J. Range Manage.
52:241–248 May 1999

Caatinga vegetation dynamics under various grazing intensities by steers in the semi-arid Northeast, Brazil

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Abstract

The effects of cattle grazing were evaluated on range dynamics of the Caatinga which is a deciduous dry woodland, covering most of the semi-arid Brazilian Northeast. Three stocking rates (SR) were studied (heavy, 1 steer 6.7 ha^{-1}; moderate 1 steer 10 ha^{-1}; light, 1 steer 13.3 ha^{-1}), in addition to an ungrazed exclosure (zero stocking). In the first phase (1978–81) each stocking rate was tested under continuous and deferred grazing. In the second phase (1981–84), deferred grazing was eliminated, so that pastures became replications of continous grazing. Six steers per pasture were used, and pasture size was used to vary stocking rate. There was no effect of stocking rate or grazing system period on the frequency of the herbaceous species. They were, however, influenced by rainfall in the period, and could be divided into 3 groups. Sixteen species increased with increasing rainfall during the last months of the rainy season, and reached the highest frequency in 1984. Eleven species also increased with increasing rainfall but reached the highest frequency in 1983. Rainfall had no effect on the frequency of 2 important species, *Herissantia crispa* (L.) Briz. and *Selaginella convoluta* Spring. Death rate of 5 shrubs (*Lippia microphylla* Cham., *Croton rhamnifolius* (Kunth em.) Mull. Arg. *Calliandra depauperata* Benth, *Cordia leucocephala* Moric., and *Bauhinia cheilantha* (Bong.) Steud.) decreased with decreasing stocking rate, 11.7, 9.3, 7.7, and 4.5%, respectively on heavy, moderate, light, and zero stocking. Death rates were higher in easily broken shrub species, *L. microphylla* and *C. leucocephala*. Stocking rate also influenced the height growth rate of the tagged shrubs, being respectively –2.7 and 9.8% for heavy and zero stocking. Mean density of shrubs and trees, determined by the Point-Centered Quarter Method, was respectively 21,109, and 447 plants ha^{-1} in 1982, and 13,230 and 401 plants in 1984; the main cause of the high shrub death (37.3%) was probably the 1982 drought. Density was not affected by stocking rate. Considering the 7 experimental areas separately, there was no regression between 1982 and 1984 shrub densities. There was, however, regression between 1982 density and the difference between 1982 and 1984 densities.

Key Words: tropical woodlands, stocking rate, native pastures, grazing system, shrubs and trees, herbaceous stratum, frequency.

The author wishes to thank Drs. José Givaldo G. Soares and Clovis Guimarães Filho, for their help in designing and setting up the study; Drs. Antônio de Pádua M. Fernandes, Mário de A. Lira and Dárdano de Andrade-Lima (in memoriam), for their support in the approval and setting up the research: Dr. João Ambrósio de Araújo Filho, for assistance in methodological procedures; Dr. Everardo V.S.B. Sampaio for reviewing this manuscript.

Published with the approval of CPATSA Publishing Committee.

Manuscript accepted 15 Aug. 1998.

Resumo

Estudaram-se 3 taxas de lotação anual (TL) (pesada, 1 boi 6,7 ha^{-1}; média, 1 boi 10,0 ha^{-1} leve, 1 boi 13,3 ha^{-1}), além de uma exclusão livre de pastejo (zero). Na 1ª etapa (1978–81), cada TL foi estudada sob 2 sistemas de pastejo, contínuo e rotacionalmente deferido com 3 subdivisões. Na 2ª etapa (1981–84), as subdivisões foram eliminadas, passando a ser repetições do pastejo contínuo. Usaram-se 6 bovinos machos por tratamento. Não houve influência nem da TL e nem do curto periodo de pastejo diferido na freqüência (FQ) das espécies (spp) herbáceas. A grande variação na precipitação anual se refletiu na FQ delas, as quais foram divididas em 3 grupos, sendo o principal deles formado por 16 spp muito influenciadas, para as quais houve correlação (P<0,05) entre os 2 parametros. Não houve efeito da precipitação na FQ de duas spp importantes (*Herissantia crispa* (L.) Briz. e. *Selaginella convoluta* Spring.). A mortalidade de 5 arbustos etiquetados (*Lippia microphylla* Cham., *Croton rhamnifolius* (Kunth em.) Mull. Arg., *Calliandra depauperata* Benth, *Cordia leucocephala* Moric. e. *Bauhinia cheilantha* (Bong.) Steud.) diminuiu com o decréscimo na TL, sendo 11, 7, 9, 3, 7, 7 e 4,5% respectivamente para Pesada Média, Leve e Zero, havendo diferença significativa entre pastejo e exclusão. Houve diferença (P<0,05) entre arbustos, sendo maior naqueles mais fáceis de serem quebrados como *L. microphylla* e *C. leucocephala.* A TL também influenciou significativamente no crescimento em altura, sendo respectivamente de –2,7 e 9,8% para Pesada e Zero. A densidade de arbustos e árvores, determinada pelo Método do Ponto Quadrante, foi respectivamente de 21.109 e 447 plantas ha^{-1} em 1982, e de 13.230 e 401 plantas ha^{-1} em 1984, sendo a grande mortalidade de arbustos (37,3%) no período 1982–84 provavelmente devido a grande seca de 1982, nao havendo influência da TL. Considerando-se as 7 áreas experimentais isoladamente, não houve regressão entre as densidades de arbustos de 1982 e 1984, havendo contudo regressão entre a densidade de arbustos em 1982 e a diferença entre as densidades de 1982 e 1984.

