	Undet 5	X			
Loganiaceae	*Strychnos parvifolia* A.DC.		X	X	X
Malvaceae	*Senegalia lewisii* (Bocage & Miotto) L.P.Queiroz	X	X	X	X
Myrtaceae	*Eugenia ligustrina* (Sw.) Willd.	X	X		
Nyctaginaceae	*Guapira opposita* (Vell.) Reitz				X
Polygonaceae	*Coccoloba schwackeana* Lindau		X		
Rubiaceae	*Cordiera concolor* (Cham.) Kuntze	X			X
Rutaceae	*Esenbeckia febrifuga* (A.St.-Hil.) A. Juss. ex Mart.				X
Solanaceae	*Metternichia principis J.C.Mikan*	X			

In which: Con = control, CC = clear cutting, SCDBH = selective cutting by minimum diameter, SCS = selective cutting by species.

The most prominent species for all phytosociological parameters in Con were *C. conduplicatus*, *C. monetaria* and *S. piauhiensis*, representing 41.08% of the total natural regeneration. The same species presented the highest values for the analyzed parameters in CC, with a total natural regeneration value of 44.95%. Moreover, *C. monetaria*, *S. lewisii* and *M. tenuiflora* presented 36.90% of total regeneration rate in SCDBH, and *C. conduplicatus*, *C. incognita* and *C. monetaria* represented 47.58% of total regeneration rate in SCS (Table 3).

Table 3. Phytosociological parameters of natural regeneration in an area subjected to different forest management techniques in the Contendas do Sincorá National Forest (BA).
Tabela 3. Parâmetros fitossociológicos de regeneração natural em área submetida a diferentes técnicas de manejo florestal na Floresta Nacional Contendas do Sincorá (BA).

	Specimen						
Species	**N**	**NCl1**	**NCl2**	**RD**	**RF**	**NRRSCi**	**TNR**
Croton conduplicatus	25	5	20	17.48	11.86	18.64	15.99
Senegalia piauhiensis	19	6	13	13.29	10.17	13.08	12.18
Combretum monetaria	19	5	14	13.29	11.86	13.57	12.91
Bauhinia cheilantha	14	2	12	9.79	3.39	10.83	8.00
Pseudobombax simplicifolium	11	6	5	7.69	6.78	6.33	6.93
Cordia incognita	11	3	8	7.69	6.78	7.81	7.43
Coursetia rostrata	9	3	6	6.29	5.08	6.12	5.83
Spondias tuberosa	6	6		4.2	3.39	2.11	3.23
Mimosa tenuiflora	4	1	3	2.8	5.08	2.88	3.59
Cordiera concolor	3	1	2	2.1	5.08	2.04	3.07
Senegalia lewisii	3		3	2.1	1.69	2.53	2.11
Calliandra spinosa	3		3	2.1	3.39	2.53	2.67
Sebastiania macrocarpa.	2	1	1	1.4	1.69	1.20	1.43
Myracrodruon urundeuva	2		2	1.4	3.39	1.69	2.16
Cnidoscolus bahianus	2	1	1	1.4	3.39	1.20	2.00
Tabebuia chrysotrichus	2		2	1.4	3.39	1.69	2.16
Indeterminada 313	1		1	0.7	1.69	0.84	1.08
Caesalpinia pyramidalis	1		1	0.7	1.69	0.84	1.08
Erythroxylum pungens	1		1	0.7	1.69	0.84	1.08
Eugenia ligustrina	1	1		0.7	1.69	0.35	0.91

Tabebuia impetiginosus	1		1	0.7	1.69	0.84	1.08
Colicodendron yco	1		1	0.7	1.69	0.84	1.08
Metternichia principis	1	1		0.7	1.69	0.35	0.91
Licania rigida	1		1	0.7	1.69	0.84	1.08
Total	143	42	101	100.0	100.0	100.0	100.0

