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HERB RECOVERY IN DEGRADED CAATINGA SITES ENRICHED WITH NATIVE TREES

REGENERAÇÃO HERBÁCEA EM ÁREAS DEGRADADAS DE CAATINGA ENRIQUECIDAS COM ÁRVORES NATIVAS

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ABSTRACT

Herb recovery was evaluated in degraded Caatinga sites protected from grazing and enriched with native trees, in Patos-PB state, Brazil. Treatments were randomized according to a block design with five treatments (no tree planting –T_0– or tree planting of three tree species in pure –T_1=*Poincianella pyramidalis*, T_2=*Mimosa tenuiflora* and T_3=*Cnidoscolus quercifolius* – or mixed balanced stands –T_4) and five replications of squared-144-m^2 plots with 36 seedlings developing in planting holes enriched with manure and chemical fertilizers, arranged in a 2 m x 2 m grid. Data were collected from September 2008 to October 2009. After this period, natural tree regeneration was still not observed, and tree canopy covered 15 to 49% of the soil and did not affect herb growth and species composition. Initial and final herb cover were 16% and 100%, respectively. The number of dicot herbs increased from five, mainly two Sida species, to 13 species, monocots were represented by one species only (*Aristida sp*.), and quantity of herb forage reached 3 ton/ha (2:1, dicot:monocot). Adjacent overgrazed plots kept the initial low level of herb cover and species composition. Animal deferment during one year allowed the increase in soil cover and plant diversity in degraded Caatinga sites into which planted tree seedlings established successfully. This management practice could be implemented to avoid further environmental degradation and recover degraded areas.
Keywords: tropical dry forest; *Poincianella pyramidalis*; *Mimosa tenuiflora*; *Cnidoscolus quercifolius*.

RESUMO

A recuperação do estrato herbáceo foi avaliada em áreas antropizadas de Caatinga protegidas de pastejo e enriquecidas com árvores nativas, em Patos - PB, Brasil. Os tratamentos foram aleatorizados de acordo com o delineamento em blocos casualizados com cinco tratamentos (Sem plantio –T_0– ou plantio puro de *Poincianella pyramidalis* –T_1–, *Mimosa tenuiflora* –T_2– ou *Cnidoscolus quercifolius* –T_3– ou misto das três espécies –T_4) e cinco repetições de parcelas quadradas de 144 m^2 com 36 mudas plantadas em covas no espaçamento 2 m x 2 m e enriquecidas com esterco e fertilizantes. Os dados foram coletados de setembro de 2008 a outubro de 2009. Após este período, ainda não havia regeneração arbórea natural, e as copas das árvores recobriam de 15 a 49% do solo e não afetavam o crescimento e a composição da comunidade herbácea. O estrato herbáceo recobria 16% e 100% do solo no início e final do período experimental, respectivamente, o número das dicotiledôneas herbáceas aumentou de cinco, majoritariamente duas espécies de Sida, para 13 espécies, as monocotiledôneas eram representadas por apenas uma espécie (*Aristida* sp.), e a quantidade de

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forragem herbácea atingiu 3 ton/ha (2:1, dicot:monocot). Parcelas adjacentes superpastejadas mantiveram os baixos níveis de cobertura e composição da comunidade herbácea. O acesso controlado de herbívoros por um ano permitiu o aumento da cobertura do solo e da diversidade de plantas em sítios degradados de Caatinga nos quais mudas plantadas de espécies arbóreas se estabeleceram com sucesso. Esta prática de manejo poderia ser implantada para evitar mais degradação ambiental e recuperar áreas degradadas.
Palavras-chave: floresta tropical seca; *Poincianella pyramidalis*; *Mimosa tenuiflora*; *Cnidoscolus quercifolius*.

INTRODUCTION

The main cause of environmental degradation is mismanagement of cleared land used for ranching and farming, practiced for centuries to supply products to human population (CUNHA; GUERRA, 2000; BUARQUE, 2002; SILVA et al., 2004). Environmental degradation is significant in the semiarid region of northeast Brazil, and results in low levels of ranching production, high risk of desertification, and depletion of fauna and flora (RODAL et al., 1998; SILVA et al., 2004).

Environmental status can be estimated by means of phytosociological parameters. According to Magurran (2003), phytosociology considers the spatial inter-relations of plant species, especially the quantitative aspects of composition, functioning, dynamics and distribution of the flora that ultimately result from a specific set of environmental conditions. This author explains that phytosociology is based on concepts of taxonomy, phytogeography and forestry, resulting in parameters such as species frequency and abundance, and diversity and importance value indexes of a community. These parameters may refer to specific communities, such as herbs, shrubs or trees, and the analysis of these numerical entities allows for the visualization of trends in plant succession and the development of management strategies.

Herbs represent a significant part of the Caatinga flora (ARAÚJO, 2003; ARAÚJO et al., 2005; SILVA et al., 2009). This community is exuberant during the rainy season, when soil moisture allows them to grow and complete their short life cycle and forage is abundant and nutritive. During the dry season senesced leaves from herbs (and from shrubs and trees, as well) are consumed by wild and domestic animals (LIMA et al., 2007; SANTOS et al., 2007), leaving the soil exposed to degrading agents if grazing pressure happens to be too high. Other tropical regions, such as the African Savanna (ONIFADE; AGISHI, 1988; NYAMUKANZA; SCOGINGS; KUNENE, 2008) and the Brazilian Cerrado (NASCIMENTO et al., 1989; PENSO et al., 2009) show this seasonal pattern of biomass quality and availability.

Although ecological succession takes place in degraded sites, its pathway may end in a new arrangement of species, quantitatively and qualitatively poorer than the observed before site degradation took place. In the Caatinga Biome, for example, Araújo Filho and Carvalho (1996) characterize succession as progressive when the legume tree *Mimosa tenuiflora* (Willd.) Poir. enriches the first phases of plant recovery of previously forested areas. In this case, environmental degradation is reversible and the expected climax will be similar to the former one in which tree stratum predominated over herbs and shrubs. In contrast, regressive succession occurs when herbs and Sida spp. predominate and trees no more re-colonize previously forested areas, generally due to human activities (e.g.: overgrazing and mismanagement of agricultural practices). In this case, environmental degradation is already at high level, and the climax tends to exclude woody species. In such situation, human intervention, such as the cessation of the action of degrading agents and the reintroduction of native species, may accelerate and assure tree re-establishment (FIGUEIREDO et al., 2012, RESENDE; CHAER, 2010).

