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WOOD AND FORAGE PRODUCTION IN CLEARED

AND THINNED DRY TROPICAL WOODLAND:

IMPLICATIONS TO GOAT NUTRITION

by

Walter H. Schacht

A dissertation submitted in partial fulfillment
of the requirements for the degree

of

DOCTOR OF PHILOSOPHY

in

Range Science

UTAH STATE UNIVERSITY
Logan, Utah

1987

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Walter H. Schacht

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ABSTRACT

Wood and Forage Production in Cleared
and Thinned Dry Tropical Woodland:
Implications to Goat Nutrition

by

Walter H. Schacht, Doctor of Philosophy
Utah State University, 1987

Major Professor: Dr. John C. Malechek
Department: Range Science

Wood for firewood, fence posts and construction material and forage for domestic livestock are key resources in the caatinga vegetation zone of northeastern Brazil. This experiment was designed as a preliminary assessment of thinned caatinga as the basis of a production system which optimizes forage and wood production. Two levels of thinning (25% and 55% tree canopy cover) were compared to cleared (0% tree canopy cover) and undisturbed (95% tree canopy cover) caatinga in terms of forage and wood production and goat nutrition.

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. After leaf fall, total available forage was similar for all four treatments.

Dietary selection differed among the treatments only in February and May, when goats on treated pastures selected higher amounts of herbaceous vegetation than those on control pastures. Herbaceous vegetation was the primary dietary constituent on treated pastures throughout the wet season. During mid to late dry season, when herbaceous vegetation was dead and leaf:stem ratios were low, browse was consistently selected at high levels. Nutrient content of diets were not different among treatments, but forage and digestible energy intakes were higher (P<.05) on treated pastures than on control.

Due to lack of wood production on cleared plots from an intact tree component, total aboveground biomass production for the cleared treatment was 30% less than that for the control and about 25% less than that for the two thinned treatments. Overall, cleared and thinned treatments had similar positive forage and animal responses but thinned treatments had the added benefit of an intact tree canopy producing valuable wood.

The dry season has been identified as the most critical time of the year for livestock due to low forage availability and quality resulting in weight losses and mortality. Results of this study indicated that either supplementation or increased availability of nutritious forage would be necessary for goats to continue to grow beyond the first half of the dry season. Thinning may be a means of increasing the availability of nutritious forage.

(112 pages)

INTRODUCTION

The woodland of the large semiarid region of northeastern Brazil is commonly referred to as the caatinga (Fig. 1). This vegetation zone covers approximately 830,000 km^2 or 10% of Brazil's total land area. It is a heterogeneous type composed of drought-deciduous shrubs and trees with an understory of annual forbs and grasses. Defining a typical stand of caatinga vegetation is not possible and more than likely is a moot point, due to the extreme heterogeneity of edaphic, climatic and cultural factors found in the sertao. For purposes of this dissertation, the focus will be on human-induced factors; more specifically, how the commonly used vegetation manipulation practices have influenced the caatinga and possible roles vegetation manipulation may have in caatinga management.

The climate of northeastern Brazil 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 period from 1979 through 1983 has been referred to as the 'five year drought' and was the sixth major drought of this century (Mason 1980). The 'five year drought' has been followed by an excessively wet period with recorded annual rainfall nearly twice that of the average. Average annual rainfall across northeastern Brazil ranges from 300 to 1000 mm (Walker 1979, Bucher 1982). Seasonal temperature variability is small with average daily temperatures ranging from 22^{o}C during the wet season to 28^{o}C during the dry season.

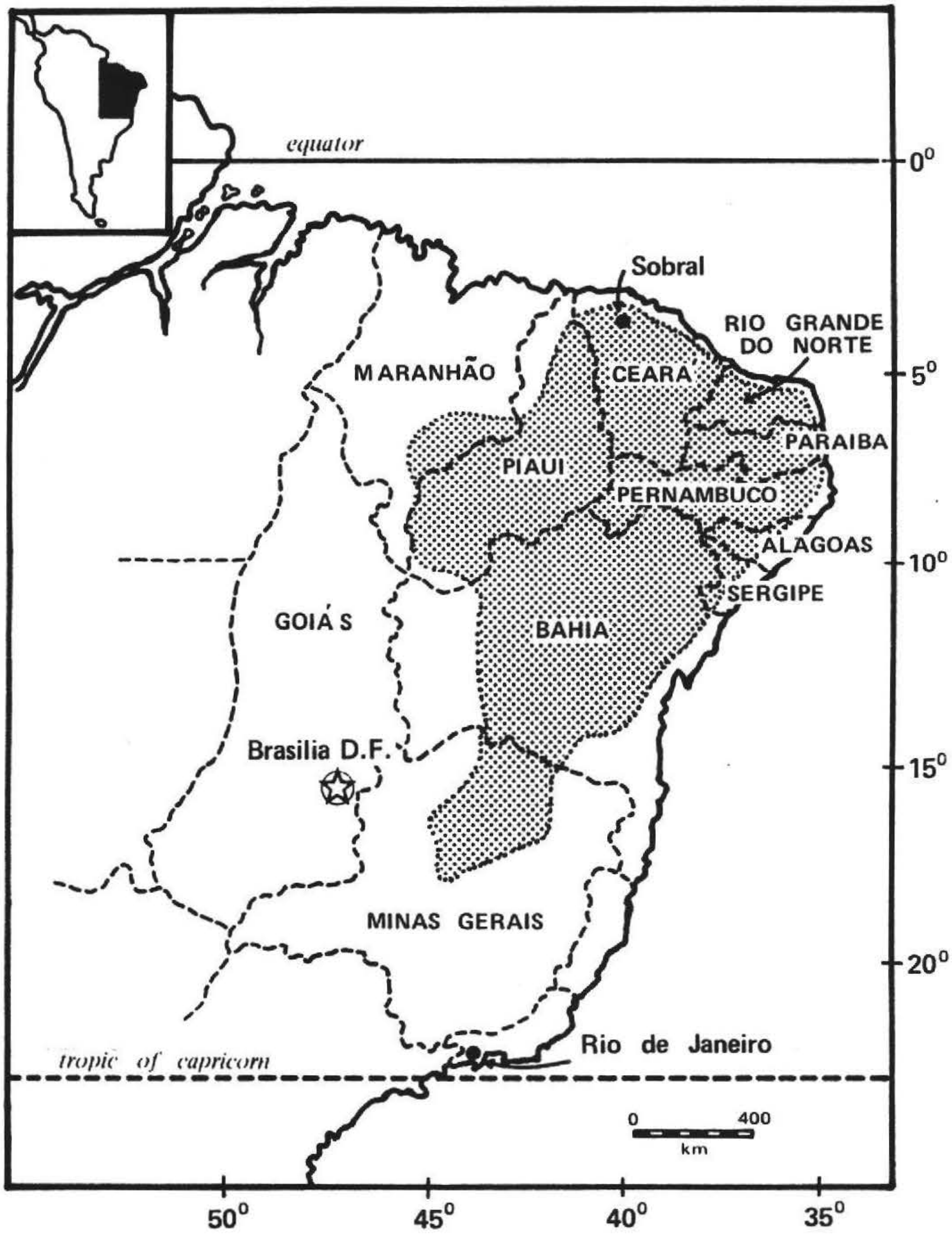

Figure 1. The caatinga vegetation zone of northeastern Brazil.