CLEAR CUTTING

Species	N	NCl1	NCl2	RD	RF	NRRSCi	TNR
Combretum monetaria	21	5	16	19.09	12.9	18.92	16.97
Croton conduplicatus	17		17	15.45	11.29	18.41	15.05
Senegalia piauhiensis	15	1	14	13.64	9.68	15.48	12.93
Senegalia lewisii	7	1	6	6.36	3.23	6.82	5.47
Bauhinia cheilantha	7		7	6.36	4.84	7.58	6.26
Cordia incognita	6	4	2	5.45	4.84	3.44	4.58
Pseudobombax simplicifolium	6	2	4	5.45	6.45	4.97	5.62
Spondias tuberosa	6	4	2	5.45	9.68	3.44	6.19
Tabebuia chrysotrichus	2		2	1.82	3.23	2.17	2.41
Calliandra spinosa	2		2	1.82	3.23	2.17	2.41
Annona vepretorum	2	1	1	1.82	3.23	1.40	2.15
Erythroxylum pungens	2	1	1	1.82	3.23	1.40	2.15
Mimosa tenuiflora	2	2		1.82	3.23	0.64	1.90
Coursetia rostrata.	2		2	1.82	1.61	2.17	1.87
Jatropha mollissima	2		2	1.82	1.61	2.17	1.87
Cenostigma pluviosum	2		2	1.82	3.23	2.17	2.41
Strychnos parvifolia	1	1		0.91	1.61	0.32	0.95
Indeterminada 9	1	1		0.91	1.61	0.32	0.95
Indeterminada 23	1		1	0.91	1.61	1.08	1.20
Indeterminada 24	1		1	0.91	1.61	1.08	1.20
Sebastiania macrocarpa	1		1	0.91	1.61	1.08	1.20
Eugenia ligustrina	1		1	0.91	1.61	1.08	1.20
Manihot carthagenensis	1		1	0.91	1.61	1.08	1.20
Coccoloba schwackeana	1	1		0.91	1.61	0.32	0.95
Tabebuia impetiginosus	1	1		0.91	1.61	0.32	0.95
Total	110	25	85	100.0	100.0	100.0	100.0

SELECTIVE CUTTING DBH

Species	N	NCl1	NCl2	RD	RF	NRRSCi	TNR
Combretum monetaria	18		18	16.98	12.96	20.40	16.78
Senegalia lewisii	12	2	10	11.32	7.41	12.11	10.28
Mimosa tenuiflora	11	1	10	10.38	7.41	11.72	9.84
Croton conduplicatus	9	2	7	8.49	11.11	8.71	9.44
Pseudobombax simplicifolium	9	4	5	8.49	7.41	7.22	7.71
Bauhinia cheilantha	7	1	6	6.6	7.41	7.19	7.07
Cordia incognita	5	4	1	4.72	5.56	2.68	4.32
Tabebuia chrysotrichus	5	1	4	4.72	3.7	4.92	4.45
Annona vepretorum	4	1	3	3.77	5.56	3.79	4.37
Senegalia piauhiensis	4	2	2	3.77	5.56	3.04	4.12
Tabebuia impetiginosus	4	1	3	3.77	1.85	3.79	3.14
Coursetia rostrata	4		4	3.77	5.56	4.53	4.62
Colicodendron yco	3	2	1	2.83	3.7	1.91	2.81
Cenostigma pluviosum	2	2		1.89	1.85	0.77	1.50
Sebastiania macrocarpa	2		2	1.89	1.85	2.27	2.00
Myracrodruon urundeuva	2	1	1	1.89	1.85	1.52	1.75
Jatropha mollissima	2	1	1	1.89	3.7	1.52	2.37
Strychnos parvifolia	1	1		0.94	1.85	0.39	1.06
Caesalpinia pyramidalis	1	1		0.94	1.85	0.39	1.06
Indeterminada 95A	1		1	0.94	1.85	1.13	1.31
Total	106	27	79	100.0	100.0	100.0	100.0

