Botanical composition of goat diets in thinned and cleared deciduous woodland in northeastern Brazil

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Abstract

Clearing and thinning of caatinga vegetation in northeastern Brazil are viewed as methods of optimizing forage and wood production. Our study compared the botanical composition of goat diets relative to forage availability in undisturbed, cleared and 2 levels of thinned (25% and 55% canopy cover) stands of tropical woodland. Clearing and thinning of caatinga vegetation resulted in higher amounts of available forage through the wet season and up to the time of leaf fall. At the end of the growing season, available herbaceous biomass was generally 7 to 8 times higher on the treated pastures than on the control; biomass of available browse was about 4 times greater. After leaf fall, total available forage was similar for all 4 treatments but about 90% of the available forage on the control was leaf litter. Diet composition differed among the treatments only in February and May; at this time, goats on the treated pastures were selecting higher amounts of herbaceous vegetation than those on the control pastures. Even though browse availability was high throughout the wet season on the treated pastures, herbaceous vegetation was the primary dietary constituent. Only during the mid to late dry season, when herbaceous vegetation was dead and leaf:stem ratios were low, was browse consistently selected at high levels. We concluded that clearing and thinning increases the amount and diversity of available forage; thereby, improving foraging conditions. Moreover, production of herbaceous vegetation declines towards control levels only at some canopy cover higher than 55%.

Key Words: caatinga, tropical forests, goats, *Capra hircus*, herbivory, plant-animal interactions

The woodland vegetation of inland northeastern Brazil is called caatinga. It is a heterogeneous vegetation type composed of drought deciduous trees and shrubs with an understory of annual forbs and grasses. Caatinga woodland is the predominant vegetation of a large part of northeastern Brazil, covering approximately 830,000 km^2 or 10% of Brazil's total land area (Pfister et al. 1983).

As in other regions of tropical woodland, clearing of caatinga is commonly practiced for agronomic purposes (slash-and-burn cultivation), as well as for the harvest of wood (Primov 1984, Queiroz 1985). In northeastern Brazil, it is also being promoted as a method of enhancing production of forage and livestock (EMBRATER/-EMBRAPA 1980, BNB 1982). Two independent studies (Araujo Filho et al. 1982, Kirmse et al. 1986a) have provided quantitative evidence of this enhancement. In the first year after clearing dense stands of caatinga, 5- to 6-fold increases in production of annual herbaceous vegetation were measured. Additionally, there was an increase in availability of green browse during the dry season.

Most caatinga tree species coppice following cutting, and the coppice shoots retain some green leaves throughout much of the dry season for the first 2 to 3 years post-treatment. Recently cleared stands, however, yield substantially lower levels of dry season leaf litter than do intact, mature stands. Cleared caatinga may be superior to undisturbed caatinga in terms of cattle, sheep, and goat production (Araujo Filho and Gadelha 1984). Kirmse et al. (1986b) also found that goats and sheep grazing cleared caatinga during the dry season had higher forage intakes and diets of higher nutritive value than did goats and sheep on undisturbed stands of caatinga.

When clearing for either agronomic or livestock production purposes, marketable wood is normally collected and sold as a byproduct. Less commonly, woodlands are also cleared or selectively thinned solely for the harvest of wood. Wood from the caatinga is the primary source of fuel, fence posts, and construction materials for northeastern Brazil. Demand for wood surpasses supply (FAO 1981), and areas of exploitation are expanding.

Even though wood and forage are key resources of the caatinga woodland, little information is available concerning overstory-understory relations of the vegetation (Silva and Araujo Filho 1984), particularly as they affect livestock production. This experiment was conducted to determine the effects of various levels of overstory canopy cover on: (1) seasonal availability of browse and herbaceous plant biomass and (2) botanical composition of goats' diets on a seasonal basis.

Study Area

This study was conducted at the Brazilian National Goat Research Center (CNPC) near Sobral, Ceara' state, in northeastern Brazil. Sobral is located at 3.42° south latitude, and 40.21° west longitude, and at an elevation of 63 m. The climate of the area is characterized by extremes in precipitation. Not only are there distinct wet (January–May) and dry (June–December) seasons but there is also a cyclical distribution of drought and flood years (Girairdy and Teixeira 1978). The most recent drought extended from 1979 to 1983 and has been followed by an excessively wet period. The 33-year average precipitation for Sobral is 788 mm, but 1,005 mm was recorded in 1984, and 1,870 mm in 1985. In contrast, seasonal temperature variability is small, with average daily temperatures ranging from 22° C during the wet season to 28° C during the dry season.