Some Caatinga trees, such as *Poincianella pyramidalis* Tul., *Mimosa tenuiflora* and *Cnidoscolus quercifolius* Pohl, colonize anthropized Caatinga sites (ARAÚJO FILHO; CARVALHO, 1996; MAIA, 2004). There are reports of positive effects of trees on soil moisture, organic matter and chemical and physical attributes, as well as on herb cover and forage quality in many situations of temperate and tropical regions, including the Caatinga Biome [see comments and review on this issue by Franke and Furtado (2001)]. Thus, it is fair to hypothesize that, if successfully re-introduced in degraded Caatinga sites, trees may contribute to restore soil cover (by tree canopy and herbs) and organic matter (litterfall and root development), reducing the level of environmental degradation of the site.

This study evaluated recovery of herb soil cover and forage production under the canopy of planted

Poincianella pyramidalis, *Mimosa tenuiflora* and *Cnidoscolus quercifolius* in degraded Caatinga sites into which no animal was allowed to graze during one growing season.

MATERIAL AND METHOD

This study took place in two overgrazed sites (Site 1 and Site 2) located at the Núcleo de Pesquisa para o Semiárido (NUPEARIDO) Experimental Station/Federal University of Campina Grande, Patos-PB state, Brazil, from August 2008 to October 2009. In Site 1 (07°04'53" S, 37°16'11" W, 254 m above sea level) no grazing was allowed since March 2005, except from September to November 2008 when two horses consumed the accumulated herbaceous forage. Animal deferment in Site 2 (07°04'45" S, 37°16'26" W, 262 m asl) was practiced since August 2008. Both sites showed eroded soil and incipient tree and herb cover due to logging and overgrazing during approximately 30 years. In August 2008, there were one grass (*Aristida* sp.), five dicotyledonous herbs (*Chamaecrista diphylla*, *Lavandula* sp., *Sida cordifolia*, *Sida* sp.), and one unidentified Fabaceae colonizing these sites quite similarly.

The amount of rainfall from September 2008 to October 2009 totaled 1657 mm (INSTITUTO NACIONAL DE METEOROLOGIA, 2010) (Figure 1), contrasting with the expected annual average of 800 mm. Data in that Figure show fairly well the regional yearly pattern of the usual short vegetative season, characterized by higher levels of precipitation and lower temperatures in the first six months of the year.

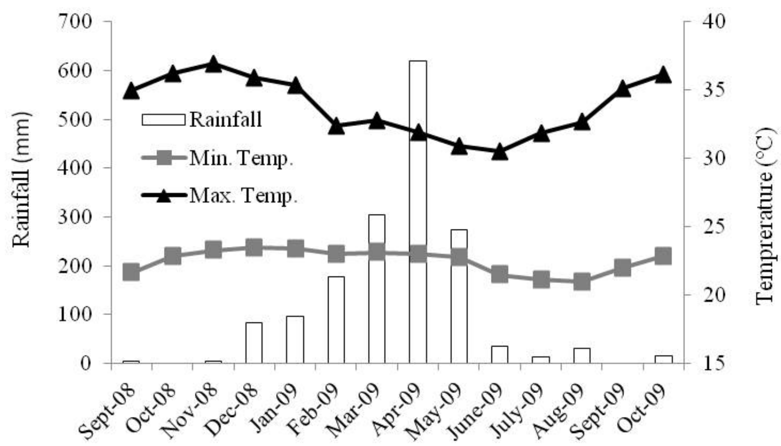

FIGURE 1: Monthly rainfall and minimum and maximum mean temperatures from September 2008 to October 2009, according to the Automatic Meteorological Station of the Instituto Nacional de Meteorologia (INMET) located at the Núcleo de Pesquisa para o Semiárido Experimental Station, Patos-PB, Brazil (INSTITUTO NACIONAL DE METEOROLOGIA, 2010).

FIGURA 1: Precipitação e temperaturas médias mínima e máxima mensal de setembro de 2008 a outubro de 2009, de acordo com a Estação Meteorológica Automática do Instituto Nacional de Meteorologia (INMET) localizada na Estação Experimental Núcleo de Pesquisa para o Semiárido, Patos - PB state, Brasil (INSTITUTO NACIONAL DE METEOROLOGIA, 2010).

From mid September 2008 to late January 2009, seedlings of each tree species (*Poincianella pyramidalis*, *Mimosa tenuiflora* and *Cnidoscolus quercifolius*) were grown in 4-L bags filled with soil and cattle manure (3:1, v:v) fertilized with 1.35 g of P, 4.81 g of K, and 40 mL of a solution containing 2.12 g of N/L.

Thirty-six planting holes/144 m^2 squared plots began to be dug in late August 2008 in a 2 m x 2 m grid, by means of a mechanical probe (30 cm θ) powered by a Massey Ferguson 275 tractor. Planting holes were manually enlarged to 40 cm x 40 cm, and 40 cm deep when soil conditions permitted. The soil of the experimental sites was loamy sand and showed limitations regarding pH, P content and thickness (Table 1).

TABLE 1: Chemical and physical attributes of the soil (0-20 cm) of the experimental sites, in October 2008, averaged from five soil samples collected in the five plots of each treatment.
TABELA 1: Médias dos atributos químicos e físicos do solo (0-20 cm) da área experimental, em outubro de 2008, obtidas de cinco amostras de solo coletadas nas cinco parcelas de cada tratamento.