SELECTIVE CUTTING BY SPECIES							
Species	**N**	**NCl1**	**NCl2**	**RD**	**RF**	**NRRSCi**	**TNR**
Croton conduplicatus	23	2	21	24.47	15.69	27.92	22.69
Cordia incognita	14	6	8	14.89	9.8	13.21	12.63
Combretum monetaria	11	1	10	11.7	11.76	13.32	12.26
Bauhinia cheilantha	6		6	6.38	7.84	7.70	7.31
Mimosa tenuiflora	5	1	4	5.32	3.92	5.62	4.95
Pseudobombax simplicifolium	5	3	2	5.32	5.88	4.04	5.08
Senegalia piauhiensis	5		5	5.32	5.88	6.42	5.87
Senegalia lewisii	5		5	5.32	7.84	6.42	6.53
Calliandra spinosa	4	2	2	4.26	3.92	3.55	3.91
Spondias tuberosa	3	2	1	3.19	5.88	2.26	3.78
Cnidoscolus bahianus	2	2		2.13	1.96	0.98	1.69
Annona vepretorum	2	1	1	2.13	3.92	1.77	2.61
Myracrodruon urundeuva	2	1	1	2.13	3.92	1.77	2.61
Strychnos parvifolia	2	2		2.13	1.96	0.98	1.69
Tabebuia chrysotrichus	1		1	1.06	1.96	1.28	1.43
Cordiera concolor	1		1	1.06	1.96	1.28	1.43
Guapira opposita	1	1		1.06	1.96	0.49	1.17
Coursetia rostrata.	1	1		1.06	1.96	0.49	1.17
Esenbeckia febrifuga	1	1		1.06	1.96	0.49	1.17
Total	94	26	68	100.0	100.0	100.0	100.0

In which: N = Number of individuals, NCl1 = number of individuals in class 1, NCl2 = number of individuals in class 2, RD = relative density, RF = relative frequency, Natural Regeneration Relative Size Class index (NRRSCi), TNR = total natural regeneration.

When analyzing the H' dynamics, it can be observed that the treatments Con and SCDBH differed statistically from CC in 2015 before the implementation of the management. Then in 2017, with only two years of regeneration, the CC treatment showed a statistical difference with all treatments, because this was the most invasive intervention. However, there was no significant difference between treatments five years after cutting in 2020. It is noticed that the CC treatment returned to the level before the management, the others had a reduction in 2017, but already show a recovery movement in 2020. A reduction in the H' of all treatments in 2017 is noteworthy (Table 4). This was probably due to the low rainfall that occurred in the first quarter of the year (147 mm) when data collection was carried out, compared to 2015 (205 mm) and 2020 (558 mm).

Table 4. Shannon-Weaver Diversity Index (H') and number of stump regrowth sampled in Caatinga Arborea subjected to forest management.
Tabela 4. Índice de Diversidade de Shannon-Weaver (H') e número de rebrotas amostradas na Caatinga Arbórea submetida ao manejo florestal.

Variables	**Treatments**	**Years**		
		2015	**2017**	**2020**
H'	Con	3.068aA	2.114cB	2.630bA
	CC	2.83aB	2.345bA	2.670aA
	SCDBH	3.187aA	2.087cB	2.696bA
	SCS	2.991aAB	2.097cB	2.493bA
Number of stump regrowth	Con	1.1aA	4.6aA	0.9aA
	CC	0.4bA	7.7aA	0.3bA
	SCDBH	0.5bA	5.9aA	0.4bA
	SCS	0.6bA	4.5aA	0.8bA

In which: Con = control, CC = clear cutting, SCDBH = selective cutting by minimum diameter, SCS = selective cutting by species. Means followed by the same lowercase letter in the row and uppercase in the column do not differ from each other by the t-test at 5% probability.

With the exception of Con, the treatments showed a statistical difference between 2017 and the years 2015 and 2020 regarding the number of sprouts. A difference can be observed between CC and SCS and the other treatments in 2015. After the interventions, in 2017, only CC showed a difference. However, in 2020, no treatment was statistically different (Table 4).

C. schwackeana, *L. rigida* and *M. principis* were not sampled in the 2015 and 2017 samples, and were therefore recruited.

When analyzing the similarity dendrogram (Figure 3), it can be seen that there is floristic similarity between the years 2015 and 2020, which demonstrates a recovery five years after installing the experiment.