We selected a 8-ha study area during the dry season of 1984. This area was gently undulating with both well-drained and poorly drained sites. Soils of the study area were relatively shallow (45–130 cm) Red and Yellow Spodosols with a crystalline bedrock of precambrian origin.

Vegetation cover of the area was a dense tree stand (95% canopy cover) composed of species typical of the caatinga of northern Cearà. Although there was evidence that some trees had been cut and removed for use as fence posts, the stand had not been otherwise disturbed by woodcutters for a period of about 40 years. Preliminary measurements showed that principal tree species on the area included the borage, pau branco (*Auxemma oncocalyx*

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Taub.); the euphorb, marmeleiro (*Croton hemiargyreus* Muell. Clrg.); and 3 leguminous species, catingueira (*Caesalpinia pyramidalis* Benth.), sabia (*Mimosa caesalpiniaefolia* Benth.) and mororo (*Bauhinia forficata* Link). These species were all drought-deciduous and composed about 92% of the total tree density. They yielded about 87% of the total foliar biomass from woody plants. Important annual forbs included *Hyptis* spp., *Bidens* spp., *Melanthera* spp., *Phaseolus* spp. and *Ipomoea* spp. Annual grasses consisted of *Paspalum* spp., *Panicum* spp., and *Brachiaria mollis.*

Methods

We divided the study area into 2 blocks, based on surface drainage and related vegetational characteristics. Within each block, we randomly allocated four 1-ha pastures to 1 of 4 treatments: (1) cleared or 0% tree canopy cover; (2) thinned to a 25% tree canopy cover; (3) thinned to a 55% tree canopy cover; and (4) control or 95% tree canopy cover. All woody plants were cut on the cleared treatment blocks. Values of species for both forage and wood was considered in determining which trees to fell on thinned areas. Of the 5 major species, the 3 legumes produce both valuable wood and foliage palatable to goats, whereas neither of the nonleguminous species produce palatable foliage and only pau branco is considered a valuable wood species. For a silvipastoral production system, the leguminous species would conceivably be the most valuable. Therefore, for the 25% and 55% cover treatments, all of the marmeleiro and pau branco, as well as similar minor species, were felled. We attained the 55% cover level without cutting many trees which produce palatable foliage. The final tree density was approximately 670 trees/ha (1,200 stems/ha). However, we cut an appreciable number of palatable trees on the 25% cover blocks, as reflected in the final density of about 385 trees/ha (800 stems/ha). Marketable wood and large slash material (greater than 2 cm in diameter) were removed from all cleared and thinned plots. The remaining fine slash (about 10,000 kg/ha) was not burned but left evenly distributed over the sites. Stumps of the cut trees (stools) did not receive further treatment.

Mature, native SRD (*sem raca definida*—without definite race) goats were esophageally fistulated (Van Dyne and Torell 1964) and used to collect dietary samples periodically throughout 1985. Collection periods corresponded to the early wet season (February), mid wet season (April), late wet season (May), early dry season or transition period (July), mid dry season (September), and late dry season (December). During each of these periods, fistula extrusa samples were collected shortly after dawn for 3 consecutive days. Eight esophageally fistulated goats were assigned to each treatment. On a sample collection day, they were fitted with screen-bottomed bags and allowed to graze freely for 30 minutes. They were then returned to the corral where the daily sample from each goat was removed from the collection bag, thoroughly hand-mixed, divided into 2 parts and frozen at −17° C. One portion was freeze-dried and used for chemical analysis (Schacht and Malechek 1989) while the other part was oven-dried at 40° C for 2 days. For each collection period, the oven-dried subsamples were pooled by animal over the 3-day period and analyzed for botanical composition. Using the microscope point method described by Harker et al. (1964), the dietary plant components were identified by species as leaf, stem, fruit or flower. When a plant part was not identifiable to the species level, it was designated as an unknown browse, forb or grass.

Due to limitations of pasture size, the esophageally fistulated goats were placed in the experimental pastures only during the collection periods mentioned above. This periodic use of the pastures by the experimental animals throughout the year effectively simulated continuous grazing in terms of total plant biomass removed. The experimental pastures were stocked equally at 1.2 ha/animal/year. This was heavier than the stocking rate of 1.7 ha/animal/year recommended by the CNPC. Although measurements were not taken, general observations indicated that heavier-than-recommended stocking rates were commonly used by private producers as well as by the CNPC.