Treat	pH	EC	P	Ca	Mg	K	Na	H+Al	CEC	SB	V
	$CaCl_2$,01M	dS/m	µ g/cm³	cmol$_c$ dm^{-3}							%
T_0	5.05	0.025	6.7	2.0	1.6	0.27	0.51	2.1	6.48	4.38	67.6
T_1	4.92	0.026	3.4	2.4	1.8	0.33	0.68	1.8	7.01	5.21	74.3
T_2	4.82	0.022	3.7	2.0	1.0	0.31	0.60	2.1	6.01	3.91	65.1
T_3	5.05	0.024	5.2	2.0	1.6	0.29	0.60	2.0	6.49	4.49	69.2
T_4	4.96	0.022	4.1	2.2	1.4	0.32	0.57	1.9	6.39	4.49	70.3

Treat	Thickness	Granulometry			Textural Class
	cm	%			USDA
		Sand	Silt	Clay	
T_0	39.6	82.0	11.2	6.8	Loamy sand
T_1	24.8	83.6	10.0	6.4	Loamy sand
T_2	36.5	81.6	10.0	8.4	Loamy sand
T_3	30.8	84.4	8.8	6.8	Loamy sand
T_4	27.2	80.8	10.0	9.2	Loamy sand

Where in: Treat=treatment; pH=potential of hydrogen; EC=electric conductivity, P=phosphorus; Ca=calcium; Mg=magnesium; K=potash; Na=sodium; H+Al=hydrogen+ alumínium; CEC=cation exchange capacity; SB=sum of bases; V=base saturation; Mean soil thickness (A, B and C soil layers) based on four central planting holes of three plots of each treatment (12 planting holes for each treatment).

Goat manure (20 L = 5.8 kg sun-dried basis) was mixed to the soil of each planting hole in December 2008 along with P and K (4.37 and 2.24 g/hole, respectively). Manure additions to bags and planting holes were equivalent to 15.2 ton/ha, and P, K and N additions totaled, respectively, 14.3, 17.6 and 0.2 kg/ha.

A 1-m diameter circle around each planted seedling was weeded in March and May 2009, and most of the Sida cordifolia L. and Sida sp. plants were uprooted manually in May 2009 from the tree-planted plots, and the resulting biomass remained on each plot for soil protection.

Treatments were allocated to plots according to a randomized complete-block design with five treatments (T_0=control=no seedling planting, and planting of T_1=*Poincianella pyramidalis*, T_2=*Mimosa tenuiflora*, T_3=*Cnidoscolus quercifolius* in pure and T_4=mixed balanced stands) and five replications (Blocks 1 and 2 were located in Site 1 and blocks 3, 4 and 5 in Site 2). Data sets (herb and tree soil cover, and quantity and quality of herb biomass) were analyzed by the ANOVA technique. There were 4, 4 and 16 degrees of freedom for Treatments, Blocks and Error, respectively (GOMES, 2003). However, biomass data were not collected in block 1, and then 4, 3 and 12 degrees of freedom were assigned to Treatments, Blocks and Error, respectively. Treatment means were compared by the Tukey test. Homocedasticy between treatment variances and normal distribution of errors were tested and no data transformation was deemed necessary.

Collection of phytosociological data took place in three randomly assigned circular 3.1416 m²-subplots in the central 64 m² area of each plot where 16 seedlings were planted or in adjacent overgrazed similar six control subplots (three of them close to Site 1 and three close to Site 2). Sampled areas totaled, respectively, 235.62 m² and 18.85 m² in experimental plots and in adjacent subplots.

The plants for each dicot herbs in subplots were counted in September 2008, and in March, July and October 2009. Vegetative and fertile materials were collected and sent to 'Herbário Jayme Coelho de Morais/CCA/UFPB', where exsicata were prepared and stored, and species identification were achieved by the taxonomist Leonardo Pessoa Félix/Universidade Federal da Paraíba/CCA/Herbário Jaime Coelho de

Morais-Areia-PB, Brazil.

Phytosociological parameters [Relative abundance (ABR_i) and frequency (FR_i), and importance value index (IVI_i) for each dicot herb species, and dicot herb diversity (Shannon-Wiener Index = H')] were estimated according to Rodal, Sampaio and Figueiredo (2013):

$$ABR_i = \frac{AB_i}{N} * 100$$

Where in: AB_i = number of sampled plants of the i-th dicot species, and N = total number of sampled dicot plants.

$$FR_i = \frac{FA_i}{\sum_{i=1}^{p} FA_i} * 100$$

Where in: FA_i = absolute frequency of the i-th dicot species in the sample.

$$IVI_i = ABR_i + FR_i$$

Where in: p_i = number of sampled plants of the i-th dicot species/total number of sampled dicot plants, and Ln = natural logarithm.

Forage quantity and quality from monocot and dicot herb species were evaluated in June 2009 in blocks 2, 3, 4 and 5. An iron frame 1.0. m long x 0.25 m wide was randomly placed in three points of the central 64-m^2 of each plot, and the herb material in the frame was cut 5 cm above soil surface. Fresh biomass of monocot and dicot herb species was separated and expressed in kg/hectare. Then, the monocot material collected from the 3 subplots of each plot was mixed, homogenized, sampled (~300 g), dried in a forced air circulation oven (65° C, 72 hours), ground and analyzed for dry matter (DM), neutral and acid detergent fiber (NDF and ADF), hemicellulose (HM), crude protein (CP) and ashes (SILVA; QUEIROZ, 2002). Similar procedures were performed on sampled dicot forage. There was no significant amount of forage in the overgrazed adjacent sub-plots.

RESULTS AND DISCUSSION

Soil cover from herbs and tree canopy averaged 16% in September 2008 (actually only herbs, as there were no trees in the plots of both sites) and 100% in October 2009 considering the 25 plots protected from grazing. In October 2009, natural tree regeneration was not observed in any plot, and soil cover by tree canopy differed between tree planting treatments ($p < 0.01$) and ranged from 15% (T_1= *Poincianella pyramidalis* and T_3= *Cnidoscolus quercifolius*) to 49% (T_2= *Mimosa tenuiflora*). However, tree cover did not affect growth and species composition of the herbaceous community**.** Thus, data on the number of dicot plants and species of the 25 plots protected from grazing were analyzed jointly. The number of dicot plants ranged from 2.04 to 5.47 plants/m^2 during the dry season (September 2008 and October 2009) or by the end of the growing season (July 2009), while in the middle of the growing season (March 2009) it ranged from 8.0 to 13.09 plants/m^2 (Table 2).

There were 1003, 2415, 1131 e 616 dicot herb plants in the 235.62 m^2 of the plots protect from grazing, respectively, in September 2008, and in March, July and October 2009, or, equivalently, from 2,61 to 10.25 plants/m^2 (Table 3). These values are less than the equivalent to 38.1 herb plants/m^2 (based on a 105 m^2 sample) reported by Araújo et al. (2005) for a Caatinga) site in the 'Agreste' region of Pernambuco, Brazil. They are also less than the equivalent to 124 or 184 herb plants/m^2 (based on two 120 m^2 samples) reported by Maracajá and Benevides (2006) in, respectively, a semi-preserved or a non-preserved hiperxerophilous open Caatinga site, previously grazed by ruminants, in Caraúbas (RN state), Brazil.