Agriculture plays the central role in the economy of this heavily populated region (24.77 inhabitants/km^2) (Medicoes Michalany 1985). Most farms in northeastern Brazil are mixed production systems (Gutierrez 1983, Queiroz and Gutierrez 1985). Farms typically have both agronomic and pastoral components, and often include an ill-defined wood production component. The importance of any one of these components to a particular farm depends on a variety of factors including property size, soil potential, economic forces and type of vegetation cover. In general, agricultural production is severely limited by such environmental constraints as shallow and infertile soils and periodic drought (Christiansen-Weniger 1977). Reliance on several production components allows the flexibility needed by farmers to cope with these adverse environmental conditions.

As in many other tropical woodland and forest regions, farmers in this region practice shifting cultivation (slash-and-burn). To prepare fields for cultivation, the caatinga vegetation is cleared and burned. Fields are then cultivated for variable periods of time, ranging from one growing season to over 50 years (Queiroz 1985). At the end of a period of cultivation, the field is simply abandoned and early-seral vegetation invades.

Livestock production is extremely important to the economy of northeastern Brazil. Cattle, sheep and goats are commonly raised throughout the region, although the 20 million cattle are found most frequently in areas with over 500 mm of rain annually (Mason 1980). The 9 million goats and 6 million sheep are distributed on farms throughout the area and represent 92 and 30 percent of the total number of goats and sheep, respectively, in Brazil (Anuario Estatistico do Brasil 1981). Caatinga vegetation generally serves as the year-round forage resource for small ruminants and, to a lesser extent, for cattle. Crop aftermath and supplements are used by producers to maintain cattle and, to varying degrees, sheep and goats through the dry season (Gutierrez et al. 1981, Queiroz and Gutierrez 1985).

Livestock production in northeastern Brazil is generally considered to be far below its potential due to a wide spectrum of factors (Mason 1980), ranging from cultural to purely technical considerations. Viewed as one of the primary factors limiting goat production, nutritional stress on goats during the dry season results in high weight losses and possibly mortality (Pfister et al. 1983). Neither forage quality or quantity appears to be a major limitation in terms of livestock production during the wet season; however, in the dry season, available forage is restricted to dry herbaceous plants and fallen leaves (leaf litter) of the deciduous trees. It is during this period that low forage availability and diminished quality seriously affect animal performance. Therefore, concerns about increasing livestock carrying capacity and performance have been directed towards methods of increasing the quantity and quality of dry season forage reserves in order to minimize the wastage of animal biomass that typically occurs at this time.

Clearing of caatinga vegetation is the method of increasing forage production which has received the most attention (EMBRATER/EMBRAPA 1980, BNB 1982, Araujo Filho and Gadelha 1984, Kirmse 1984). Araujo Filho et al. (1982) and Kirmse et al. (1986a) have reported that clearing of dense stands of caatinga vegetation results in a five- to sixfold increase in production of annual herbaceous vegetation and 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. Recently cleared stands, however, yield substantially lower levels of dry season leaf litter. A study conducted by Araujo Filho and Gadelha (1984) indicated that recently cleared areas are superior to undisturbed caatinga in terms of cattle, sheep and goat production (kg/ha). Kirmse et al. (1986b) also found that goats and sheep grazing on cleared areas 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, some woodlands are also clearfelled or selectively thinned solely for the harvest of wood. Many local industries (e.g., bakeries, brick and cement factories) rely entirely on firewood and charcoal originating from caatinga woodland for fuel. Some caatinga tree species are also valued as sources of fence posts and construction materials. Harvest of marketable wood is generally concentrated in areas surrounding population centers because of relatively high costs of transport. Demand is currently surpassing supply (FAO 1981), however, and the areas of exploitation are expanding.

Clearfelling operations, regardless of their purpose, tend to be exploitive in nature. Little concern for or knowledge of silvicultural practices or watershed management is shown. Very few precautions are taken to assure regeneration of stands of desireable woody species or to control soil and water losses (Ramos and Marinho 1980). These practices are leading to domination of vast areas by early-seral species (Queiroz 1985) which have little value as either forage or wood.

This brief review suggests that modifications of the ubiquitous practice of land clearing need to be developed and tested as methods of assuring long-term production of forage and wood. These modifications should be simple and in accordance with production strategies of the farmers (Primov 1984). Inexpensive methods that assure retention of livestock and wood production at their current level are likely to be acceptable to producers. For example, thinned stands of caatinga woodland might provide for sustained production of both forage and wood without the potentially high levels of site degradation that can accompany clearfelling.

This experiment is viewed as a preliminary assessment of thinned caatinga woodland as the basis of a production system which optimizes forage and wood production. Of special interest is the identification of diet deficiencies of goats on undisturbed caatinga, and how these deficiencies relate to forage availability and quality. This then can serve as a basis for evaluating thinning as a method of improving dry season forage and livestock production. The objectives of this study were:

1. To determine if the dry season diets of free-ranging goats are deficient in nitrogen, energy or both;
2. To determine the botanical and nutritive composition of diets

of goats on cleared, thinned and undisturbed stands of caatinga vegetation;

3. To determine the daily forage intake and digestible energy intake of goats on cleared, thinned and undisturbed stands of caatinga vegetation;

4. To estimate total aboveground production of cleared, thinned and undisturbed stands of caatinga vegetation.

This dissertation is divided into five interrelated chapters. The first chapter attempts to characterize the energy and crude protein limitations of free-ranging goats during the dry season and how this might relate to forage availability (Objective 1). In chapters II and III, thinned, cleared and undisturbed (the control) stands of caatinga vegetation are compared in terms of botancial and nutritive composition of goats' diets and forage intake of goats (Objectives 2 and 3). The potential of thinned and cleared treatments as methods of improving the nutrition and intake of goats is discussed. Estimates of total aboveground production on thinned, cleared and undisturbed stands of caatinga are presented in Chapter IV (Objective 4). All major components of gross primary production are reported and implications of the treatment effects on forage and wood production are discussed. In Chapter V, the results of the entire research project are summarized and recommendations for the management of forage and wood production in the caatinga vegetation zone are presented.