We randomly allocated the esophageally fistulated animals to the treatment blocks before each collection. All collection periods included a 2-day adaptation period. During intervals between collection periods, the esophageally fistulated goats were pastured in an adjacent area having vegetation similar to that of the experimental pastures.

We estimated availability of herbaceous vegetation and browse

Table 1. Available herbage biomass (Kg/ha) for 6 dates in 1985 on the cleared, 25% cover, 55% cover and control pastures.

	February			April			May		
Treatment	Forb	Grass	Browse[1]	Forb	Grass	Browse	Forb	Grass	Browse
Cleared	380	104	552	765	264	756	1720	229	989
25% Cover	276	67	489	567	189	802	1339	178	1021
55% Cover	186	46	341	476	159	572	1297	164	876
Control	152	17	47	112	20	99	277	40	185
Contrasts:									
1 & 2 & 3 vs. 4	NS	*	*	*	*	*	*	*	*
1 vs. 2 & 3	NS	NS	NS	NS	NS	NS	NS	NS	NS
2 vs. 3	NS	NS	NS	NS	NS	NS	NS	NS	NS

	July			September		December	
Treatment	Forb	Grass	Browse	Herbaceous[2]	Browse	Herbaceous	Browse
Cleared	2109	77	885	1766	402	1079	851
25% Cover	1404	108	1071	1436	526	843	1479
55% Cover	1211	63	815	1399	819	903	1341
Control	452	62	198	236	1789	230	1760
Contrasts:							
1 & 2 & 3 vs. 4	*	NS	*	*	*	*	NS
1 vs. 2 & 3	NS	NS	NS	NS	NS	NS	NS
2 vs. 3	NS	NS	NS	NS	NS	NS	NS

[1]Browse represents green foliage for the first 4 sampling dates and leaf litter for the final 2.
[2]Herbaceous plants were not separated by species or life form in September and December.
NS = Nonsignificant ($P>0.1$)
* = Significant ($P<0.1$)

immediately preceding each diet collection period. Herbaceous vegetation was harvested in 25, randomly placed, 0.3-m² quadrats in each pasture. Plant material was clipped at ground level, hand-separated according to species, and placed in individual paper bags. It was then dried in a forced air oven at 60° C for 48 hours and weighed. This dried material was later hand-separated into leaf and stem components, and the components were weighed.

Biomass of fallen leaves was determined for each species by harvesting fallen dry leaves in the same quadrats used to sample herbaceous vegetation. Leaf fall did not begin until after the July collection period; therefore, dry leaves were not a component of total available herbage biomass until the September period.

We used the reference unit method (Andrew et al. 1979, Kirmse and Norton 1985) to estimate live biomass of tree and coppice foliage present in the zone from ground-level up to a browsing height of 1.6 m. The reference unit method is a visual estimate technique developed for estimating forage weight of plants by use of a reference unit (a leafy branch in the case of our study). For each collection period, we developed regression equations that described the relationship between estimated and actual foliar biomass (n = 20). Separate relationships were developed for both tree and coppice components of each of the 5 major species. Linear equations were determined to provide suitable prediction equations for all species and life forms. Subsequently, on each of the manipulated pastures, the number of reference units (up to a height of 1.6 m) on 25 randomly selected coppicing stools (i.e., cut stumps with shoots) was estimated for each each species. Similarly, on the 2 thinned treatments and the control, the number of reference units (up to 1.6 m) on 25 randomly selected trees was estimated for each species. Density was determined by counting the number of individual trees and coppicing stools in 22 randomly placed 4 × 10 m quadrants in each pasture. Total foliar biomass of each species was

Table 2. Relative botanical composition (%) of diets of goats foraging on manipulated and intact caatinga woodland during 6 periods in 1985.