Dicot herbs density in the grazed plots was five to twenty times greater than the respective density observed in the plots where grazing was not allowed (Table 3), but composed mainly by the two unpalatable *Sida* species. This trend resulting from grazing was also observed by Andrade et al. (2009). It is probable that there are few developed plants/m^2 in ungrazed plots and many small plants/m^2 in grazed plots. This possibility should be considered in future studies.

TABLE 2: Number of dicot herbs/m² according to dates and blocks in two degraded Caatinga sites, protected from or exposed to grazing, Patos-PB state, Brazil.

TABELA 2: Número de dicotiledôneas herbáceas/m² de acordo com as datas e blocos em duas áreas degradadas da Caatinga, protegida ou exposta ao pastejo, Patos - PB, Brasil.

	Site 1 (protected from grazing)			Site 2 (protected from grazing)		
	Blocks			Blocks		
Month/year	1	2		3	4	5
Sept/08	4.03[1]	4.12		4.54	4.35	4.24
March/09	13.09	10.44		10.72	9.00	8.00
July/09	5.47	5.24		3.44	4.90	4.94
Oct/09	3.44	2.93		2.04	2.59	2.08
	Site 1(exposed to grazing)			Site 2 (exposed to grazing)		
Sept/08	58.25[2]	48.70	48.38	35.01	32.47	34.38
March/09	59.84	48.06	54.43	49.34	53.48	51.57
July/09	52.84	56.34	53.48	49.34	50.61	45.84
Oct/09	63.66	56.34	58.89	49.97	52.52	46.79

Where in: *Average from data collected in five plots protected from grazing and present in each block; [2]Each value based on data collected from individual plots exposed to grazing and adjacent to the indicated site.

The total number of dicot herbs sampled in 235.62 m² in Site 1 and Site 2 (no grazing allowed) in the four dates represented 33 species (Table 3), from which 12 could not be clearly identified and were classified as morphospecies, and 21 could be identified and were distributed in 18 genera and 15 families. The total number of species was higher than those reported in Caatinga studies by Sizenando Filho et al. (2007) (12 species from 8 families in a less anthropized site, and 16 species from 10 families in a more degraded site), Costa and Araújo (2003) (19 morphospecies) and Moreira et al. (2006) (28 species from 16 families in a grazed Caatinga site), and lower than the observed by Araújo et al. (2005) (62 species from 36 families), Andrade et al. (2009) (40 species from 21 families) and Silva, Araújo e Ferraz (2009) (78 species from 32 families in an alluvial preserved site, and 69 species from 31 families in an upland preserved site). Comparing to the low number of herb species (6 species) observed in the grazed plots, these data suggest that less degraded sites show more species than more degraded sites, and confirm the richness of herb species in the Caatinga Biome.

Initially, five dicot species were observed in the ungrazed plots, and this number increased to ten species in October 2009, seven of them were absent in the initial sample (Table 3). Additionally, in September 2008, more than 99% of the counted herbs were two unpalatable *Sida* species, while in October 2009, four of the seven observed new species are palatable to ruminants (*Gomphrena* sp., *Cleome tenuiflora* (Mart & Succ.) H. H. Hiltis, *Mollugo verticillata* L. and *Turnera ulmifolia* L.). Although the number of dicot species observed in the grazed plots increased from three in September 2008 to six in October 2009, only one of these new ones is palatable to ruminants. This difference in the number and palatability of the observed new species certainly result from differences in grazing pressure.

The two Malvaceae species were by far the most abundant species, and represented 57% of the sampled herbs from ungrazed plots, and 73% of the sampled herbs from grazed plots. From the 15 identified families sampled from plots not exposed to grazing, 11 were represented by one species, three (Amaranthaceae, Malvaceae and Turneraceae) by two species, and one (Fabaceae) by four species (plus one morphospecies). All genera were represented by one species, except Centrosema (Fabaceae), Sida (Malvaceae) and Turnera (Turneraceae) that showed two species. Twenty-three species were observed only in one of the dates, while *Lavandula* sp., *Sida cordifolia* L. and *Sida* sp. were observed in all four dates. Certainly, this resulted from species differences in the velocity of germination, growth and phenological phases (ARAÚJO; FERRAZ, 2003). In the adjacent overgrazed plots, only six dicot herbs species endured

TABLE 3: Density of dicot herbs observed in degraded Caatinga sites protected from or exposed to grazing, classified by family and species, in four dates, and potential for forage production, Patos-PB, Brazil.

TABELA 3: Densidade de dicotiledôneas herbáceas observados em áreas degradadas da Caatinga protegidas ou exposta ao pastejo, classificadas pela família e espécie, em quatro datas, e potencial de produção de forragem, Patos - PB, Brasil.