CHAPTER I

EFFECT OF SUPPLEMENTAL NITROGEN AND ENERGY ON DRY SEASON WEIGHT GAINS OF GOATS IN THE SEMIARID TROPICS OF BRAZIL

It is often questioned whether nutrient content of dry season forage (consisting of fallen tree leaves and dry forbs produced during the wet season) is adequate for maintaining goats and sheep under normal dry season conditions (Pfister 1983). Studies to date (Pfister 1983, Kirmse 1984), however, indicate that sheep and goat diets primarily composed of fallen tree leaves are of relatively good quality. These diets contained crude protein (CP) levels of 8 to 12%, *in vitro* organic matter digestibility (IVOMD) of 40 to 50% and sustained organic matter intake levels of 2 to 3% of body weight. Pfister (1983) and Kirmse et al. (1983) have hypothesized, however, that nutrient availability, particularly of protein, in certain species is affected by anti-quality compounds.

The objective of this study was to determine if the dry season diets of free-ranging goats are deficient in nitrogen (N), energy or both.

Methods

This study was conducted at the Brazilian National Goat Research Center 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 33 year average precipitation for Sobral is 788 mm with 1005 mm of rainfall recorded in 1984, the year of this study. Dry season temperatures normally exceed 35ºC during the daylight hours and fall to about 25ºC at night.

Vegetation cover of the study area was a dense stand (95% canopy cover) of caatinga woodland composed of many of the plant species typical of the caatinga of northern Ceara. Although it was apparent that some trees had been cut and removed for use as fence posts, the tree stand of the study had not been extensively disturbed by woodcutters for a period of about 40 years. Principal tree species on the study area were pau branco (Auxemma oncocalyx Taub.), marmeleiro (Croton hemiagyreus Muell. Clrg.), catingueira (Caesalpinia pyramidalis Benth.), sabia (Mimosa caesalpiniaefolia Benth.) and mororo (Bauhinia forficata Link). Important annual forbs included Hyptis spp., Melanthera spp., Bainvillea spp. and Ipomoea spp. Dominant annual grasses were Paspalum spp., Panicum spp. and Brachiaria mollis.

Forty male SRD (sem raca definida - without definite race) goats about four months old and averaging 15.1 kg were used in this experiment. The goats were blocked on basis of liveweight and allocated ten to each treatment in a randomized complete-block design. The treatments were as follows: 1) caatinga range (CR); 2) caatinga range + 5 g of of urea/day (CR + U); 3) caatinga range + 140 g of molasses/day (CR + M); and 4) caatinga range + molasses (140 g/day) and urea (5 g/day) (CR + MU). This design allowed for supplementing N alone (treatment 2), energy alone (treatment 3) and a balanced mixture of N and energy (treatment 4). Quantities of urea and molasses were supplemented to furnish 32% of maintenance crude protein (CP) and digestible energy

(DE) requirements for a 15 kg goat (NRC 1981). The molasses fed in treatments 3 and 4 was presented in dry, powdered form. In diet 4, dry urea was thoroughly mixed with molasses. In diet 2, the urea was dissolved in water and administered orally using a 12 cc syringe.

The experiment began on September 19, 1984 (mid dry season) and ended on December 31, 1984 (late dry season), with a 20-day adaptation period and a 84-day growth trial. All of the animals grazed the same 18-ha pasture of caatinga vegetation and every night were separated and penned by treatment group. Each animal in treatments 2, 3 and 4 received its supplement two times daily (6 a.m. and 5 p.m.) during both periods of the experiment. A complete mineral mix and water were offered ad libitum. The animals were weighed weekly. Animals in treatment 1 were handled less than the other experimental animals since they did not receive any supplement. This procedural difference among treatment groups was not considered to be important because all of the experimental animals were relatively tame and adapted easily to routine handling.

Diet sampling was conducted using seven, 18-month-old esophageally fistulated SRD goats. The samples were collected during the first week (October 10-12), sixth week (November 14-16) and tenth week (December 17-19) of the growth trial. For each three-day collection period, samples were pooled by animal and used to estimate the botanical and nutritive composition of the diets of the experimental goats. Biomass and composition of available forage were estimated immediately prior to each collection as well as on two other occasions. Sampling procedures involved collecting all dead herbaceous plants and fallen tree leaves from 50 randomly placed quadrats (50 x 60 cm) within the experimental pasture. The samples were separated by species, oven dried and weighed.

Results

For the 12-week growth trial, cumulative weight gain for the CR + MU group (3.9 kg) was nearly twice as high as the weight gains for the other three (Fig. 1.1). There were no significant differences (P>.05) between the CR (2.1 kg), CR + U (2.1 kg) and CR + M (1.9 kg) groups. Although the CR + MU group began deviating from the trend of the other groups during the sixth to eighth week period, it was not until the tenth week that significant differences (P<.05) appeared between the CR + MU group and the other three. From the sixth week to the end of the trial, the CR, CR + U and CR + M groups only maintained weight while the CR + MU group continued to gain weight. Average weights of the goats at the end of the trial was 17.1, 17.3, 16.9 and 19.2 for the CR, CR + U, CR + M and CR + MU treatment groups, respectively.

Total available biomass of dead herbaceous plants and fallen tree leaves decreased significantly (P<.05) from 3806 kg/ha to 2888 kg/ha over the course of the study (Fig. 1.2). For the five collection dates, fallen tree leaves ranged from 73 to 79% of the total biomass. Therefore, between 21 and 27% of the total biomass was dead herbaceous plants with herbaceous leaves accounting for only 3% of the total. In terms of individual species, there were no significant changes in relative species composition over the course of the study.