	February				April				May			
	Cleared	25% cover	55% cover	Control	Cleared	25% cover	55% cover	Control	Cleared	25% cover	55% cover	Control
Herbaceous:	79.5	62.2	54.4	33.2	88.1	73.1	71.6	36.6	90.5	72.3	73.6	80.5
Early maturing, small forbs	1.5	2.8	1.6	1.4	0	0.8	1.9	0	4.0	1.3	0.8	0.3
Late maturing, large forbs	15.1	16.5	14.0	11.5	51.6	39.6	33.9	17.5	50.9	37.0	43.3	46.0
Vines	1.5	7.9	5.9	6.3	16.5	9.4	16.4	8.6	15.3	13.5	13.5	10.9
Other Forbs	9.6	12.9	8.0	7.2	8.5	15.8	10.1	3.4	9.7	9.0	5.0	8.9
Total Forbs	28.8	33.1	29.5	26.3	76.6	65.5	62.3	29.5	79.9	60.8	62.6	66.0
Total Grasses	50.8	29.2	24.9	6.9	11.5	7.6	9.4	7.1	10.6	14.5	11.0	14.5
Leaf:Stem	2.9	6.7	5.9	5.0	4.4	5.4	7.7	9.3	2.1	2.0	2.9	2.6
Browse:	20.5	37.8	45.5	66.8	11.5	26.9	28.4	63.4	9.6	24.4	26.3	19.5
Sabia	8.5	18.8	17.4	21.0	4.3	4.8	8.3	13.5	3.7	8.6	5.5	4.0
Manicoba	0	4.5	8.9	17.9	0.5	9.5	14.0	22.0	0.7	9.5	13.5	7.5
Mororo	4.9	0.3	3.6	3.3	0.6	2.6	0.5	0	0.2	0.8	0	0
Mofumbo	0	0.8	2.1	15.4	1.4	0	0.1	4.9	0	0.1	2.3	5.1
Catingueira	0.4	0.9	0.5	1.0	0	0.4	1.5	9.3	0.4	0.1	0.1	0.8
Pau branco	1.9	1.0	3.4	2.5	0	0	0.9	3.3	0	0.1	0.3	0.5
Contrasts:	Forb	Grass		Browse	Forb	Grass		Browse	Forb	Grass		Browse
1 & 2 & 3 vs. 4	NS	*		NS	*	NS		*	NS	NS		NS
1 vs. 2 & 3	NS	*		NS	NS	NS		*	NS	NS		*
2 vs. 3	NS	NS		NS	NS	NS		NS	NS	NS		NS

	July				September				December[1]			
	Cleared	25% cover	55% cover	Control	Cleared	25% cover	55% cover	Control	Cleared	25% cover	55% cover	Control
Herbaceous:	75.5	52.9	62.1	74.3	16.1	27.2	28.5	31.1	54.7	33.0	43.7	36.0
Early maturing, small forbs	1.1	2.3	0.4	2.9	0.4	1.3	0.9	0.9				
Late maturing, large forbs	35.4	24.0	32.1	35.6	9.6	14.9	13.9	17.1				
Vines	30.6	20.0	19.8	23.5	0.5	4.1	7.6	3.4				
Other Forbs	4.4	4.2	4.5	7.8	5.4	6.2	5.7	8.1				
Total Forbs	71.5	50.5	56.8	69.7	15.9	26.6	28.0	29.5				
Total Grasses	4.0	2.4	5.4	4.5	0.2	0.6	0.5	1.6				
Leaf:Stem	3.9	4.2	4.8	2.5	1.0	2.9	1.1	2.0				
Browse:	24.5	47.1	37.9	25.8	83.9	72.8	71.5	68.9	45.3	67.0	56.3	64.0
Sabia	15.5	18.4	9.8	5.0	56.6	29.4	15.7	6.4	12.7	7.3	15.3	9.6
Manicoba	0	5.4	10.1	0	0	0	0	0	0	0	0	0
Mororo	0	0.4	1.0	2.5	1.6	0.4	2.5	7.1	0.7	6.3	10.3	21.4
Mofumbo	1.1	1.1	4.6	6.1	0.6	2.5	8.8	1.0	2.7	0	0	0
Catingueira	0.8	2.4	1.6	2.5	1.3	7.0	7.8	11.4	11.3	32.3	9.0	17.7
Pau branco	0	1.9	2.0	1.8	9.5	6.9	9.1	9.9	4.2	6.7	7.3	3.9
Contrasts	Forb	Grass		Browse	Forb	Grass		Browse	Herbaceous		Browse	
1 & 2 & 3 vs. 4	NS	NS		NS	NS	NS		NS	NS		NS	
1 vs. 2 & 3	NS	NS		NS	NS	NS		NS	NS		NS	
2 vs. 3		NS		NS	NS	NS		NS	NS		NS	

[1]Herbaceous species were generally not identifiable to the species level in December.
NS = Nonsignificant ($P>0.1$)
* = Significant ($P<0.1$)

calculated as the product of average foliage yield per tree (or stool) and density. Tree and coppice foliage biomass was not determined in September and December.