The Caatinga, a thorny, deciduous, dry woodland that covers most of the Brazilian Northeast, is dominated by woody plants, and may be a range with the highest density of shrubs and trees in the world. Most of the Caatinga types are shrub dominated, although as quoted by Sampaio (1995), some authors have claimed that most of the Caatinga area was orginally covered with trees. Most woody species are deciduous, and leaf litter represents an important source of forage in the dry season (Kirmse et al. 1987). In spite of being less sensitive to overgrazing than pastures dominated by herbaceous vegetation, the Caatinga has also been degradated (Vasconcelos Sobrinho 1949, Andrade-Lima 1981). Degradation was probably caused by shifting cultivation and fuel wood harvest because the Caatinga-covered region is densely populated. The paucity of grasses is one of its characteristics (Cole 1960), but there is evidence that the Caatinga invaded some formerly more open areas covered by grasses (Smith 1974), a situation analogous to those in USA and Australia, in which overgrazing resulted in establishment of woody plants (Herbel 1985, Harrington and Hodgkinson 1986).

Annual stocking rate (SR) is the most important factor in maintaining the stability of a native pasture. In Caatinga, a stocking rate of 15 ha head^{-1} of cattle is usually recommended (Banco do Nordeste do Brasil 1971, Rodrigues and Borges 1979). On most of the properties, however, cattle are associated with goats and sheep. Adjustments in stocking rate may be followed by adjustment in grazing system for range rest (Hickey 1977). Rotationally deferred grazing is designed to help degraded ranges recover (Sampson 1913).

This research was undertaken to study the effect of stocking rate and rotationally deferred grazing by cattle on the Caatinga of the semi-arid region of Pernambuco State, in the Brazilian Northeast.

Materials and Methods

The research was conducted at the Caatinga Experimental Station (CEC) (9°21' S Lat; 370 m altitude) of the Brazilian Agricultural Research Corporation (EMBRAPA)-Agricultural Research Center for Semi-Arid Tropics (CPATSA), in Petrolina municipality. The area has flat topography and red-yellow podzolic soils (Burgos and Cavalcanti 1991) with the following characteristics: pH = 5.8; Ca^{2+} + Mg^{2+} = 3.3 meq/100 g;/ Al^{3+} = 0.7 meq/100 g; P - 3 ppm. Annual potential evaporation is 2,630 mm, with a mean annual precipitation of 567 mm (Table 1). The vegetation is an arboreous-shrubby Caatinga, with the tree stratum dominated by *Mimosa tenuiflora* (Wiild.) Poir., and the shrub stratum dominated by *Lippia microphylla* Cham., *Croton rhamnifolius* (Kunth em.) Mull. Arg., *Calliandra depauperata* Benth., *Cordia leucocephala* Moric, and *Bauhinia cheilantha* (Bong.) Steud. The last 3 are endemic to the Caatinga (Prado 1991). The distinction between shrubs and trees follows criteria of Walker (1976).

The study was conducted from August 1978 to August 1984, being divided into 2 phases. In the first one (August 1978–August 1981), 3 stocking rates were tested: heavy, H, 1 steer 6.7 ha^{-1} (40 ha); moderate, M, 1 steer 10 ha^{-1} (60 ha); light, L, 1 steer 13.3 ha^{-1} (80 ha). These were combined with 2 grazing systems: continuous (C), and rotationally deferred, with 3 sub-divisions (D). A fourth treatment was an ungrazed exclosure of zero stocking (40 ha). None of the 7 experimental units was replicated. In the second phase (August 1981–August 1984), the pastures used for deferred grazing were eliminated, becoming replications of the continuous grazing treatments. Six steers per experimental unit were utilized, resulting in a total area of 400 ha, including the exclosure of 40 ha.

To evaluate the effect of grazing intensity on vegetation, macro plots of 20 x 5 m were located systematically within each experimental unit, with 6 in continuous grazing and in the exclosure, and 12 in deferred grazing (4 in each sub-division). In each macro plot, the following 2 aspects were evaluated: (1) frequency of herbaceous species and density of seedlings (height <0.5) of woody plants, determined annually, in May (in 1979, 1981, 1983, and 1984) or in April (in 1980 and 1982), by using five 1-m^2 (2 x 0.5 m) quadrats, placed at random; and (2) mortality and growth in height and in canopy cover of 7 aluminum tagged shrub species, including the 5 dominant ones already cited plus *Lantana camara* L. and *Croton sonderianus* Mull. Arg. Measurements were taken biennially, by monitoring up to 10 plants of each shrub species in each macro plot, starting in 1980.

A third aspect was evaluated in the experimental units in 1982 and 1984: the density of trees and shrubs (height > 0.5 m) as determined by the Point-Centered Quarter Method (PQM) (Cottam and Curtis 1956). Our purpose was to measure effect of stocking rate on the woody stratum as a whole. In the areas of 40 ha (1 steer 6.7 ha^{-1} and exclusion), 60 ha (1 steer 10.0 ha^{-1}) and 80 ha (1 steer 13.3 ha^{-1}), 100, 150, and 200 points were placed respectively. The sampling points were distributed in lines, and in each one, the minimum and maximum distances between sampling points were 21 and 26, m respectively, any distance in this interval being determining by sorting. From each quarter of each sampling point, I measured the distance to the nearest shrub and to the nearest tree. Shrubs were classified into 3 heights (H1 > 0.5 – 1 m; H2 > 1–2; H3 > 2m).