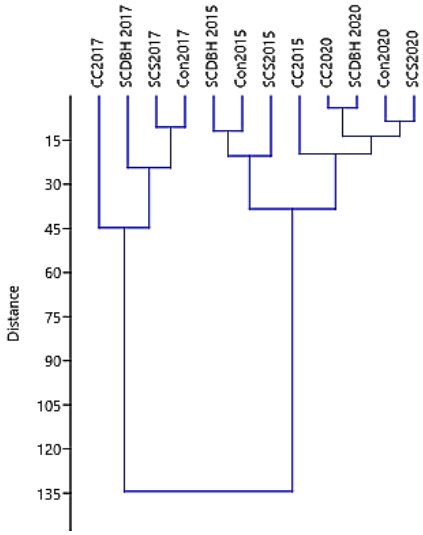

Figure 3. Cluster analysis by the Ward method of the treatments in the years 2015, 2017 and 2020, in which: Con = control, CC = clear cutting, SCDBH = selective cutting by diameter at breast height, and SCS = selective cutting by species.

Figura 3. Análise de agrupamento pelo método Ward dos tratamentos nos anos de 2015, 2017 e 2020, em que: Con = testemunha, CC = corte raso, SCDBH = corte seletivo por diâmetro na altura do peito e SCS = corte seletivo por espécie.

The CC treatment obtained the most species with positive FEI in the period from 2015 to 2017: *A. vepretorum*, *B. brevipes*, *C. yco*, *C. monetaria*, *C. rostrata*, *C. floribundus*, *M. ophthalmocentra*, *S. piauhiensis* and *S. tuberosa*. It is worth noting that *C. yco*, *C. floribundus* and *S. tuberosa* only presented this result in CC. Another favored species was *A. vepretorum*, which increased its representativeness only in the most invasive treatments (CC and SCDBH). Only three species had a positive FEI in all treatments (*B. brevipes*, *C. monetaria* and *S. piauhiensis*), therefore being, indifferent to the degree of intervention. The SCDBH treatment obtained the highest number of species (7) regarding the negative FEI, highlighting that *A. quercifolius*, *E. daphnites*, *M. urundeuva* and *S. glandulatum* had this result only in this treatment.

In Table 5 it can be seen that the vast majority of species were eliminated from the forest structure (FEI = 0 and A1 = 0) or remained stable in the stand (FEI = 0 and NRr = 0) between 2015 and 2017. This pattern is similar considering 2017 and 2020 (Table 5), however with fewer species eliminated from the forest structure compared to 2015 and 2017. Another highlight is related to the positive FEI, with fewer species occupying the spaces of others, which demonstrates greater competition between species.

Table 5. Number of species per natural regeneration category of the Floristic Expansion Index of the Arborea Caatinga, in an area subjected to management in the Contendas do Sincorá National Forest, Bahia, Brazil.

Tabela 5. Número de espécies por categoria de regeneração natural do Índice de Expansão Florística da Caatinga Arbórea, em área submetida ao manejo na Floresta Nacional Contendas do Sincorá, Bahia, Brasil.

Period	Treatment	Positive FEI	Negative FEI	NRr = 100% and low FEI	Low FEI	FEI = 0 and A1 = 0	FEI = 0 and NRr = 0
2015 to 2017	Con	5	4	0	2	66	49
	CC	9	1	0	5	63	54
	SCDBH	5	7	0	3	62	51
	SCS	4	5	0	0	67	55
2017 to 2020	Con	1	3	0	1	42	46
	CC	2	4	0	1	40	42
	SCDBH	1	4	0	1	45	40
	SCS	0	4	0	0	47	45

In which: Con = control, CC = clear cutting, SCDBH = selective cutting by diameter at breast height, SCS = selective cutting by species, FEI = Floristic Expansion Index, NRr = natural regeneration rate, and A1 = final abundance.

DISCUSSION

The species which were present in all treatments are considered important for establishing natural regeneration processes because they are considered highly resistant to environments with some human intervention. In addition, the semi-arid region faces dry and drought periods, which can motivate the dominance of species which are more resistant to limiting conditions. *M. carthagenensis* and *C. schwackeana* were only sampled in the CC treatment. These species are classified as pioneers, and need larger amounts of light to germinate, therefore they have adapted to the environment with direct light incidence. *M. carthagenensis*, which is found in almost all of the Brazilian semi-arid region, has the characteristic of being able to vegetate in different soil types, in addition to being highly resistant to drought, as it has roots with a large reserve capacity. On the other hand, species which grow under a canopy or dense vegetation cover generally do not require much light, which explains the presence of *M. principis* and *L. rigida* species, which were only identified in the Con treatment.