Plant parts that were important dietary components were also hand-harvested for determination of nutritive value. These plant samples were oven-dried at 55° C for 48 hours and ground through a 1-mm screen before being analyzed for crude protein content (AOAC 1970).

The experimental design was a split-plot in time with an incorporated randomized complete-block design. There were 2 blocks with 4 treatments on which successive measurements were made at 6 times through the study year. Data analysis was conducted using the statistical package Rummage (Bryce et al. 1980). Least squares analysis was performed and orthogonal contrasts were used used to separate means. Orthogonal contrasts were (1) cleared and 25% cover and 55% cover vs. control; (2) cleared vs. 25% cover and 55% cover; (3) 25% cover vs. 55% cover. Because of the inherently high degree of variability within the caatinga vegetation type, the 0.1 significance level was considered appropriate for testing differences.

Results

Available Herbage

For the growing season from February through May, herbaceous standing crop for the treated pastures was several times greater than for the control (Table 1). Although yields of herbaceous biomass for the cleared pastures was 25% to 50% greater than for the 2 thinned treatments, the differences were not significant ($P>0.1$). The 2 thinned treatments consistently yielded similar ($P>0.1$) amounts of herbaceous biomass. Amounts of herbaceous vegetation remained relatively constant from May through September for all treatments except the control. Probably due to the prolonged wet season, some of the late-maturing, large forbs and climbing vines appeared to remain photosynthetically active until the first part of July. By September, however, all herbaceous vegetation was dead and dry.

The late-maturing, large forbs included primarily *Hyptis* spp., *Bidens* spp. and *Melanthera* spp. They tended to grow in the better drained sites, attaining heights of 3 to 4 m and flowered during the late wet season and into the early dry season. They contributed the most biomass to the herbaceous vegetation component on all treatments. For example, in May, they contributed 82%, 67%, 79%, and 58% of the total herbaceous biomass for the cleared, 25% cover, 55% cover, and control treatments, respectively.

Grasses (including *Carex* spp.) were generally not a major component of the herbaceous standing crop. The ratio of grasses to forbs was not significantly ($P>0.01$) affected by treatment. Much of the grass biomass was produced by early maturing species which flowered 30 to 50 days after the first rains and began to senesce shortly thereafter. In early April, when forbs had achieved less than half of their total growth the standing biomass of grasses had already peaked. As much as 25 to 35% of the available herbaceous biomass on the treated pastures was grasses in April.

Leaf:stem ratios of herbaceous plants during the growing season were initially high for the 3 reduced canopy treatments (1.74, 1.61, and 1.51 for the cleared, 25% cover and 55% cover treatments, respectively) but showed substantial decreases by May to approximately 0.5 for each of the treatments. Leaf:stem ratios for the control remained relatively constant at about 0.95 throughout the growing season. During the dry season, leaf:stem ratios declined to the point that, by December, herbaceous foliage became an insignificant part of total herbage biomass (leaf:stem ratios of 0.09, 0.07, 0.08, and 0.14 for the cleared, 25% cover, 55% cover and control treatments, respectively).

Coppicing stools responded quickly to precipitation. By mid-February, a little more than a month after the first rains of the wet season, coppice foliar biomass was already 50% of the total foliar biomass produced in the wet season (Table 1). Coppice foliar biomass had peaked by May and remained constant through July. For the first 4 sampling periods, over 90% of the coppice biomass was contributed by pau branco, marmeleiro, and catingueira. These species are the least palatable to goats of the 5 major woody species studied (Kirmse et al. 1983). Biomass of sabia, mororo and catingueira remained relatively constant from February through July, probably because consumption by goats and insects (in the case of catingueira) was roughly equal to plant growth. Leaf fall began in August, but coppice shoots for all species except marmeleiro retained some leaves (visual estimate: 10 to 20% of July's biomass) until the end of the dry season. Coppice shoots shed their leaves from bottom to top, therefore, most of the remaining green leaves were out of reach of browsing goats by December.