Data were interpreted, taking into account the effect of stocking rate and year on the frequency of herbaceous species, the effect of stocking rate and biennium on the performance of the tagged shrubs, and the effect of the year on the density of shrubs and trees. Data on mortality and changes in height and canopy cover of the tagged shrubs were transformed from percentage to arc sin and evaluated with analysis of variance (Snedecor and Cochran 1976). As treatments were not replicated, the interactions involving stocking rate, biennia, and plant species were used as residual variance.

Table 1. Rainfall from October 1978—September 1984, and historical mean, October 1963—September 1997.

Month	Precipitation						
	1978–79	1979–80	1980–81	1981–82	1982–83	1983–84	Historical mean
	(mm)						
Oct.—Nov.	42.2	52.1	56.0	14.6	0.0	62.8	58.7
Dec.	12.2	54.8	34.0	90.7	82.8	7.2	75.1
Jan.	118.1	186.0	20.3	10.4	60.0	20.5	72.2
Feb.	96.4	201.3	4.8	20.6	166.4	3.9	83.7
Mar.	28.3	44.7	340.3	79.1	205.2	314.2	140.9
Apr.	118.4	10.6	20.5	97.4	0.8	122.9	86.4
May	18.4	1.2	0.5	1.4	0.0	44.6	20.2
Jun.–Sep.	24.0	1.3	8.4	50.2	37.6	29.2	30.3
Total	**458.0**	**552.0**	**484.8**	**364.4**	**552.8**	**605.3**	**567.5**

Results and Discussion

There were 29 herbaceous species which occurred with average frquency > 4.33%, considering the means calculated over 6 years and 4 treatments. Plant types were distributed as follows: pteridophyte, 1 species; monocotyledonous, 6 species (5 grasses and 1 sedge); and dicotyledonous, 22 species. The lowest limit of 4.33% was chosen arbitrarily.

Grazing system had no effect on either herbaceous species frequencies or on woody seedling densities. This was an expected result because each deferred sub-division was kept free of grazing only once during the rainy season in the first phase. In the review conducted by Gammon (1978), long duration of deferred grazing was necessary to get improvement in pastures. Grazing system effect on the tagged shrubs was not evaluated because measurements were started in 1980 and the deferred system was discontinued in 1981.

Through the years, there was a remarkable variation in frequency of most of the herbaceous species, probably caused by variation in the precipitation. Based on this aspect, the species were divided into 3 groups (Table 2). The frequencies of the first 16 species were strongly infuenced by rainfall, and an association (P<0.01) was detected between rainfall in the period February–April (or Feb.–Mar.) and their mean frequency (Fig. 1). In another Caatinga, Araújo Filho (1985) detected that herbaceous plants reacted more to fluctuation in rainfall than to livestock use. If phytomass had been measured, similar associations would probably have been obtained, confirming that in semi-arid climates, increases in rainfall result in linear increases in primary productivity (Whittaker 1975). In the second group (11 species), the frequencies also varied strongly through the years, but their highest value was in 1983. There was a change of positions between the first 2 groups in 1983 and 1984, i.e. the first group had the highest mean frquency in 1984, while the second group did so in 1983. The third group, made up of 2 very important Caatinga forbs, *H. crispa* and *S. convoluta*, was little influenced by rainfall. *S. convoluta* is a reviviscent pteridophyte that passes the dry season completely desiccated, i.e., in air dried stage with a saturation deficit of up to 72–74% (Morello 1954). On a small ranch near the experimental site, these species pro-

Table 2. Frequency of herbaceous species in 3 groups (Group 1 = very influenced by rainfall but with highest frequency in 1984; Group 2 = Same as Group 1, but with highest frequency in 1983; Group 3 = little influenced by rainfall), in the period 1979–84.