Sites protected from grazing					
Family Scientific name (common name)	Density (plant/m^2)				Forage*
	Sept/08	March/09	July/09	Oct/09	
AMARANTHACEAE					
Gomphrena sp.	0	0.11	0	0.06	yes
Froelichia lanata Moq.	0	0.83	0.01	0	yes
ASTERACEAE					
Bidens sp. (carrapicho)	0	0	0	0.01	no
BORAGINACEAE					
Heliotropium procumbens Mill.	0	0	0	0.03	no
CLEOMACEAE					
Cleome tenuifolia (Mart. & Succ.) H. H. Hiltis	0	0	0	0.24	yes
CONVOLVULACEAE					
Jacquemontia heterantha (Nees & Mart.) Hallier	0	0.44	0.02	0	yes
EUPHORBIACEAE					
Croton hirtus L'Hér.	0	0.68	0	0	no
FABACEAE					
Centrosema brasilianum (L.) Benth.	0	0	0.07	0	yes
Centrosema sp. (feijão-bravo)	0	~0	0	0	yes
Chamaecrista diphylla (L.) Greene	0.03	0	0	0	yes
Senna obtusifolia (L.) Irwim & Barneby (*m*ata-pasto)	0	0.39	0.17	0	yes
Morphospecies 12	0.03	0	0	0	nd*
LAMIACEAE					
Lavandula sp. (alfazema brava)	0.14	0.62	0.53	0.08	no
LYTHRACEAE					
Cuphea campestris Mart. ex Koehne	0	0.03	0	0	+
MALVACEAE					
Sida cordifolia L. (malva branca)	3.97	1.30	1.13	1.31	no
Sida sp. (Malva)	0.09	2.85	1.42	0.59	no
MOLLUGINACEAE					
Mollugo verticillata L.	0	0	0	(0.04	yes
NYCTAGINACEAE					
Boerhavia coccinea Mill. (pega-pinto)	0	0.22	0	0	yes
PASSIFLORACEAE					
Passiflora foetida L.	0	0	0	0,24	no
PORTULACACEAE					
Portulaca oleracea L.	0	0.03	0	0	no
TURNERACEAE					
Turnera ulmifolia L. (chanana)	0	0.04	0.04	0.01	yes
Turnera subulata Sm.	0	~0	0	0	yes
Morphospecies 1	0	2.46	~0	0	nd
Morphospecies 2	0	0.06	0	0	nd
Morphospecies 3	0	0	0.73	0	nd
Morphospecies 4	0	~0)	0	0	nd
Morphospecies 5	0	0.02	0	0	nd
Morphospecies 6	0	0	0.04	0	nd
Morphospecies 7	0	0	0.03	0	nd
Morphospecies 8	0	0	0.16	0	nd
Morphospecies 9	0	0	0.42	0	nd
Morphospecies 10	0	0.14	0	0	nd
Morphospecies 11	0	0.01	0	0	nd
ASTERACEAE					
Bidens sp. (carrapicho)	0	0	0	0.11	no
FABACEAE					
Senna obtusifolia (mata-pasto)	0	2.71	2.44	2.65	yes
MALVACEAE					
Sida cordifolia L. (malva branca)	26.5	24.3	24.3	24.6	
Sida sp. (malva)	15.9	24.4	20.2	22.7	no
NYCTAGINACEAE					
Boerhavia coccinea Mill (pega-pinto)	0	1.06	0.90	1.22	yes

Continued...

TABLE 3: Continued...
TABELA 3: Continuação...

Sites protected from grazing					
Family Scientific name (common name)	Density (plant/m^2)				Forage*
	Sept/08	March/09	July/09	Oct/09	
TURNERACEAE					
Turnera ulmifolia L. (chanana)	0.42	0.32	0.48	0.48	yes
Total of plants/m^2	42.9	52.8	51.4	54.7	
Number of species	3	5	5	6	

Where in: *"nd": unknown potential of forage production.

overgrazing. The low number of herb species and the predominance of the two unpalatable *Sida* species certainly result from grazing pressure, and show the negative effect of overgrazing on species richness. Also, the higher number of herb species on the protected areas (33 species) compared to only six species sampled in the grazed area shows the positive effect of animal deferment on herb recovery of degraded Caatinga sites.

In ungrazed plots, *Sida* species were uprooted manually in May 2009, and this contributed to the decrease in their number. However, it is possible that part of this decrease derived from interspecies competition, as other species were capable to grow in this protected environment. Predominance of *Sida* species in grazed plots does not necessarily mean that they are more adapted to dry tropical conditions than the other dicot herbs. Certainly, their predominance comes from their low palatability and the resulting low grazing pressure on them that ultimately increased their abundance and frequency over herbs that are more palatable.

Dicot herbs showing the highest relative abundance were the two *Sida* species (Malvaceae*)* (Figure 2), specially in the grazed plots, where *Sida cordifolia* relative abundance reached 61.9, 46.0, 53.4 and 50.4% in September 2008 and March, July and October 2009, respectively. The respective values for *Sida* sp. were 37.1, 46.2, 39.2 and 41.4%. Moreira et al. (2006) reported high abundance of *Sida* species, although at more modest values. Probably, this denotes the higher anthropization level of the experimental sites of the present study. Also, abundance of *Sida* species may mean that a process of regressive succession may be under way due to overgrazing, as apposed to the process of progressive succession, characterized by the presence of perennial species such as *Mimosa tenuiflora* and *Croton* spp. that leads to a climax when tree species will prevail (ARAÚJO FILHO; CARVALHO, 1996). In other studies that considered monocots and dicots in the Caatinga Biome, some of the families were similar to those listed in the present study, but the Malvaceae plants were surpassed by Poaceae, Cyperaceae, Asteraceae, Amaranthaceae, Lamiaceae, Fabacea and Rubiaceae representatives (ANDRADE et al., 2009; SIZENANDO FILHO et al., 2007; MARACAJÁ; BENEVIDES, 2006). It is possible that Poaceae abundance could be ranked first if this family were considered in the present study, but still the Malvaceae abundance would be ranked in second place, certainly due to the high level of environmental degradation on the plots of the present study.

Sida cordifolia and *Sida* sp. (Malvaceae) were the most frequent species (i.e.: with the best distribution), especially in the overgazed plots (Figure 3). These results differ from those by Andrade et al. (2009), Maracajá and Benevides (2006) and Sizenando Filho et al. (2007). These authors report that Amaranthaceae, Asterareae, Cyperaceae, Fabaceae, Lamiaceae, Poaceae and Rubiaceae species are the most frequent in the Caatinga Biome. Although many factors surely act on herb community, these differences in plant families may result from the high level of degradation present in the experimental area.

The relative frequency of these species tends to decrease during the rainy season (March to July), when environmental conditions favor the presence of more species in the herb community. Also, comparing the September 2008 (Figure 3 a) and October 2009 (Figure 3 d) relative frequency values, both estimated in the dry period of each year, it seems that the relative frequency of these *Sida* species decreased. For example, the relative frequency value of any of the two *Sida* species was 42.9% in September 2008 and 25.0% in October 2009, in grazed plots, although this trend was not observed for *Sida cordifolia* in ungrazed plots.