Available tree foliage on the control pastures steadily increased through the wet season (Table 1). Collectively, foliage of pau branco, marmeleiro and catingueira consistently composed over 90% of this biomass. In contrast, foliage over the 25% cover and 55% cover pastures was below 15 kg/ha for all sampling periods. Leaf fall from trees was nearly complete by September; therefore, very little green foliage was available on trees in September and December.

Diet Composition

The relative amounts of browse, forbs, and grasses in the goats' diets varied substantially across treatments and throughout the year ($P<0.1$) (Table 2). Dietary leaf:stem ratios varied significantly ($P<0.05$) over periods but were unaffected by treatments. These analyses reflect the seasonal fluctuations in selectivity by goats.

In both February and April, goats selected low to intermediate amounts of browse on the treated pastures compared to high amounts on the control (Table 2). Sabia and manicoba (*Manihot glaziovii* Muell. Arg.) were the favored browse species for all treatments. Although grasses represented only 8 to 10% of total available herbage biomass in February, they constituted from 25 to 50% of diets on the treated pastures compared to only 7% on the control. On the cleared areas, the grass *Brachiaria mollis* accounted for nearly 16% of the goats' diets with its seeds alone composing 5%. Grasses were never an important dietary constituent after February. In April, the late-maturing, large forbs were the major herbaceous dietary component for all treatments.

Goats selected low to intermediate amounts of browse on all pastures during both May and July (Table 2). Sabia and manicoba were still the major browse species selected. Large forbs were the dominant diet constituent for all treatments in May as well as in July. Vines were prominent dietary constituents throughout the wet season and reached their peak of importance in July. Fruits and flowers became very important dietary components in July (Fig. 1). About 20% of diets on the cleared areas was composed of fruits and flowers. Most of this was in the form of seeds and flowers of the large forbs and vines.

The amounts of browse selected were generally high for all treatments during the 2 dry season sampling periods (Table 2). In September, green foliage from coppice shoots of sabia and pau branco was heavily consumed on the treated pastures while a wide variety of mostly dried leaves was selected on the control. Most of the browse material consumed in December was in the form of leaf litter, although some green foliage from sabia and pau branco coppice shoots was still available and was utilized on the treated pastures. Variable amounts of dry herbaceous vegetation were consumed through the dry season although most of it was stem material.