Group/Species	Plant class	Frequency 1979	1980	1981	1982	1983	1984
		--(%)--					
Group 1							
Paspalum scutatum Nees ex Trin.	Grass	2.14	9.29	7.38	0.71	2.38	4.05
Hyptis suaveolens (L.) Poit.	Forb	0.00	8.81	11.19	0.00	5.24	10.95
Eragrostis ciliaris (L.) R. Br.	Grass	4.05	3.10	8.33	0.00	13.33	14.52
Diodia teres Walt.	Forb	1.19	5.24	10.00	3.57	11.43	15.71
Phyllanthus ninuri (L. em.) Mull Arg.	Forb	0.00	3.81	25.71	0.00	8.10	12.62
Marsypianthes chamaedrys (Vahl.) Kuntze	Forb	0.00	11.67	4.76	0.00	1.67	32.38
Borreria ocymoides DC.	Forb	0.00	0.00	4.29	0.00	16.67	37.62
Cuphea sp.	Forb	0.00	3.81	12.14	0.71	10.71	31.19
Polygala brizoides St. Hil.	Forb	0.95	3.81	7.14	1.90	19.52	33.33
Mitracarpus frigidus K. Schum.	Forb	1.19	8.81	32.14	8.57	17.14	19.05
Turnera pumilea L.	Forb	0.00	3.81	19.29	12.38	35.48	39.29
Schwenkia americana Roy ex L.	Forb	6.67	24.52	38.33	0.00	41.67	61.67
Cyperus uncinulatus Schrad. ex Nees	Sedge	0.48	17.62	40.48	34.05	39.52	48.57
Gymnopogon rupestris Ridley	Grass	29.52	45.78	35.95	17.86	37.38	51.67
Panicum trichoides Sw.	Grass	18.10	49.05	55.48	2.38	58.09	75.71
Centratherum punctatum Cass.	Forb	25.48	54.29	59.05	1.67	54.29	73.81
Mean		**5.61**	**15.84**	**23.22**	**5.24**	**23.29**	**35.13**
Group							
Macroptilium martii Benth.	Forb	0.00	2.86	1.43	0.71	16.67	6.19
Triumfetta sp.	Forb	0.00	0.00	2.38	1.90	20.00	10.48
Croton glandulosus (L. em) Mull. Arg	Forb	1.43	8.10	5.00	2.38	22.86	2.62
Pavonia cancellata (L.F.) Cav.	Forb	1.67	5.95	2.86	1.90	21.19	14.52
Portulaca oleracea L.	Forb	0.00	3.33	7.14	0.00	33.33	16.67
Bernardia sinoides Mull Arg.	Forb	0.00	5.00	9.29	13.10	24.76	16.43
Brachiaria molis (Sw.) L. Parodi	Grass	6.67	8.57	0.48	0.95	45.00	9.29
Microtea scabrida Urb.	Forb	0.48	0.48	15.48	1.43	38.81	24.52
Althernanthera brasiliana (L.) Kuntze	Forb	7.38	26.90	24.76	1.67	38.81	35.71
Hybanthus calceolaria (L.) Schulze	Forb	2.86	19.52	29.29	9.05	51.43	24.52
Corchorus argutus H.B.K.	Forb	6.90	29.05	21.90	3.10	48.33	37.86
Mean		**2.49**	**9.98**	**10.91**	**3.29**	**32.83**	**18.07**
Group 3							
Selaginella convoluta Spring	Pteridophyte	29.76	26.90	30.00	34.05	30.00	35.48
Herissantia crispa (L.) Briz.	Forb	48.81	39.05	42.86	37.86	59.05	58.33
Mean		**39.28**	**32.97**	**36.43**	**35.95**	**44.52**	**46.90**

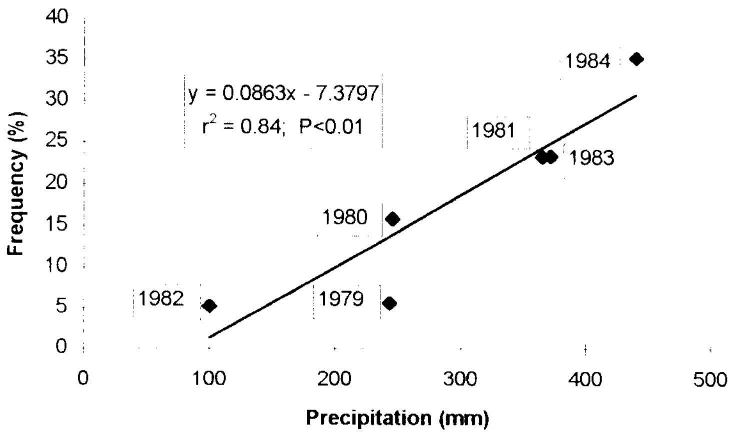

Fig. 1. Relationship between rainfall of last months of rainy season and mean frequency of 16 herbaceous species.

vided 70% of the herbaceous phytomass at the end of the dry season (Leal 1996).

There were so few plants of *L. camara* and *C. sonderianus* tagged in 1980 that neither the effect of biennium nor of stocking rate could be estimated. *L. microphylla* suffered high mortality, so that parameters other than death rate could not be evaluated. There was a significant influence of biennia on mortality rate, which was highest in the second biennium. The influence of the 1981–82 drought could only be detected in 1984. Rainfall in the crop year 1980–81 was not low, but was highly concentrated in March.

There was no apparent effect of stocking rate on frequency of herbaceous species, and differences among treatments were attributed to heterogeneity of the area. Frequency data might not have been sensitive enough to measure effect of stocking rate as in the work of Hacker (1984) in a semi-arid range in Australia. On the other hand, in a dense vegetation with a forage phytomass of ca. 1,000 kg ha^{-1}, distributed equally in both the herbaceous and woody strata (Albuquerque and Bandeira 1995), steer diets were made up of herbs and shrub leaves, decreasing the grazing pressure on the lower stratum. In addition, the high density of *Neoglaziovia variegata* (Arr. Cam.) Mez and other thorny species in the lower stratum could form micro-sites, protecting the herbs from over-use, and providing them the opportunity to set seed. In South Africa, medium sized stone rubble was considered important in protecting grass seedlings from overgrazing by large herbivores (Van der Walt 1980).