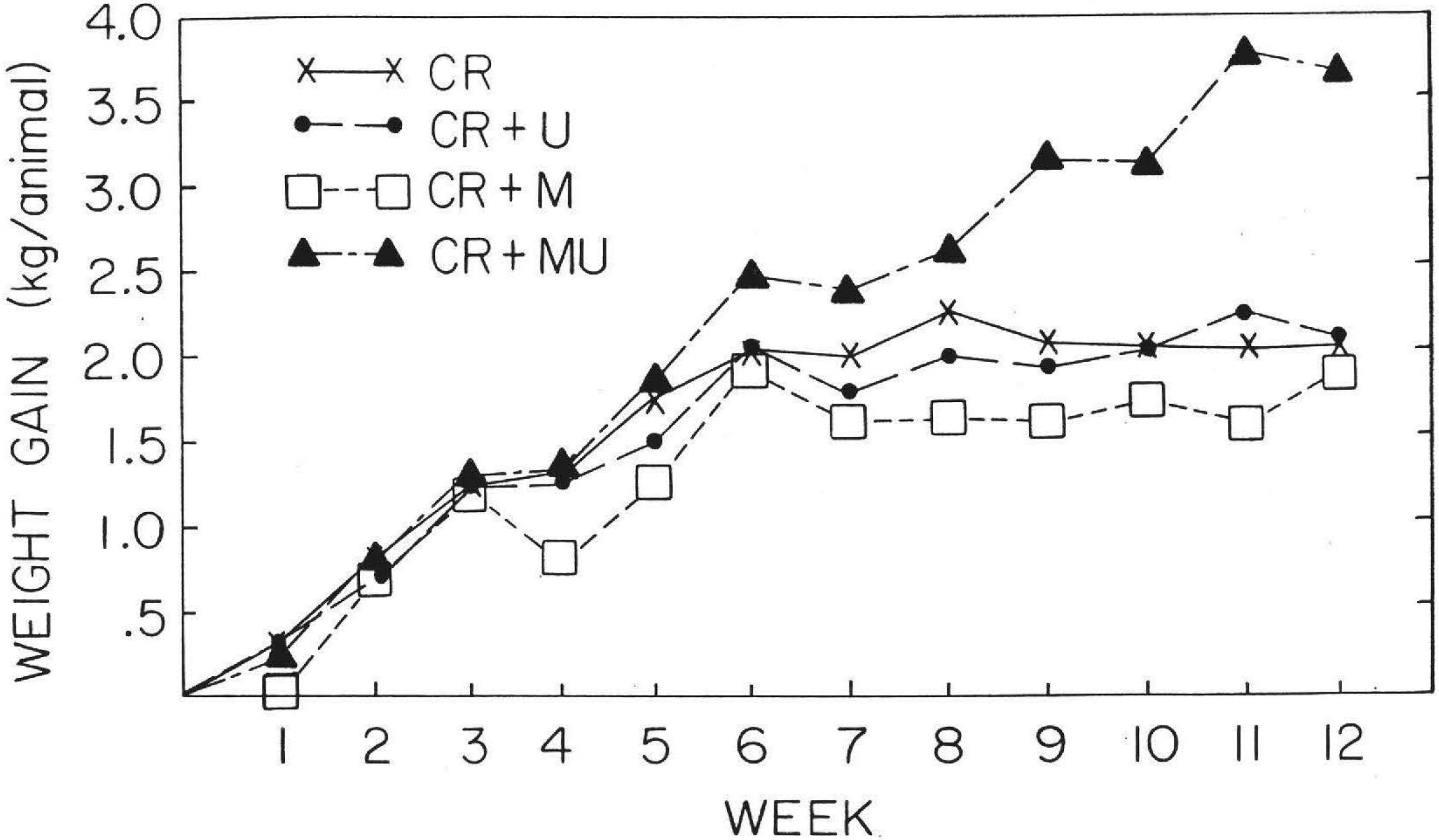

Figure 1.1. Cumulative wieght gain by treatment group for the 12 week growth trial. Weight gain for the CR + MU group was significantly (P .05) higher than for the CR, CR + U and CR + M groups in the 10th, 11th and 12th week.

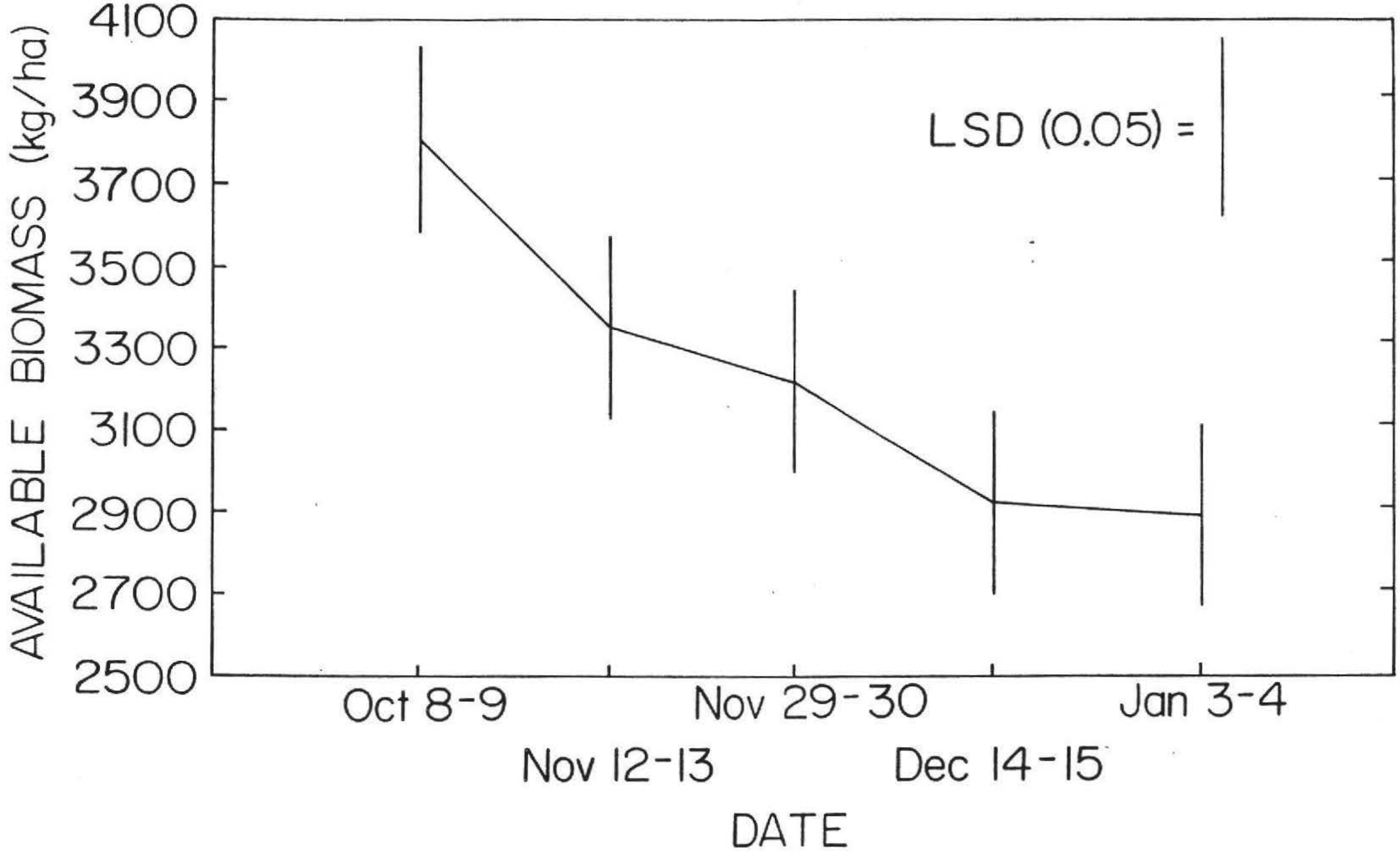

Figure 1.2. Total biomass of dry season forage at five dates over the course of the growth trial.