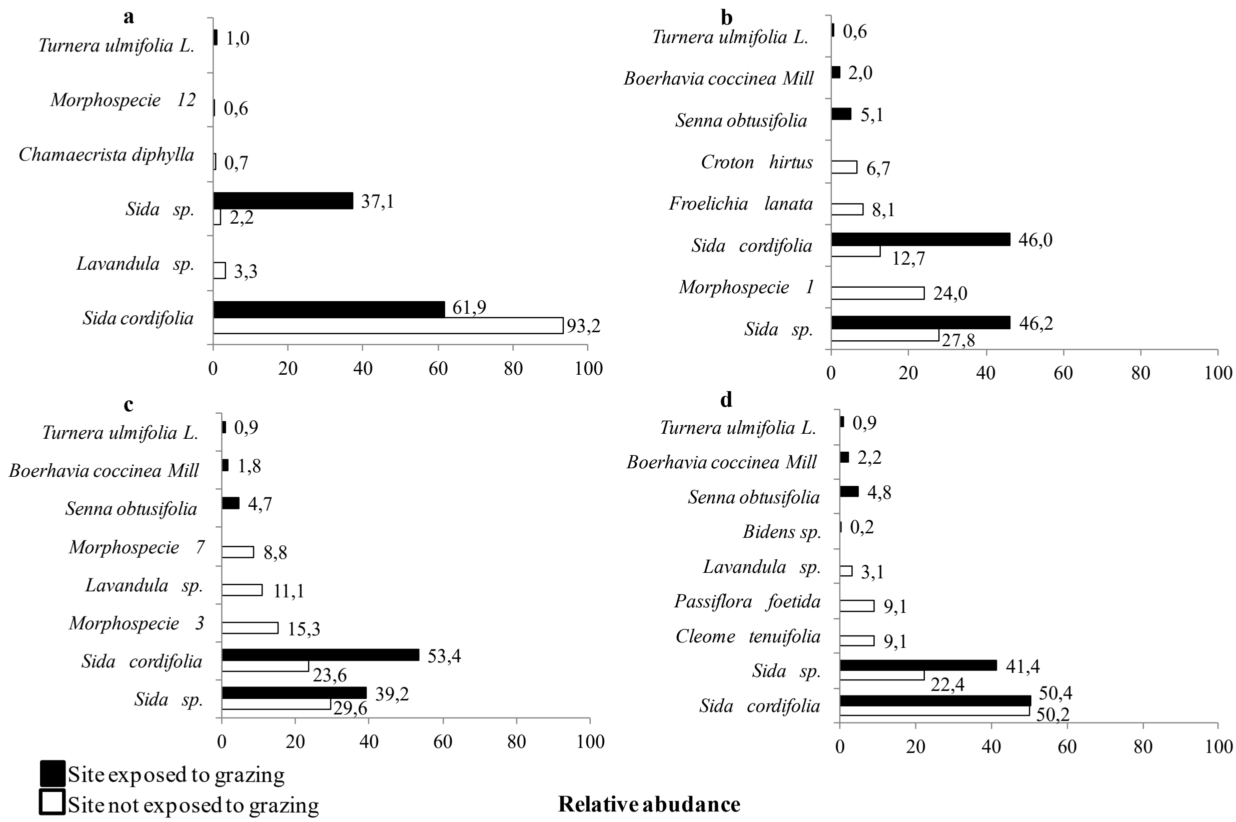

FIGURE 2: Relative abundance (%) of the main dicot species observed in four dates [a) September 2008, b) March 2009, c) July 2009 and d) October 2009], in degraded Caatinga sites not exposed to grazing and planted with three native tree species and exposed to grazing, Patos-PB state, Brazil.

FIGURA 2: Abundância relativa das principais espécies dicotiledôneas observadas em quator datas [a) setembro de 2008, b) março de 2009, c) julho de 2009 e d) outubro de 2009], em áreas degradadas de Caatinga não expostas ao pastejo e plantadas com três espécies arbóreas nativas e expostas ao pastejo, Patos -PB, Brasil.

This decrease may result not only from the effect of the manual control of the two *Sida* species performed in May 2009 in the ungrazed plots, but also from other factors such as the annual rainfall above average in two consecutive years (Figure 1). This condition should have contributed to other herbs to join the community, because the relative frequency of *Sida* species also decreased in the grazed plots from September 2008 to October 2009, regardless of no manual control of these species. Further studies are necessary to test if this trend continues and what factors are acting on the decrease of the relative frequency of these *Sida* species.

The differences in abundance and frequency values reported here and elsewhere may result from many factors such as soil type, fertility and moisture, air humidity, seed bank, and species richness of the Caatinga Biome, that allow for a variety of plant assemblages according to the environmental factors acting in each site.

Considering the ungrazed and grazed plots, dicot herbs with the higher IVI values in the four dates of data collection were the two *Sida* species (Malvaceae). For these species, IVI values were higher than 25. The low IVI values (IVI < 3.3) estimated for most of the other dicot species resulted from the presence of a few plants irregularly distributed in the area. The IVI decrease of *Sida cordifolia* in the ungrazed plots (from IVI = 127.01 to IVI = 77.63) shows that, additionally to the negative effect on IVI resulting from the intentional uproot of plants of these species, other species established in the area where no grazing