Most of the herbaceous species occurred less frequently in the exclosure than in the grazed areas, except *A. brasiliana* and *P. ninuri*, which occurred most frequently in the exclosure. Most research on grazing in range pastures have been done in the USA, where ranges are dominated by grasses and forbs. Dyksterhuis (1949) based his work on such pastures, and recognized that rest in woodlands does not lead to range dominated by herbaceous plants, but to a denser woody vegetation. This is probably the reason that most of our herbaceous species were less abundant in the exclosure. The density of woody species seedlings was not related to stocking rate (Table 3). Friedel (1986) detected influence from sheep and rabbits on woody seedlings, but no effect from cattle. An important point is the trend for the density of woody seedlings to decrease in the exclosure, following the same trend as most of the herbaceous species. The woody canopy of Caatinga in rest trends to become closed, curtailing the space suitable for the herbaceous stratum. Seedling density also decreased under deferred heavy and moderate stockings, but the decrease in the exclosure was more evident. Seedlings of *Tabebuia spongiosa* Rizzini were not included in Table 3 because in 1983 a great germination of seeds of this tree occurred (mean of 16.4 plants m^{-2}), being completely different from other woody species.

Mortality of the tagged shrubs increased with increasing stocking intensity, and grazing treatments were significantly different from the zero grazing (Table 4). This indicates that cattle could cause overgrazing in the shrub stratum as detected by Toutain (1986), and damage can also be caused by trampling (Chesterfield and Parsons 1985). On the other hand, Kelly and Walker (1976) did not detect any harmful influence of cattle and goats on the woody stratum. Mortality was higher for *C. leucocephala* and *L. microphylla*, shrubs that can be broken easily. Stocking rate had a significant effect on the height of the 4 shrubs (Fig. 2). Shrubs under heavy stocking always decreased in height in both biennia, although in one of the pastures, heavy stocking under deferred grazing until August 1981 (HD), all shrubs except *C.*

Table 3. Density of woody species seedlings (height <0.5 m) in the period 1979–84, under 4 stocking intensities [Heavy (H) = 1 steer 6.7 ha^{-1}; Moderate (M) = 1 steer 10 ha^{-1}; Light (L) = 1 steer 13.3 ha^{-1}; Zero = No grazing] and 2 grazing systems (C = Continuous grazing; D = Deferred grazing until 1981).

Year	Stocking intensity/Grazing system							Mean
	HC	HD	MC	MD	LC	LD	Zero	
	(seedlings m^{-2})							
1979	3.03	5.72	2.50	7.68	2.33	0.87	8.67	**4.40 ± 3.0**
1980	2.47	7.28	2.20	5.77	2.17	2.37	8.63	**4.41 ± 2.8**
1981	4.03	5.74	2.36	4.65	1.80	1.79	6.50	**3.84 ± 1.9**
1982	1.40	5.10	1.53	4.35	2.27	1.45	3.60	**2.81±1.5**
1983	1.83	4.08	5.10	3.95	2.80	1.03	3.57	**3.20 ± 1.4**
1984	2.23	3.37	2.53	3.75	2.53	4.14	3.77	**3.19 ± 0.7**
Mean	**2.50 ± 0.9**	**5.21 ± 1.4**	**2.71 ±1.2**	**5.03±1.5**	**2.32 ± 0.3**	**1.94 ± 1.2**	**5.79± 2.5**	**3.64**

Table 4. Mortality of 5 tagged shrubs, submitted to 4stocking intensities, in the period 1980–84 (heavy = 1 steer 6.7 ha^{-1}; Moderate = 1 steer 10 ha^{-1}; Light = 1 steer 13.3 ha^{-1}; Zero = No grazing).

Shrub species	Stocking intensity: Heavy	Moderate	Light	Zero	Mean
	(%)				
	1st biennium (1980–82)				
C. leucocephala	10.90	11.38	7.38	0.00	**7.41**
L. microphylla	22.92	21.31	13.16	0.00	**14.35**
B. cheilantha	0.00	8.79	6.09	0.00	**3.72**
C. depauperata	0.90	0.00	1.39	0.00	**0.57**
C. rhamnifolius	1.55	0.65	0.00	0.00	**0.55**
Mean	**7.25**	**8.43**	**5.60**	**0.00**	**5.32 A**
	2nd biennium (1982–84)				
C. leucocephala	32.25	31.08	17.70	11.43	**23.86**
L. microphylla	21.62	4.17	9.09	30.00	**16.22**
B. cheilantha	18.18	7.23	12.04	2.08	**9.88**
C. depauperata	2.73	4.17	7.04	0.00	**3.48**
C. rhamnifolius	3.15	4.55	3.61	1.96	**3.32**
Mean	**16.19**	**10.24**	**9.90**	**9.09**	**11.35 B**
	biennia mean				
C. leucocephala	23.07	21.23	12.54	5.71	**15.64 a**
L. microphylla	22.27	12.74	11.12	15.00	**15.28 a**
B. cheilantha	9.09	8.01	9.06	1.04	**6.80 b**
C. depauperata	1.81	2.08	4.21	0.00	**2.03 b**
C. rhamnifolius	2.35	2.60	1.80	0.98	**1.93 b**
Mean	**11.72 a**	**9.33 a**	**7.75 a**	**4.55 b**	**8.34**

*Means with same lower case letters in the same line, in the same column, and with same capital letters in the same column, are not statistically different (Duncan, P>0.05). In spite of the difference between Heavy and Light being higher than between Light and Zero, there is statistical difference between Light and Zero, because of angular transformation.

leucocephala increased in height in the period 1982–84. This increase was probably caused by the good rains in 1983 and 1984 and lack of competition because HD had the lowest shrub density among the 7 experimental units in 1982. Moderate stocking had the opposite effect compared to HD, plants generally grew until 1982, then lost height the following biennium and became shorter than the initial height. Under light and zero grazing, there was a steady increase in growth of all species in the 2 biennia, except for *C. leucocephala*, which is easily broken and probably reacted to browsing even with the lightest use.