Chemical analysis of individual plant species that were hand-harvested generally did not indicate significant ($P<.05$) changes in the quality of the dry season forage during the experimental period. Percent crude protein (CP) remained relatively constant for catingueira leaves and herbaceous plant leaves, examples of the higher quality and more palatable components of dry season forage. Pau branco leaves and stems of herbaceous plants, two of the lower quality and less palatable components, also maintained consistent levels of CP over the course of the dry season (Fig. 1.3). Similarly, percent neutral detergent fiber (NDF) remained constant throughout the course of the study for the four representative examples (Fig. 1.4).

Chemical analysis of the diet samples collected from the esophageally fistulated animals indicated a general decline in quality from October to December (Table 1.1). NDF remained relatively constant from the first to the sixth week and, subsequently, increased significantly ($P<.05$) in the tenth week. IVOMD also remained relatively constant from the first to sixth week but decreased significantly $P<.05$) in the tenth week. Decreases in CP were significant ($P<.05$) for both the sixth and tenth weeks.

Botanical analysis of diet samples indicated that 75 to 80% of the diets of EF animals collected during the first and sixth weeks was composed of leaves (Fig. 1.5). In the tenth week, only 60% consisted of leaves while 40% was stems and low quality flower parts. Most of the flower and seed component consisted of the calyx of bamburral branco (<u>Blainvillea rhombiondea</u>), a large forb species.

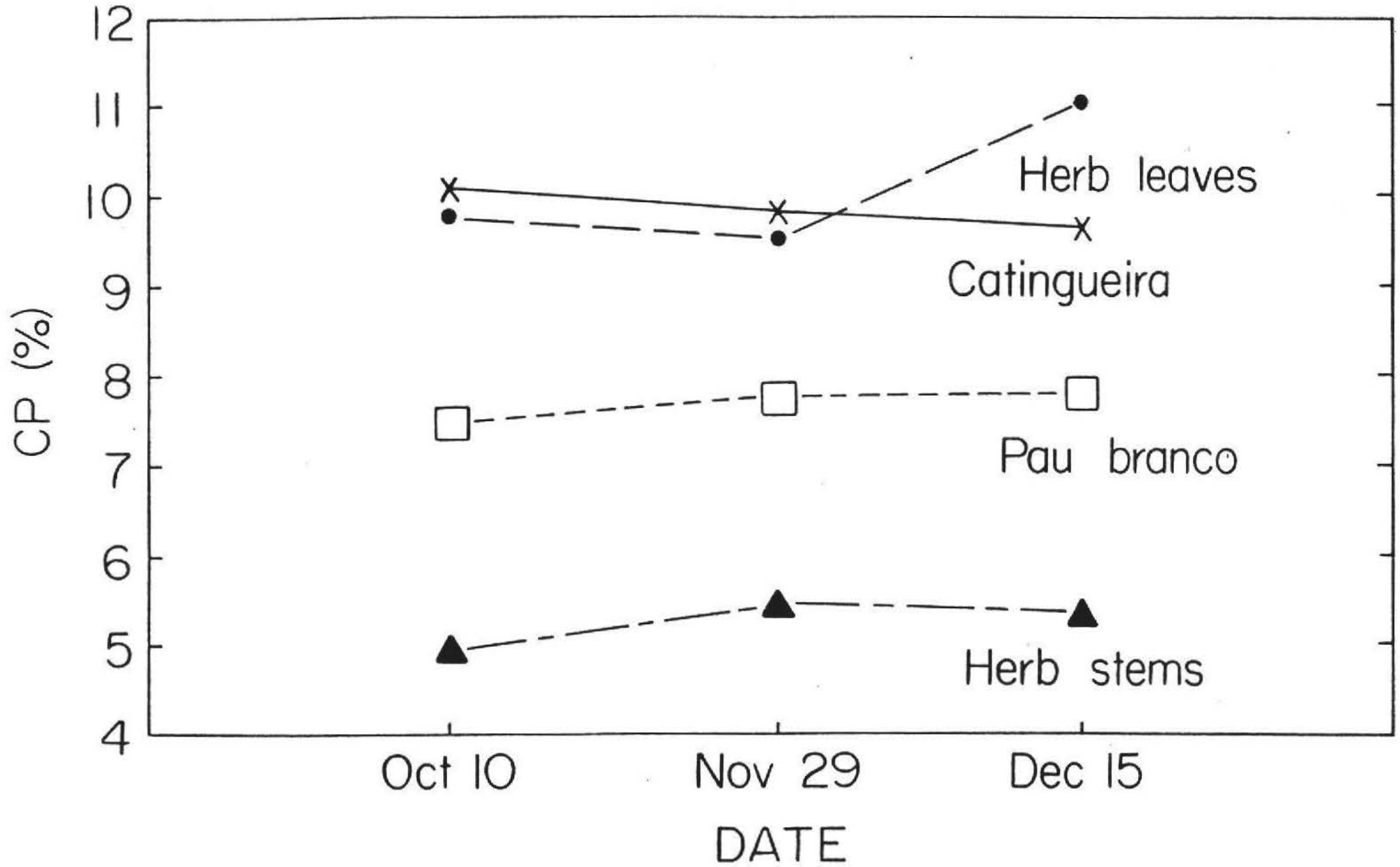

Figure 1.3. CP of four representative components of the dry season forage at three dates over the course of the growth trial.