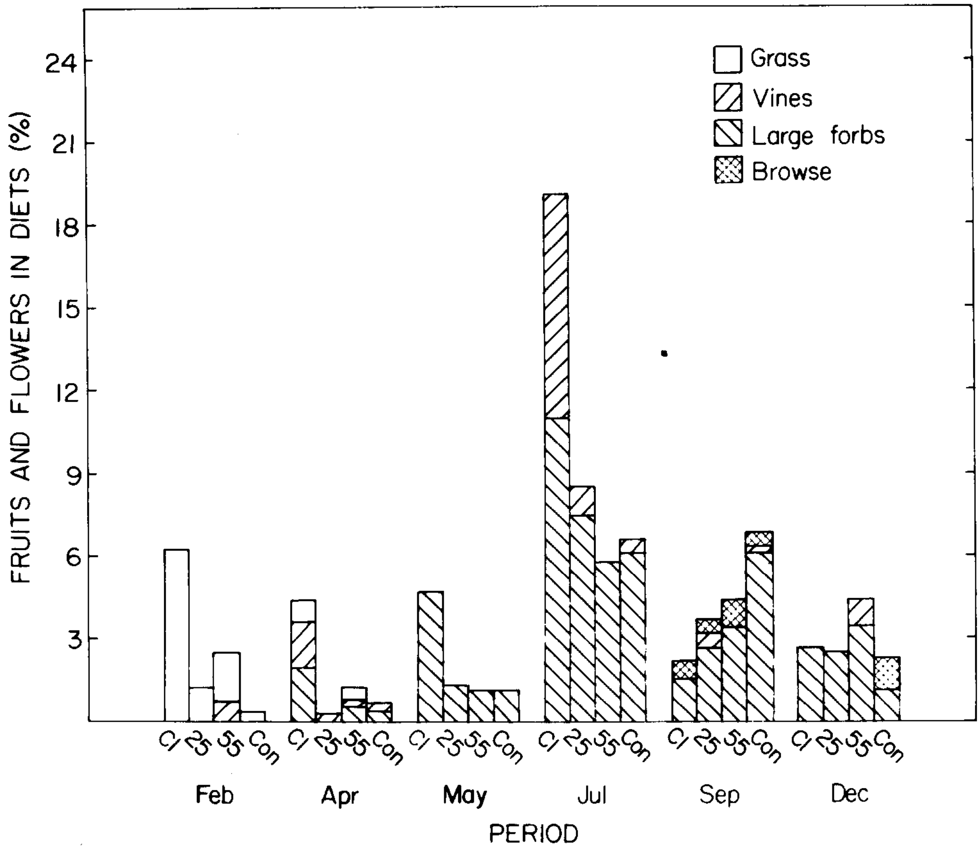

Fig. 1. Relative amounts of fruits and flowers in the diets of goats utilizing the cleared (Cl), 25% cover (25), 55% cover (55) and control (Con) pastures.

Discussion

Consumption of the various components of the herbaceous vegetation category varied greatly from season to season. The use of grasses was highly seasonal, considering that availability of green, good quality grass was mostly limited to the early wet season. Pfister and Malechek (1986) also reported seasonal use of grass by goats on caatinga range, as have numerous other researchers studying other vegetation types (Malechek and Leinweber 1972, du Toit 1972, Nge'the and Box 1976 and Bryant et al. 1979).

Late maturing, large forbs were the basic dietary component for all reduced canopy treatments from April through July and for the control in both May and July. These forbs are particularly important as forage because they are relatively high in nutritional quality (Table 3) and are available throughout the wet season and into the early dry season. Most of the grasses and early maturing forbs certainly do not share this latter characteristic. Dry leaves from large forbs are also consumed during the dry season. Unfortunately, large forbs are generally considered undesirable by local researchers and livestock producers as they are generally not eaten by the economically more important cattle.

Climbing vines were important dietary items for goats year-long and across all treatments. Although they never attained the level of importance in our study that Pfister and Malechek (1986) reported, peak use of the vines occurred at about the same time (early to mid dry season). In July, climbing vines represented only 3% of the total available herbage biomass but contributed 20% or more to the diets on all treated pastures. Lopes and Stuth (1984) found that vines were the forage class most preferred by goats in the Post Oak

Table 3. Crude protein content (% of dry matter) of hand-harvested samples of plant species that were important constituents of animal diets during the dry season.

Plant Species	July	September	December
Herbaceous			
flowers, *Ipomoea* spp.	13.3	—	—
flowers, *Hyptis* spp.	12.0	—	—
seeds, *Bidens* spp.	12.1	—	—
leaves, *Ipomoea* spp.	14.6	—	—
leaves, *Hyptis* spp.	12.3	—	—
seeds, *Ipomoea* spp. (vine)	—	29.3[1]	—
seeds, fava de boi vine	—	28.4	—
seed pods, fava de boi vine	—	1.9	—
seeds, herbaceous plants pooled	—	8.2	—
leaves, herbaceous plants pooled	—	8.3	8.0
stems, herbaceous plants pooled	—	3.2	3.4
Browse			
green foliage, sabia coppice	15.5	14.4	13.3
green foliage, pau branco coppice	12.2	11.6	10.0
leaf litter, sabia coppice	—	8.7	6.1
leaf litter, catingueira tree	—	11.7	9.8
leaf litter, mororo tree	—	8.5	7.4

[1]From Pfister and Malechek (1986).

Savannah of Texas, regardless of season or treatment.

Fruits and flowers of herbaceous plants were particularly important dietary constituents during the transition period (Fig. 1) when the large forbs and vines were mature and the availability of green leafy material was declining. Fruits and flowers are generally considered to be high in nutrients (Everitt and Alaniz 1981, Pfister and Malechek 1986); while hand-harvested samples of several of the fruits and flowers consumed in our study had crude protein levels similar to those of other herbage available at that time (Table 3), seeds of 2 vines, *Ipomea* sp. and fava de boi, had crude protein levels approaching 30%. Consumption of fruits and flowers of all species declined as the dry season advanced and availability decreased. Fruits and flowers of woody species never were an important dietary constituent.

Browse was the dominant diet component during the 2 dry season collection periods on all pastures and in February and April on the control pasture (Table 2). The relatively high level of browse utilization in the dry season may have been related to the low availability of good quality herbaceous material; however, its high level of use on the control pastures in the wet season is not readily explainable. During the wet season, goats on the treated pastures selected diets comparatively high in herbaceous material even though the ratio of available browse biomass: herbaceous plant biomass was higher on the treated pastures than on the control. Mechanics of diet selection of goats in the caatinga vegetation zone needs to be the topic of further research.