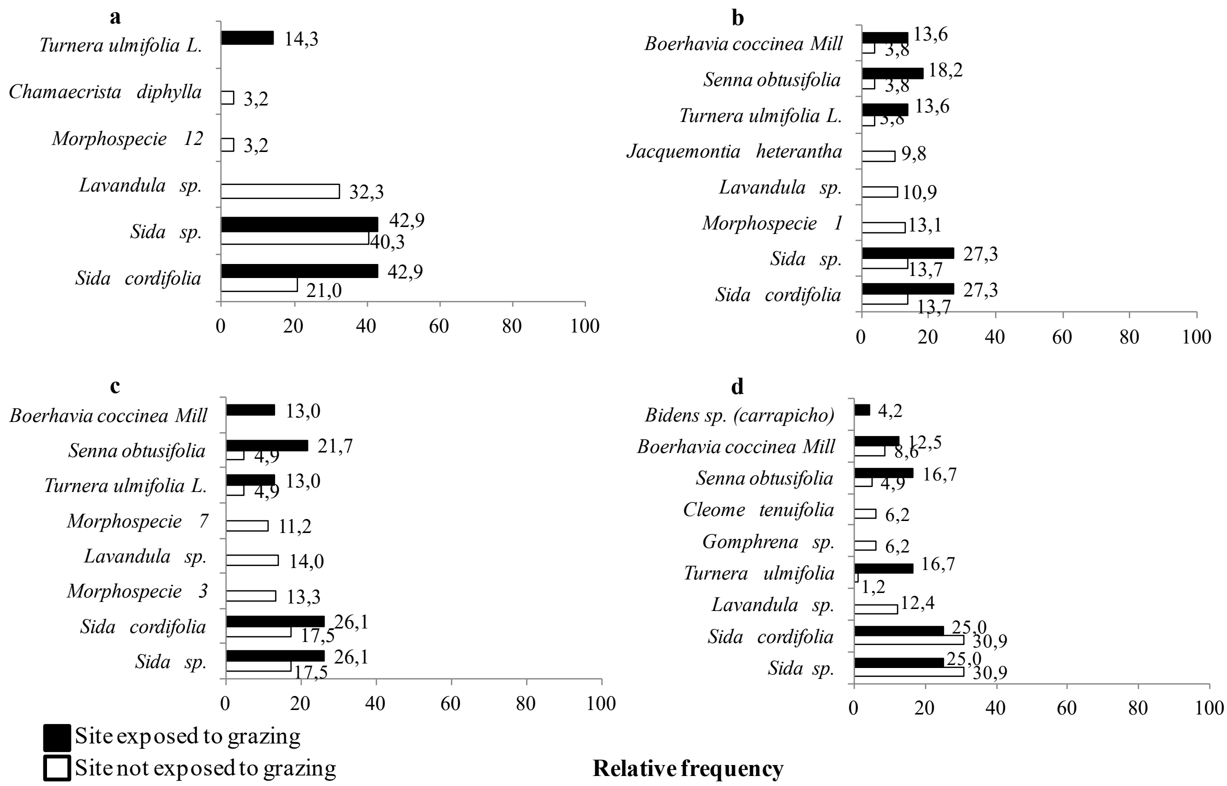

FIGURE 3: Relative frequency of the main dicot species observed in four dates [a) September 2008, b) March 2009, c) July 2009, d) October 2009], in degraded Caatinga sites not exposed to grazing and planted with three native tree species and exposed to grazing, Patos-PB state, Brazil.

FIGURA 3: Frequência relativa das principais espécies dicotiledôneas observadas em quatro datas [a) setembro de 2008, b) março de 2009, c) julho de 2009 e d) outubro de 2009], em áreas degradadas de Caatinga não expostas ao pastejo e plantadas com três espécies arbóreas nativas e expostas ao pastejo, Patos -PB, Brasil.

was allowed. This is corroborated by the IVI decrease of both Sida species in the adjacent plots where overgrazing continued: 104.74, 73.30, 76.46, and 75.44 for *Sida cordifolia*, and 79.99, 73.50, 62.29 and 66.42 for *Sida* sp., respectively in September 2008, and March, July and October 2009. Certainly, factors such as the high level of rainfall in two consecutive years benefited the establishment of new herbs species. Andrade et al. (2009) reported similar result for a species considered less palatable to ruminants, when reported IVI = 115.81 and 84.9 for *Aristida adscensionis* (Poaceae, monocot), respectively in sites with less preserved vegetation submitted to grazing and more preserved vegetation grazed during part of the year, showing a trend of IVI decrease from a worse to a better environmental scenery.

Diversity (H'=Shannon-Wiener index) of dicot herbs in September 2008 was considered low (Table 4), probably due to overgrazing. Although these H' values are higher than the reported by Sizenando Filho et al. (2007) and Lira et al. (2007), in general they showed to be similar (ARAÚJO et al., 2005) or lower (MARACAJÁ; BENEVIDES, 2006; ANDRADE et al., 2009) than those reported in Caatinga studies. After the peak observed in March 2009, in the middle of the rainy season, H' decreased in July and October 2009, however remained higher than the observed in September 2008, an increase in diversity certainly resulting from the protection of the area from grazing. This is corroborated by the constant low H' values in the overgrazed plots, and shows that barring the action of the degrading agents tends to restore diversity.

Herb biomass in June 2009 (end of the rainy season) was not affected ($p > 0.05$) by treatments (levels of tree planting) (Table 5). Total fresh biomass averaged 8527 kg/ha, and was composed by monocots and

TABLE 4: Floristic diversity (Shannon-Wiener's index = H') of herbaceous dicot species in two degraded Caatinga sites, protected from or exposed to grazing, Patos-PB state, Brazil.
TABELA 4: Diversidade florística (índice de Shannon-Wiener = H') de espécies dicotiledôneas herbáceas em duas áreas degradadas da Caatinga, protegidas ou expostas ao pastejo, Patos - PB, Brasil.

Date	H'	
	Sites protected from grazing	Sites exposed to grazing
September/08	0.29	1.00
March/09	2.08	0.98
July/09	1.90	0.96
October/09	1.48	1.00

TABLE 5: Partial results of the ANOVA on production and bromatological composition data sets of forage collected from herbs growing in degraded Caatinga sites protected from grazing and submitted to five levels[1] of tree planting with native species, Patos-PB state, Brazil.
TABELA 5: Resultados parciais da ANOVA dos dados de produção e composição bromatológica da forragem coletada das plantas herbáceas se desenvolvendo em áreas degradadas da Caatinga protegidas do pastejo e submetidas a cinco níveis[1] de plantio de árvores nativas, Patos - PB, Brasil.