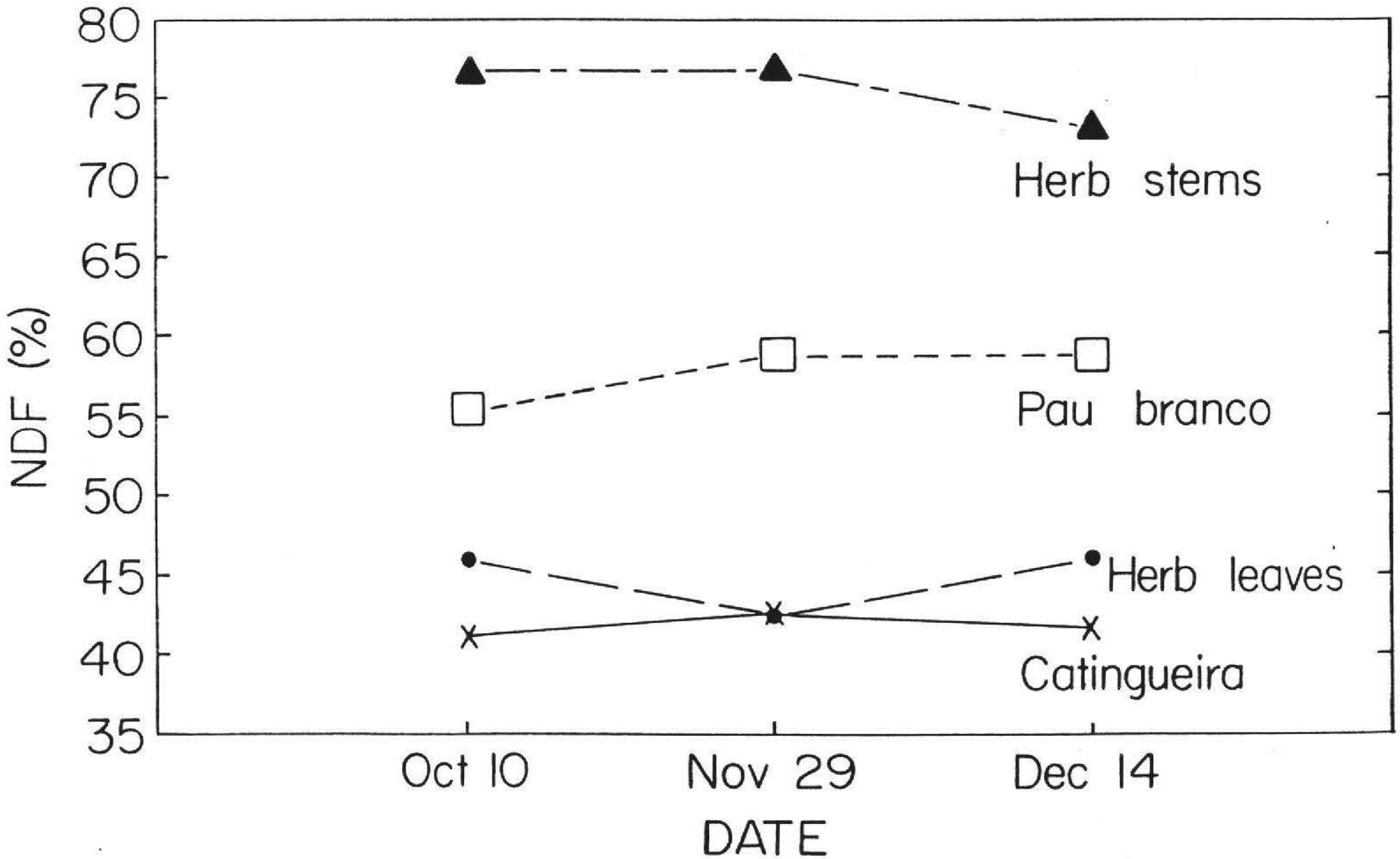

Figure 1.4. NDF of four representative components of the dry season forage at three dates over the course of the growth trial.

Table 1.1. NDF (%), CP (%) and IVOMD (%) of diet samples collected by esophageally fistulated goats in the first, sixth and tenth weeks of the growth trial.

	Week		
	First	Sixth	Tenth
NDF	44.90^{a}	45.06^{a}	52.14^{b}
IVOMD	43.94^{a}	43.79^{a}	40.69^{b}
CP	11.97^{a}	9.64^{b}	8.36^{c}

[a-b]Means in the same row, followed by a different letter, are signficantly different (P<.05).

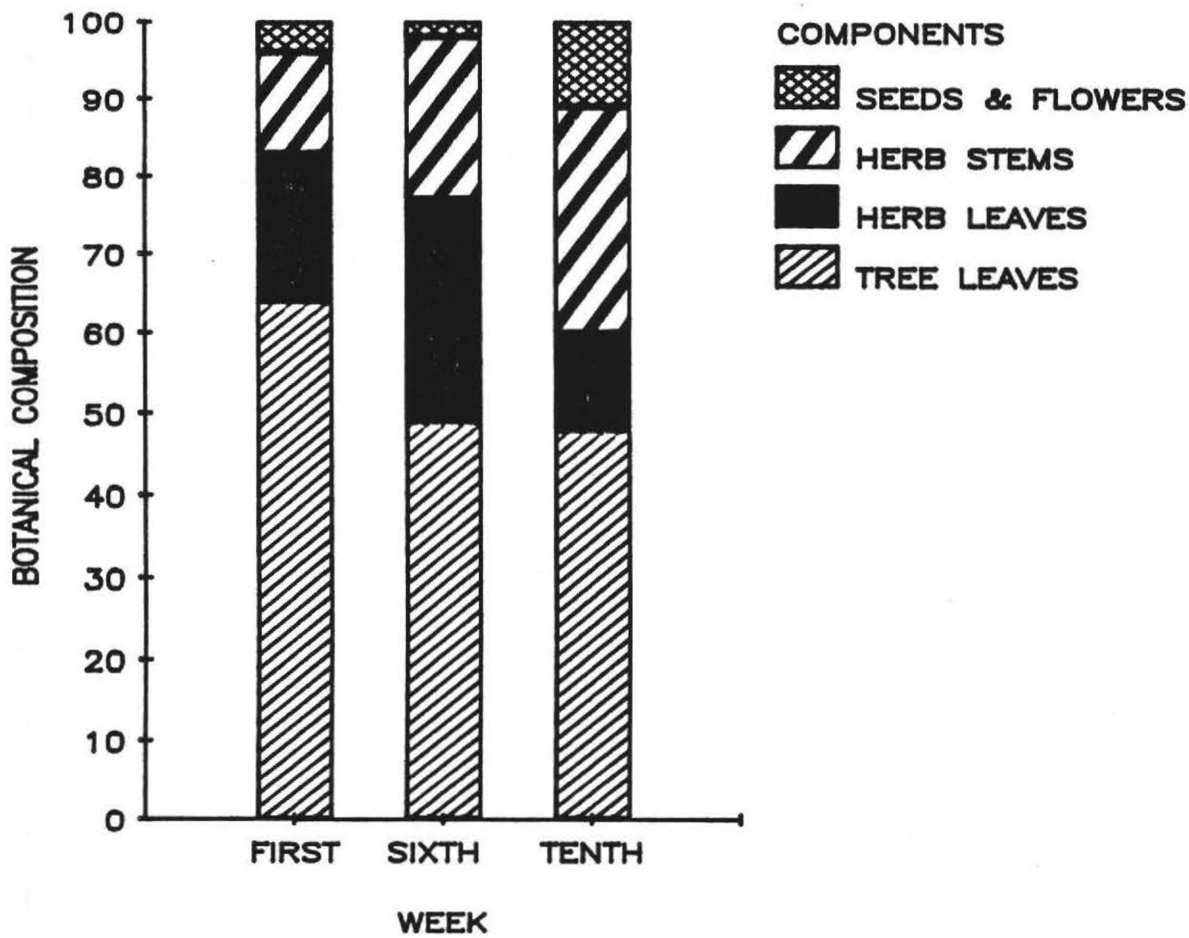

Figure 1.5. Botanical composition (%) of esophageally fistulated goat diets collected the first, sixth and tenth week of the growth trial.