Sabia was the browse species most consistently eaten by goats regardless of season or treatment (Table 1). This ubiquitous, leguminous tree was highly sought for its green foliage throughout the growing season and for its leaf litter during the dry season. Sabia coppice responded to browsing by readily producing new foliage, even during the dry season. The impacts of heavy use on sabia coppice shoots has not been quantified, although numerous dead plants were noted by the end of the study.

The other major browse species varied greatly in dietary use (Table 2). Catingueira was generally unacceptable as green foliage but was consumed at moderate levels as dry leaves on both manipulated and control pastures during the dry season. Although mororo is considered a very palatable species (Kirmse et al. 1983, Pfister and Malechek 1986), it was an important constituent only on the control pastures during the dry season. Its availability was relatively low on the treated pastures. While pauo branco foliage is generally considered to be unacceptable to goats, it was eaten in substantial quantities on the treated pastures during the dry season. At this time, pau branco coppice shoots were one of the few sources of green foliage available. Marmeleiro was never eaten in significant quantities.

The heavy use of manicoba was somewhat a surprise although its use was limited to the wet season (Table 2). It does not retain its leaves into the dry season either as a coppice shoot or an intact tree. Even though manicoba is a very palatable browse species, it does not appear to be a promising forage plant. It is very susceptible to browsing damage because aggressively foraging goats can break coppice shoots and young trees at their bases. Also, this species has a very low leaf:stem ratio and, unlike most caatinga woody species, it does not respond to late wet season or early dry season browsing by producing new leaves.

Stand Manipulation

Considerable changes in forage conditions for goats were noted in the first-year posttreatment as a result of stand manipulation. Herbaceous production was increased, green foliage from coppice shoots was available far into the dry season and moderate levels of dry season leaf litter were also present. Herbage availability, including herbaceous standing crop and green and dry browse, was relatively high throughout the year on manipulated caatinga. In dense stands of caatinga, availability of herbaceous vegetation is typically low throughout the year and browse availability is relatively low until leaf fall begins in mid dry season. From a forage resource perspective, it is understandable why many researchers and livestock producers favor stand manipulation (primarily clearing) as a means of increasing livestock production.

The results of our study indicate that thinning as a management scheme has the most potential to increase livestock production in much of the caatinga vegetation zone of northeastern Brazil. A thinning level of 55% cover has the combined advantages of both newly cleared caatinga and undisturbed caatinga: high herbaceous vegetation production as well as high yields of palatable leaf litter during the dry season. In addition, woody species (such as sabia) which produce palatable foliage are susceptible to overuse as coppice. However, when such palatable species are left uncut in thinned stands, they are not only protected from browsing damage but they also provide extremely important dry season forage in the form of palatable leaf litter.

Aside from the potential forage benefits, the 55% cover treatment provides for wood production opportunities. Forage and wood are 2 of the caatinga's most readily produced and heavily utilized renewable resources. A multiple use land management approach should be taken where forage and livestock production is maintained under a stand of valuable wood producing trees. The region has a mix of tree species (e.g., sabia and mororo) that yield both valuable wood and palatable foliage and would be excellent candidates for silvipastoral schemes. In addition, natural regeneration following harvest of managed stands could be rapid since caatinga woody species coppice readily after being cut. Livestock, however, would need to be excluded from recently harvested areas for 1 or 2 years to protect the coppicing plants from browsing.

Management of thinned stands of caatinga for sustained high yields of forage and wood is complicated by the fact that economic control of coppice shoots and seedlings of undesirable species has not been realized. Rapidly growing coppice shoots have the potential of quickly recapturing a recently cleared area and of attaining a canopy cover equal to that of adjacent undisturbed sites by the fourth year post-clearing (Schacht et al. 1989). Herbaceous vegetation production declines rapidly as the canopy cover increases. Therefore, the coppicing woody plants must be controlled if the high yields of herbaceous plants are to be sustained. Since the 2 dominant tree species in northern Ceara, pau branco and marmeleiro, are relatively unacceptable to livestock, biological control of them with livestock is probably not practical. Other methods (e.g., burning or re-cutting) need to be tested as means of effectively controlling undesirable coppicing species. Sustained high yields of herbaceous vegetation under a canopy of trees appears to be a promising management scheme that needs further study.

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