Herb forage production													
		FB_T		FB_M		FB_D		DM_T		DM_M		DM_D	
SV	DF	SQ	F	SQ	F	SQ	F	SQ	F	SQ	F	SQ	F
Treat	4		1.98		0.32		1.93		1.29		0.23		1.75
Error	12	$7.5x10^7$		$3.9x10^7$		$10.5x10^7$		$9.3x10^5$		$60.0x10^5$		$8.2x10^5$	
Bromatological characteristics of herb forage													
Monocot													
		NDF		ADF		HC		CP		Ashes			
SV	DF	SQ	F	SQ	F	SQ	F	SQ	F	SQ	F		
Treat	4		1.5		0.9		1.0		2.01		2.0		
Error	16	389.2		182.3		218.2		0.299		32.3			
Dicot													
		NDF		ADF		HC		CP		Ashes			
SV	DF	SQ	F	SQ	F	SQ	F	SQ	F	SQ	F		
Treat	4		1.1		1.0		0.4		1.2		0.4		
Error	16	256.5		144.3		348.3		0.658		56.1			

Where in: [1]Experimental treatments: T_0=control=no tree planting, and planting of T_1=*Poincianella pyramidalis*, T_2=*Mimosa tenuiflora* and T_3=*Cnidoscolus quercifolius* in pure and T4=mixed stands. FB_T=total fresh biomass; FB_M=monocot fresh biomass; FB_D=dicot fresh biomass; DM_T=total dry mater; DM_M=monocot dry matter; DM_D=dicot dry matter; SV=source of variation; DF=degree of freedom; SQ=sum of squares; F=ANOVA's statististic of the Snedecor F test; NDF=neutral detergente fiber; ADF=acid detergente fiber; HC=hemicelulose; CP=crude protein.

dicots in a 1:2 weight ratio (Table 6). In a dry matter (DM) basis, overall mean was 3030 kg/ha, 42% from monocots and 58% from dicots. ARAÚJO FILHO et al. (2002b) report annual DM biomass production of 4000 kg/ha in the Caatinga Biome. However, not all biomass is available to animal consumption. Moreira et al. (2006) estimate that ruminants consume from 452 to 1369 kg/ha (DM basis). In a *Mimosa tenuiflora* plantation close to Site 2, Pereira, Pereira Filho and Arriel (1997) reported 2491 kg of herbaceous forage/ha (23% monocots and 77% dicots), while Araújo Filho et al. (2002a) collected 4085 kg of herbaceous forage/ha in an open Caatinga site. These data indicate that the applied management practices (tree planting and no grazing) allowed partial recovery of degraded Caatinga site. Further studies are necessary to determine the period of time and grazing pressure for the effective recovery of the potential of forage production.

Herb biomass quality was similar in control and in tree planted plots ($p > 0.05$) (Table 5). Neutral detergent fiber averaged 76.9% and 60.6% for monocot and dicots, respectively (Table 6). For ADF the respective averages were 47.3% and 44.7%. These NDF and ADF values characterize roughage fodder with high fiber content, especially those from monocot forage. However, these values are within the range reported by Moreira et al. (2006) and Pinto (2008), except for monocot NDF that showed to be higher in the present study, certainly due to the grass species (*Aristida* sp.) that is known to produce fibrous forage especially when collected at the end of the growing season (June).

Hemicellulose content, the proportion of fiber that can be digested by ruminants (i.e.: the difference between NDF and ADF contents) averaged 29.6% for the monocot and 15.9% for dicots. However, both types of fiber are important in the diet, as the high fiber and hemicelluloses content of monocots keeps the digestive apparatus of the ruminants working properly, and the low fiber and hemicellulose value in dicot forage means more cellular content that represents readily available nutrients (PINTO, 2008).

Overall CP content for monocots and dicots were 5.9% and 10.6%, respectively. The respective values for ashes were 7.9% and 8.6%. These values showed to be similar to those reported by Moreira et al. (2006), and lower than the ones by Pinto (2008). However, the degraded site in which this study took place maintained a reasonable qualitative potential as the observed mean for dicot CP is higher than the minimum

TABLE 6: Mean biomass production (kg/ha) and bromatological characteristics (% of DM) of herbs collected in June 2009 from degraded Caatinga sites protected from grazing and revegetated with five levels[1] of native tree planting, Patos-PB state, Brazil.

TABELA 6: Médias de produção (kg/ha) de biomassa e características bromatológicas (% da MS) de espécies herbáceas coletadas em junho de 2009 de áreas degradadas da Caatinga protegidas do pastejo e revegetadas com cinco níveis[1] de plantio de árvores nativas, Patos - PB, Brasil.

TREATMENTS[1]	Fresh biomass			Dry matter		
	Monocot	Dicot	Total	Monocot	Dicot	Total
T_0	2980.0	4506.7	7486.7	1271.7	1431.8	2703.5
T_1	3206.7	3286.7	6493.3	1395.7	1048.9	2444.6
T_2	2650.0	8540.0	11190.0	1374.7	2375.1	3749.7
T_3	2166.7	6793.3	8960.0	998.3	2207.6	3205.9
T_4	3500.0	5006.7	8506.7	1390.2	1657.1	3047.3
Overall means	2900.7	5626.7	8527.3	1286.1	1744.1	3030.2

TREATMENTS[1]	NDF		ADF		HC		CP		Ashes	
	Monocot	Dicot	Monocot	Dicot	Monocot	Dicot	Monocot	Dicot	Monocot	Dicot
T_0	74.9	58.2	45.5	42.5	29.4	15.7	7.3	11.0	7.8	9.4
T_1	74.5	59.8	47.2	45.3	27.4	14.5	5.4	9.9	8.5	8.1
T_2	81.4	60.5	49.4	45.6	32.0	14.9	5.8	11.0	7.0	8.8
T_3	76.9	61.3	47.9	44.6	29.0	16.7	5.3	10.6	9.0	8.2
T_4	76.6	63.3	46.8	45.7	29.9	17.6	5.5	10.4	7.1	8.3
Overall mean	76.9	60.6	47.3	44.7	29.5	15.9	5.9	10.6	7.9	8.6

Where: [1]Experimental treatments: T_0=control=no tree planting, and planting of T_1=*Poincianella pyramidalis*, T_2=*Mimosa tenuiflora* and T_3=*Cnidoscolus quercifolius* in pure and T4=balanced mixed stands. **NDF=neutral detergente fiber; ADF=acid detergente fiber; HC=hemicellulose; CP=crude protein.

7% value generally considered satisfactory to feed ruminants (PINTO, 2008).

CONCLUSIONS

The most abundant and frequent herb species were *Sida cordifolia* and *Sida* sp., however participation of other herbs increased along time.

Diversity of the herb species increased during the experimental period, indicating partial recovery of the herb community.

Biomass production from herbs was not affected by trees in the first growing season after planting *Poincianella pyramidalis*, *Mimosa tenuiflora* and *Cnidoscolus quercifolius*.

The quality and quantity of herb forage suggest that it is possible to reincorporate degraded Caatinga sites into the production system, although data collection should continue to determine herb recovery in years of less rain and under higher levels of soil cover by tree canopy.

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