Discussion

The goat weight responses illustrated in Figure 1.1 can be discussed in terms of two major components: 1) the plant and animal factors that relate to the leveling-off of weight gains for CR, CR + U and CR + M groups during the sixth to eighth week, and 2) the weight responses to supplementation.

In terms of the first point, measured animal-related factors indicated that diet quality significantly declined after the sixth week and that low quality constituents such as stems of herbaceous plants increased during the sixth to tenth week period. These two factors correspond closely with the leveling-off of weight gains in the sixth to eighth week period. Related changes in the plant component, however, are not detectable. A summary of plant-related factors are as follows: 1) nutritive value of the forage components remained constant; 2) available forage biomass appeared to be high even at the end of the study; and 3) relative species composition of the available forage did not significantly change during the course of the study. None of these factors indicates that diet composition or weight gains should have changed over the course of the study. However, as the shift to more stems in the diet by the tenth week indicates the relative species composition of the dry season forage was changing. Probably by the latter part of the trial, the availability of high quality, palatable forage had decreased to the point that goats could no longer efficiently select adequate levels of the more desireable forage species and were forced to partially switch to lower quality material (stems). Identifying statistically significant changes in relative species composition of the available forage was not realized because of the low precision of the vegetation sampling method used. Therefore, it was not possible to quantitatively relate any of the changes in relative species composition of the available forage to animal performance.

The lack of weight responses to the urea-alone and molasses-alone treatments during the latter part of the growth trial indicates that the leaf litter was deficient for growth in both N and energy. A proper balance between the amounts of N and energy available to the rumen microorganisms is needed to maintain a relatively high roughage intake and, thereby, realize weight gains (National Research Council 1976). Supplementation of roughage diets with N alone or energy alone produces variable results, at best, as the level of deficiency of the nonsupplemented nutrient is normally the limiting factor (Loosli and McDonald 1968, Nolan et al. 1975, Milne et al. 1979, Winks et al. 1979).

The positive weight responses during the latter part of the growth trial for the CR + MU group supports the contention that dry season forage is deficient in both N and energy. Similar studies (Winks et al. 1979, Mulholland and Coombe 1979) have also shown that urea- and molasses-supplemented groups do not gain more weight than nonsupplemented groups during periods of adequate quality forage. These studies also suggest that when the nonsupplemented animals are able to maintain weight, the urea-and molasses-supplemented animals will gain weight. Apparently, at times when the forage supplies only maintenance requirements, the urea and molasses supply the N and energy needed to create the favorable rumen conditions required for increased roughage intake.

Summary

Goats grazing caating range were able to select a relatively good quality diet during the first half of the study and make sizeable weight gains. During the middle part of the trial, however, forage conditions changed and goats were no longer able to select a good quality diet, as indicated by weight responses and diet composition. This change in weight gain and diet composition during the last half of the study was probably due to a decline in the availability of palatable, good quality forage rather than a decline in the nutritive value of any forage component.

Supplementing N alone or energy alone did not improve goat performance (weight gains) in comparison to the nonsupplemented group during the last half of the trial. At this time, when diet quality was decreasing, supplementation of both N and energy was required to sustain the earlier rates of growth.

CHAPTER II

DIETARY SELECTION BY GOATS AS INFLUENCED BY THINNING AND CLEARING OF HARDWOOD WOODLAND IN NORTHEASTERN BRAZIL

Considering that livestock production, particularly in terms of goats and sheep, is the fundamental economic component of the caatinga vegetation region, the value of a practice involving vegetation manipulation must be assessed in terms of its effects on livestock. Earlier studies have reported on nutrition of sheep and goats in undisturbed stands of caatinga (Pfister and Malechek 1986) and under conditions of complete clearing (Kirmse et al. 1986a). However, prior to the present study, nothing was known of the effects of intermediate levels of canopy reduction on forage production and dietary selection by small ruminants. This experiment was conducted to determine the effects of various levels of overstory canopy cover on: 1) available browse and herbaceous plant biomass and 2) botanical composition of goats' diets on a seasonal basis.

Study Area

A 8-ha study area was selected 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 Podzols with a crystalline bedrock of precambrian origin.

Vegetation cover of the area was a dense stand (95% canopy cover) of caatinga woodland composed of a mixture of tree species typical of the caatinga of northern Ceara. Although it was apparent that some trees had been cut and removed for use as fence posts, the tree stand of the study area had not been extensively disturbed by woodcutters for a period of about 40 years. Principal tree species on the study area included the borage, pau branco (Auxemma oncocalyx Taub.), the euphorb, marmeleiro (Croton hemiargyreus Muell. Clrg.) and three leguminous species, catingueira (Caesalpinia pyramidalis Benth.), sabia (Mimosa caesalpiniaefolia Benth.) and mororo (Bauhinia forficata Link). These species were drought-deciduous and composed about 92% of the total trees/ha and yielded about 87% of the total foliar biomass from woody plants. They are all multiple-stemmed, drought deciduous species that coppice readily after being cut. Stand density prior to application of treatment was 4180 trees/ha (s_x=415) with 8164 stems/ha (s_x=630). 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

The study area was divided into two blocks, based on surface drainage features and related vegetational differences. Within each block, four 1-ha pastures were randomly allocated to one of four 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 pastures. Value of species for both forage and wood was considered in determining which trees to fell on thinned areas. Of the five major species, the three 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. The desired 55% cover treatment was attained without cutting many trees which produce palatable foliage and final tree density was approximately 670 trees/ha (1200 stems/ha). However, an appreciable number of palatable trees were cut on the 25% cover plots, 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 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 in the morning for three consecutive days. Eight esophageally fistulated goats per treatment were fitted with screen-bottomed bags and allowed to graze freely for 30 minutes. The daily sample from each goat was thoroughly hand-mixed, divided into two parts and frozen at -17°C. One portion was later freeze-dried and the other portion was oven-dried at 40°C for two 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 a species level, it was designated as an unknown browse, forb or grass.

Due to limitations of pasture size, the esophageally fistulated goats were on the experimental pastures only during the periods mentioned above. The periodic use of the pastures by the experimental animals throughout the year, however, did simulate continuous grazing. Pastures were stocked equally at a rate (1.2 ha/animal/year) heavier than the one recommeded by the CNPC (1.7 ha/animal/year). Although statistics were not available, observations indicated that heavier-than-recommended stocking rates were generally used by private producers as well as by the CNPC. The experimental animals were randomly allocated to the pastures before each period. All collection periods included a 2-day adaptation period. The goats were penned at night and allowed to forage freely from 7:00 a.m. to 4:00 p.m. during each of the collection periods. Between collections, the esophageally fistulated goats were pastured in an adjacent area with vegetation similar to that of the experimental pastures.