There was no significant influence of stocking rate on mean canopy cover of the 4 shrubs, even though cover tended to increase under light to zero stocking, and decrease under heavier grazing (Fig. 3). Shrub height was generally measured on the central twig in the canopy, which was most likely to be damaged by browsing. Canopy cover was determined by taking 2 perpendicular measures of canopy diameters, and there was always the chance that all 4 twigs were not browsed, mainly when they are tangled with other shrubs. This is probably the reason for the lack of statistically significant effect of stocking rate on canopy cover.

It could be concluded that cattle might cause degradation of the shrub stratum, but even in the heaviest stocking rate in this study, the degradation was lighter than the alteration caused by the 1981–82 drought. Stocking rates are more likely to be determined by animal performance, rather than vegetation response.

Mean density of shrubs was 37.3% lower in 1984 than in 1982, the difference being considered very high (Table 5). Apparently, this was not caused by stocking rate, because in HD as well as in zero stocking, there were increases in shrub densities (Fig. 4). One point that shows the difference very clearly is the correlation between the mortality of the 7 tagged shrubs in 1982–84 and their “mortality” detected by point-centered quatrum method (PQM) (Table 6). The difference in the columns of this table might be attributed to the plant size. Shrubs marked in 1980 had a mean height of 1 m, while shrubs 0.5 m high were included in the PQM measurements, and younger plants of lower stature are more likely to die. Shrubs 0.5–1 m high made up 67.3 and 47.7% of the total in 1982 and 1984, respectively, while shrubs >2 m high made up 9.3 and 21.4% in 1982 and 1984, respectively. The loss of shrubs in the period 1982–84, that was detected by PQM, might have been caused by the 1982 density, i.e. a high density caused high competition for water in 1982. There was no regression (P>0.05) between 1982 and 1984 densities, there being however regression (P<0.01) between 1982 density and the difference between 1982 and 1984. In 2 of the 3 shrub species in which there were no regression between 1982 density and number of plants that disappeared in the

Table 5. Shrub densities in 1982 and 1984, and percent of shrubs with height between 0.5 and 1 m.

Botanical name	Density 1982	Density 1984	Height (0.5–1 m) 1982	Height (0.5–1 m) 1984
	(plants ha^{-1} ± SD)		(%)	
C. leucocephala	4,739 ± 2,585	2,231 ± 864**	75.6	52.6
C. depauperata	2,909 ± 1,755	2,254 ± 1,415 ^{ns}	84.2	68.5
C. rhamnifolius	2,675 ± 912	2,417 ± 860 ^{ns}	39.2	26.7
B. cheilantha	1,545 ± 1,433	1,241 ± 810*	77.6	56.6
L. microphylla	1,463 ± 1,142	770 ± 469**	47.4	72.3
L. camara	1,268 ± 1,063	349 ± 262**	89.5	72.3
C. sonderianus	953 ± 1,085	942 ± 1,153 ^{ns}	21.9	14.5
C. microphylla[1,2]	540 ± 520	428 ± 208**	97.8	42.9
M. arenosa[1,2]	520 ± 821	233 ± 325**	98.3	65.1
M. tenuiflora[1]	258 ± 28	214 ± 91*	87.3	40.2
Other tree spp[1]	688 ± 282	516 ± 543 ^{ns}	94.8	64.3
Other shrub spp	3,550 ± 3,213	1,633 ± 976*	68.4	49.8
Total	21,109 ± 6,825	13,229 ± 3,601**	67.3[3]	47.7[3]

**,*, and ns—Refers to regression coefficient (r^2) between shrub densities in 1982 and difference between shrub densities in 1982 and 1984, in the 7 experimental areas.
[1]Tree species in shrub state.
[2]Complete botanical names of species appearing for the first time: *Caesalpinia microphylla* Mart.; *Mimosa arenosa* (Willd.) Poir.
[3]Weighted mean