In a study carried out in the same experimental area in 2015, Paula *et al.* (in press) found 771 individuals belonging to 53 morpho-species, 22 families and 37 genera. In 2017, 1,164 individuals were sampled, distributed in 24 genera and 14 families. The increase in density after two years of management occurred due to spaces and gaps that help to increase germination, consequently promoting higher regenerating densities. There was subsequently a reduction in the number of individuals in 2020, thus corroborating Souza *et al.* (2019), who observed that the longer the interval of time elapsed between the intervention and the measurement, the lower the density in analyzing the influence of time on the number of individuals in the explored Caatinga area.

Management practices did not have a negative impact on the floristic richness of natural regeneration, considering the species which had greater representation in the regeneration percentage. Another result that corroborates this statement lies in the fact that only two species are only present in the control treatment, demonstrating that the area recovers well even after the performed interferences. The *M. tenuiflora* and *C. conduplicatus* species are recognized as pioneers in the Caatinga biome areas which have undergone environmental changes. These species have the ability to colonize areas with more severe environmental conditions due to their greater pioneering degree and because they are more specialized in inhabiting early succession stages (LUCENA *et al.*, 2018). In an area of arboreal-shrubby Caatinga, *M. tenuiflora* and species of the *Croton* genus were the most important for regeneration when the total natural regeneration parameter was evaluated (LUCENA *et al.*, 2017).

With the exception of Con, all treatments showed an increase in the stump regrowth number in 2017. This result was due to cutting individuals, increasing open spaces and the possibility of stump regeneration due to less competition in the managed areas. There was a reduction in regrowth and a greater number of individuals from seeds after five years of intervention.

The presence of *E. febrifuga* species decreased considerably in relation to the study carried out by Paula *et al.* (in press). A total of 31 individuals were registered in all treatments in the first survey, while only one individual was sampled in this survey. According to Alves Junior *et al.* (2013), the reduction in density over time may show evidence that species from the Caatinga do not have continuous recruitment. *M. carthagenensis*, common in studies in the Caatinga and which requires light (SÁTIRO; ROQUE, 2008), was only sampled with one individual in this survey.

When analyzing the similarity dendrogram, it is observed that the survey carried out in 2017 was distinguished by the clearings generated by management, giving greater advantage to pioneer species which are more adapted to disturbed habitats. The germination of the seed bank in the soil is an important factor that made this recovery possible, since 2020 presented the highest values in analyzing the regeneration rates in all treatments. For example, *C. monetaria* presented several regenerating individuals in all treatments in 2020. This species has always been recorded in semi-arid environments, typical of the Caatinga (LOIOLA; SOUZA, 2014) and the genus is a colonizer of disturbed areas (SILVA *et al.*, 2012).

CONCLUSION

- Treatments did not affect regeneration diversity after five years of intervention.
- Stump regrowth was very important at the beginning of regeneration after two years of management. Recruitment by seed sprouting was subsequently more relevant.
- Management practices did not have a negative impact on the floristic richness of natural regeneration, demonstrating that the area recovers well even with the interference carried out in the area.

REFERENCES

ALVES JUNIOR, F. T.; FERREIRA, R. L. C.; SILVA, J. A. A.; MARANGON, L. C.; CESPEDES, G. H. G. Regeneração natural de uma área de caatinga no sertão Pernambucano, nordeste do Brasil. **Cerne**, Lavras-MG, v. 19, n. 2, p. 229-235, jun. 2013.

ÁVILA, M. A.; SOUZA, S. R.; VELOSO, M. D. M.; SANTOS, R. M.; FERNANDES, L. A.; NUNES, Y. R. F. Structure of natural regeneration in relation to soil properties and disturbance in two swamp forests. **Cerne**, Lavras-MG, v. 22, n. 1, p. 1-10, mar. 2016.

HAMMER, Ø.; HARPER, D. A. T.; RYAN, P. D., PAST: Paleontological statistics software package for education and data analysis. **Palaeontologia Electronica**, [S.L.], v. 4, n. 1, p. 1-9, 22 jun. 2001.

IBGE. Instituto Brasileiro de Geografia e Estatística. Manual técnico da vegetação brasileira. 2. ed. Rio de Janeiro, 2012. 275 p. (Série manuais técnicos em Geociências, 1).