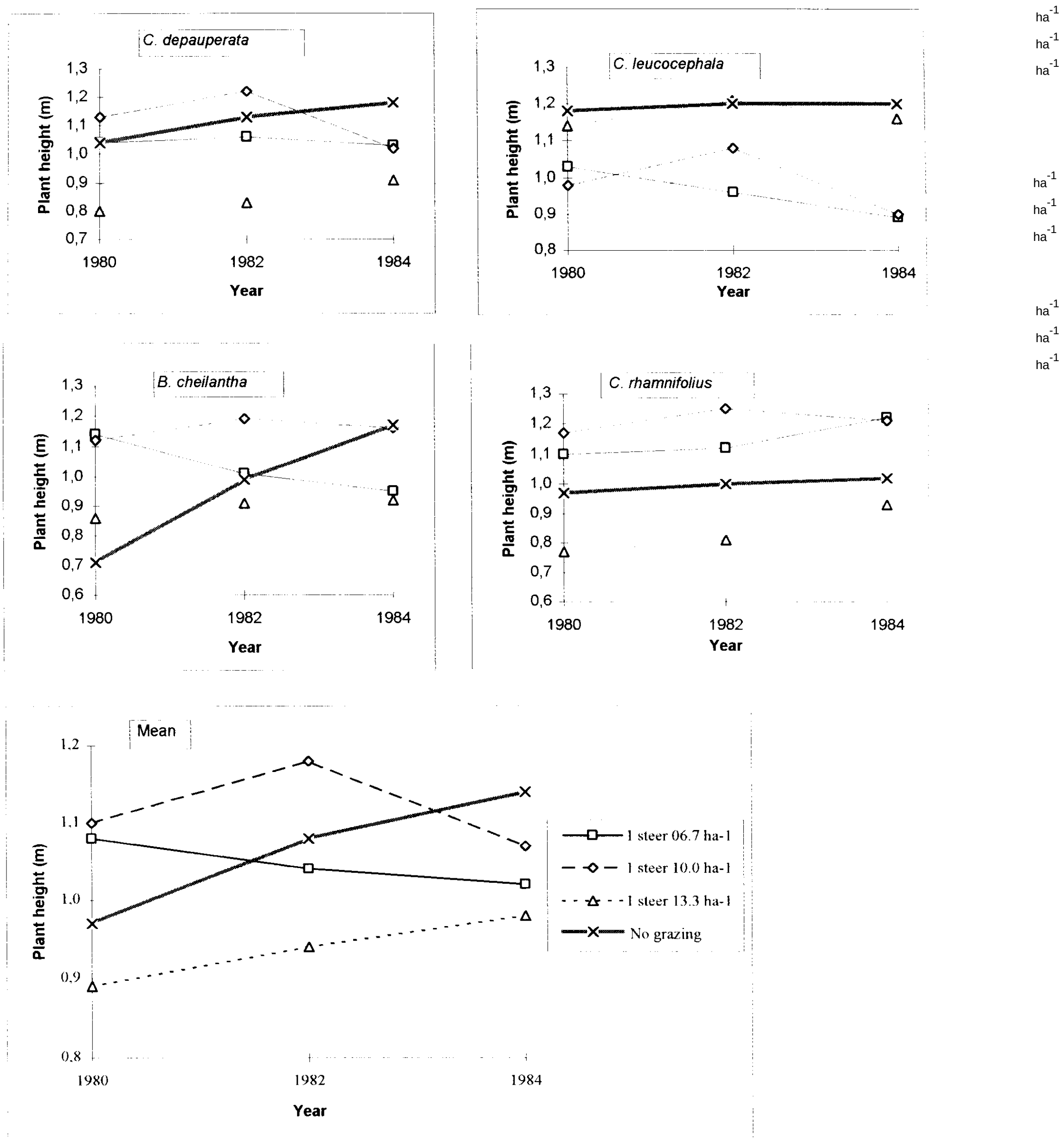

Fig. 2. Effect of stocking rate on height of *C. depauperata, C. leucocephala, B. cheilantha, C. rhamnifolius,* and the mean of these 4 shrubs.

period 1982–84, *C. rhamnifolius* and *C. sonderianus*, the difference between 1982 and 1984 densities were very low, resembling the performance of trees.

There were increases in shrub density from 1982 to 1984 in heavy deferred and zero grazing, the areas with lowest densities, and the origin of these additional plants can be questioned. It is supposed that competition and browsing determines which plants will die, which ones will stay below 0.5 m height, and which ones will grow. In the zero grazed exclosure, the 4 main shrubs always increased in height from 1982 to 1984, and this is evidence that some plants passed from lower height to height > 0.5 m. Under heavy stocking, *C. rhamnifolius* increased in height, while *C. leucocephala* decreased. Although *C. depauperata* and *B. cheilantha* decreased in mean height, these 2 shrubs had small increases in height in heavy deferred from 1982 to 1984. *C. depauperata*, in spite of having a small increase in height in this paddock, decreased in density, together with *C. leucocephala*. Most of the increase in density in heavy deferred in 1982–84 came from *B. cheilantha* and *C. rhamnifolius,* because a number of plants of these 2 species passed from seedling stage to the height >0.5 m stage, and compensated for the number of plants killed by browsing. In addition, the few plants of *L. microphylla* that escaped mortality increased in height, although this parameter was not evaluated statistically.

Therefore, the high shrub disappearance in the period 1982–84 might be attributed mainly to the drought, and the amount was determined by the density present in 1982, not only by grazing intensity. In the Sahel, the drought of

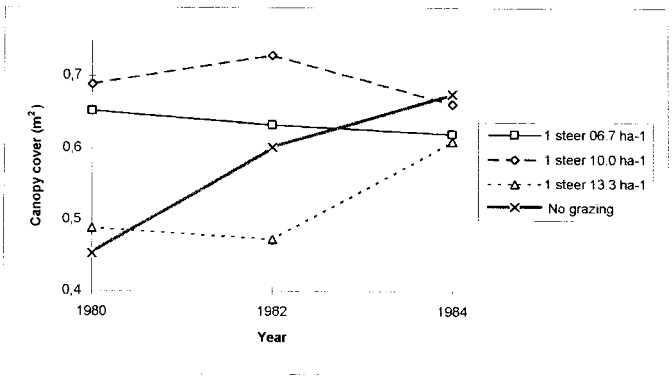

Fig. 3. Effect of stocking rate on mean canopy cover of 4 shrub species cited in Fig. 2.