JARDIM, F. C. S. Índice de expansão florística na floresta equatorial de terra-firme. **Acta Amazonica**, Manaus-AM, v. 18, n. 3-4, p. 211-220, 1988.

LIMA JÚNIOR, C.; LIMA, R. L. F.; LIBERAL, B. G.; GUERRERO, J. R. H.; SAMPAIO, E. V. S. B.; MENEZES, R. S. C. Viabilidade Econômica do Uso Energético de Lenha da Caatinga sob Manejo Sustentável. **Revista Brasileira de Geografia Física**, Recife-PE, v. 8, n. 1, p. 156, 17 jun. 2015.

LOIOLA, M. I. B.; SOUZA, S. S. G. Ampliando o conhecimento sobre a flora fanerogâmica do Ceará. **Revista do Museu de Biologia Mello Leitão**, Santa Teresa-ES, v. 36, p. 137-148, 2014.

LUCENA, M. S.; ALVES, A. R.; BAKKE, I. A. Regeneração natural da vegetação arbóreo-arbustiva de Caatinga em face de duas formas de uso. **Agropecuária Científica no Semiárido**, Patos-PB, v.13, n. 3, p. 212-222, 2017.

LUCENA, M. S.; ALVES, A. R.; BAKKE, I. A. Composição florística, diversidade e estrutura da vegetação arbóreo-arbustiva de Caatinga sob sistemas silviculturais. **Nativa**, Sinop-MT, v. 6, n. 5, p. 506, 4 set. 2018.

MAIA, J. M.; SOUSA, V. F. O.; LIRA, E. H. A.; LUCENA, A. M. A. Motivações socioeconômicas para a conservação e exploração sustentável do bioma Caatinga. **Desenvolvimento e Meio ambiente**, Curitira-PR, v. 41, n. 1, p. 295-310, 30 ago. 2017.

PAULA, A.; SILVA BRILHANTE, F.; BARRETO-GARCIA, P. A. B.; OLIVEIRA SOARES FILHO, A.; FONSECA, R. S. Florística e estrutura da regeneração natural de Caatinga Arbórea na Floresta Nacional Contendas do Sincorá, Bahia. **Agrarian**, Dourados-MS, v. 14, n. 53, p. 281-294, abr. 2022.

SÁTIRO, L. N.; ROQUE, N. A família Euphorbiaceae nas caatingas arenosas do médio rio São Francisco, BA, Brasil. **Acta Botanica Brasilica**, Brasília-DF , v. 22, n. 1, p. 99-118, mar. 2008.

SHEPHERD, G. J. **Fitopac versão 2.1: manual do usuário.** Campinas: Departamento de Botânica da Universidade Estadual de Campinas, 2010.

SHANNON, C. E.; WEAVER, W. **The mathematical theory of communication**. The University of Illinois Press, No. 49-11922, 1964.

SOUZA, M. P.; ALVES, A. R.; BAKKE, I. A.; LOPES, J. A.; SANTOS, W. S.; FERNANDO, E. M. P.; FREITAS, A. L.; AMORIM, F. S. Natural Regeneration Under Influence of Sustainable Management Plan in Caatinga. **Journal of Agricultural Science**, Ontario, v. 11, n. 10, p. 194, 15 jul. 2019.

SILVA, S. O.; FERREIRA, R. L. C.; SILVA, J. A. A.; LIRA, M. A.; ALVES JUNIOR, F. T.; CANO, M. O. O.; TORRES, J. E. L. Regeneração natural em um remanescente de caatinga com diferentes históricos de uso no agreste pernambucano. **Revista Árvore**, Viçosa-MG, v. 36, n. 3, p. 441-450, jun. 2012.

SILVA, E. M.; ANDRADE, E. M. G.; DANTAS, E. A.; LACERDA, R. R. DE A.; LOPES, K. P. Diagnóstico do uso de leguminosas em propriedades rurais no município de Aparecida-PB. **Revista Verde de Agroecologia e Desenvolvimento Sustentável**, Pombal-PB, v. 7, n. 3, p. 212 - 217, 28 nov. 2012.

VALENTIM, J. L. Ecologia numérica: uma introdução à análise multivariada de dados ecológicos. **Interciência**. Rio de Janeiro**,** ed. 2, p. 168, abr. 2012.