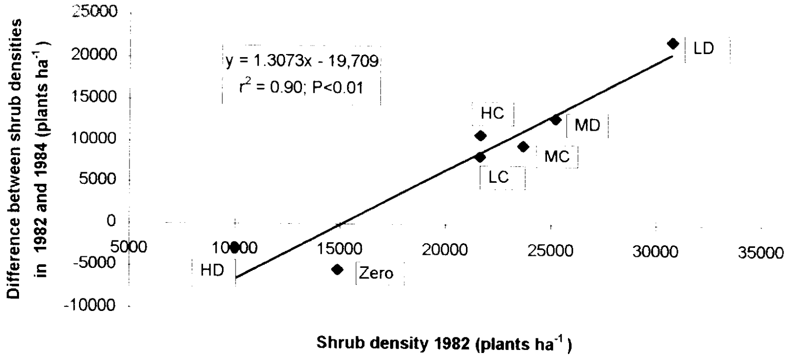

Fig. 4. Relationship between shrub density in 1982 and difference between shrub density in 1982 and 1984 [H = heavy grazing (1 steer 6.7 ha^{-1}); M = moderate grazing (1 steer 10.0 ha^{-1}; L = light grazing (1 steer 13.3 ha^{-1}); Zero = no grazing; C = continuous grazing always; D = rotationally deferred grazing until 1981].

1972 caused death of 50% of shrubs (Bille 1978), even though the density was much lower in comparison to our study. Extreme weather fluctuations in almost all semi-arid environments caused changes in ecosystem appearance, and it is difficult to distinguish between temporary and permanent changes (Dodd 1994). Data from both shrub and herb strata prove that Caatinga and African ranges similarly react more to climate than to grazing pressure (Ellis and Swift 1988).

Table 6. Mortality of all tagged shrubs independently of treatments from 1982 to 1984, and difference between 1982 and 1984 densities..

Shrub	Mortality when tagged	Difference between 1982 and 1984
C. rhamnifolius	3.61[1]	9.64[2]
C. depauperata	3.67	22.52
C. sonderianus	7.95	1.15
B. cheilantha	10.20	19.74
L. microphylla	13.77	47.37
C. leucocephala	27.36	52.92
L. camara	46.76	72.48
Mean	**16.19**	**32.33**

**Correlation coefficient (r) between columns = 0.89 ($P<0.01$).
[1]Data based on whole number of tagged plants.
[2]From Table 5.

For density of trees, the difference from 1982–84 was only 10.3% there being an association ($r^2 = 0.71$; $P<0.05$) between both densities (Table 7). The difference might be attributed to normal tree mortality, being aggravated a little by drought. Bille (1978) found tree morality of 20%. This normal rate of tree mortality is illustrated by the fact that in 1982 there was an association ($r^2 = 0.67$; $P<0.05$) between density of trees and density of tree species in shrub stage. In 1984, there was no association ($P>0.05$) probably due to the high mortality of 30.6% among trees in shrub stage in the period 1982–84.

Table 7. Tree densities in 1982 and 1984.

Botanical name	Tree density 1982	1984
	---- (plants ha^{-1} ± SD) ----	
M. tenuiflora	174.2 ± 94.90	148.8 ± 89.20**
C. microphylla	55.6 ± 41.61	49.1 ± 38.76**
T. spongiosa	54.2 ± 26.66	55.9 ± 21.08*
M. arenosa	41.7 ± 59.56	34.1 ± 40.84**
C. phyllacanthus[1]	30.5 ± 18.75	22.3 ± 11.65**
M. pseudoglaziovii[1]	24.6 ± 12.35	25.7 ± 18.90*
B. leptophloeos[1]	19.1 ± 11.52	16.8 ± 9.05**
C. vitifolius[1]	14.5 ± 12.53	15.7 ± 10.60**
A. piauhiensis[1]	10.0 ± 13.04	11.7 ± 13.40**
P. obliqua[1]	3.3 ± 2.37	3.4 ± 1.98*
S. tuberosa	1.8 ± 1.87	2.8 ± 2.80^{ns}
Other spp	17.3 ± 7.23	14.7 ± 5.20^{ns}
Total	446.8 ± 94.21	401.0 ± 91.93*

**,*, and ns—Refers to regression coefficient (r^2) between tree densities in 1982 and 1984, in the 7 experimental areas.
[1]Complete botanical names of species appearing for the first time: *Cnidoscollus phyllacanthus* (Pohl) Mull. Arg.; *Manihot pseudoglaziovii* Pax & K. Hoffm.; *Bursera leptophloeos* (Mart.) Engl.; *Cnidoscollus vitifolius* (Mull. Arg.) Pohl; *Acacia piauhiensis* Benth; *Piptadenia obliqua L. (*Pers.).

Among the trees present in the study area, neither seedlings (height<0.5 m) nor shrubs of *Spondias tuberosa* Arr. Cam. were found. The causes are unknown. It is one of the most important Caatinga fruit trees, providing employment for many people during the 2 month fruiting season.

Conclusion

Neither stocking rate nor the short period of rotationally deferred grazing system affected frequency of herbaceous species. Most of them tended to be less abundant under zero grazing, which might have been caused by the trend of woody plants in the Caatinga to become denser when in rest. There was a remarkable increase in the frequency of herbaceous species with an increase in rainfall in the last months of the rainy season. Low precipitation in 1982 probably caused a high mortality of shrubs. Increasing stocking rate significantly increased mortality and decreased growth in height of most shrubs. Cattle can cause degradation in the shrub stratum, but the 1982 drought caused more damage than the heaviest stocking rate of 1 steer 6.7 ha^{-1}.

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