Availability of herbaceous vegetation and browse was estimated immediately preceding each diet collection period. Herbaceous vegetation was harvested in 25, randomly placed, 0.3 sq m quadrats in each pasture. Plant material was clipped at ground level, separated by species, individually sacked, dried in a forced air oven at 60°C for 48 hours and weighed. This dried material was later separated into leaf and stem components and weighed. Biomass of fallen leaves was determined by species by collecting fallen dry leaves in these same quadrats used to sample herbaceous vegetation. Leaf fall did not begin until after the July collection; therefore, dry leaves were not a component of total available herbage biomass until the September collection.

The reference unit method (Andrew et al. 1979, Kirmse and Norton 1985) was used to estimate live biomass of tree and coppice foliage up to a browsing height of 1.6 m. For each collection period, regression equations describing the relationship between estimated and actual foliar biomass were developed for both trees and coppice of each of the five major species. Based on r^2 and S.E. values, linear regression equations were evaluated as being suitable predictive 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 was estimated for each species. Similarly, on the two 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 x 10 m quadrats in each pasture. Total foliar biomass by species was calculated by multiplying the average foliage yield per tree or stool by the density estimate. Tree and coppice foliage was not estimated in September and December.

The experimental design was a spit-plot in time with an incorporated randomized complete-block design. There were two blocks with four treatments on which successive measurements were made at six times through the study year. Data analysis was conducted using the statistical package Rummage (Bryce et al. 1980). Least squares analysis was performed and the protected LSD procedure was used to detect differences among significant treatment means (Steele and Torrie 1960).

Results

Available Forage

For the growing season from February through May, herbaceous standing crop for the cleared treatment was three to seven times greater than for the control (Fig. 2.1). The two thinned treatments consistently yielded similar ($P>.1$) amounts of herbaceous biomass and generally yielded significantly ($P<.1$) greater amounts than the control. Availability of herbaceous vegetation remained relatively constant from May through September for all treatment levels except for the control. Probably due to the prolonged wet season, some of the late maturing, large forbs and climbing vines were 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 better drained sites, attained heights up to 3 to 4 m and flowered in the late wet

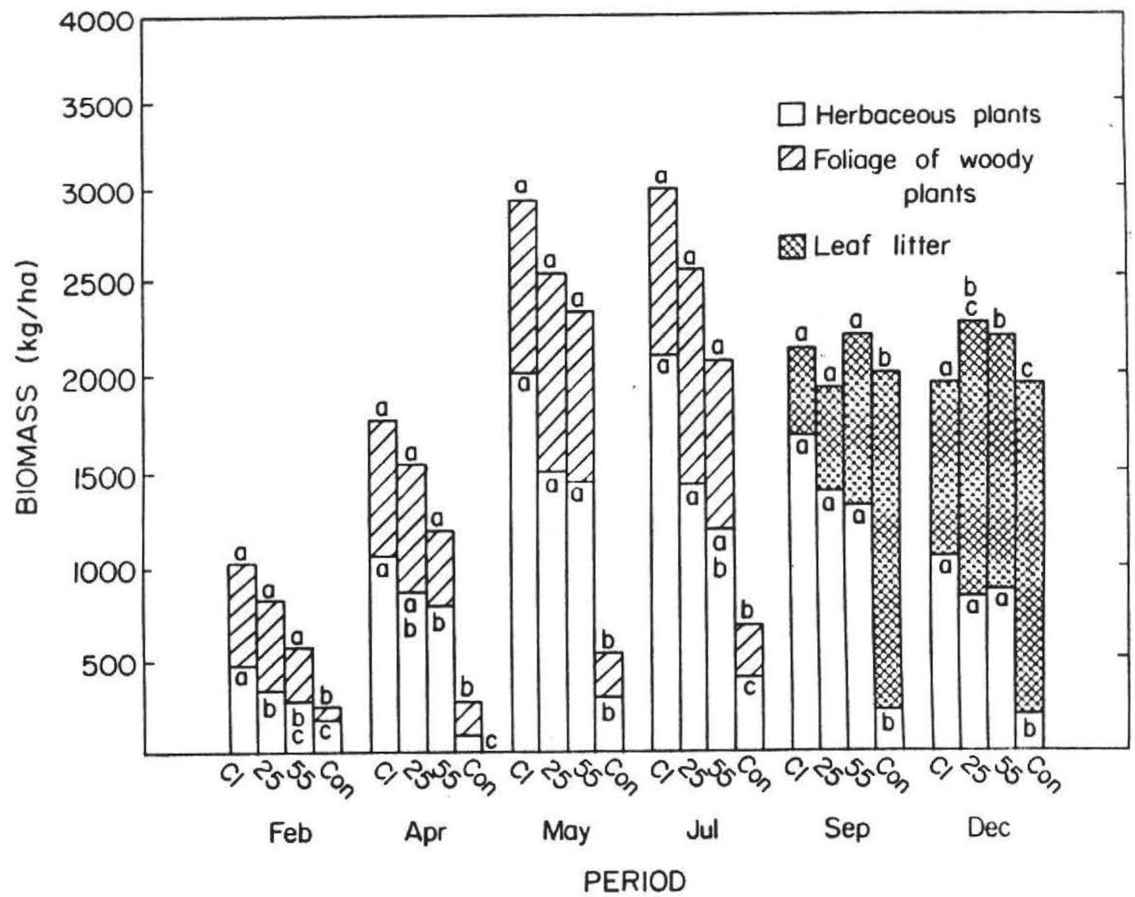

Figure 2.1. Available herbage biomass for six dates in 1985 on the cleared (Cl), 25% cover (25), 55% cover (55) and control (Con) pastures. Foliage of woody plants included green leaves of both coppice shoots and intact trees. Coppice foliage contributed 100%, over 97% and 0% ofthe total foliage of woody plants of the cleared, thinned and control pastures, respectively. Foliar biomass of woody plants was not estimated in September and December. Bar sections with a common letter in a season and within a forage class are not significantly different (P .1).

season and into the early dry season. They were the dominant herbaceous vegetation component by weight for all treatments. 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 (along with Carex spp.) were generally not a major component of the herbaceous standing crop biomass and the relative amount of grasses to forbs was not significantly ($P>.1$) 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 the forbs had produced less than half of their total wet season biomass, the yields 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 three 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 (0.49, 0.48 and 0.53 for the respective treatments mentioned above). These 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 (Fig. 2.1). By mid-February, a little over one 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. Coppice foliar biomass peaked by May and remained constant through July. For the first four periods, over 90% of the available coppice foliar biomass was contributed by pau branco, marmeleiro and catingueira. These three species are the least palatable to goats of the five major woody species (Kirmse et al. 1983). Available biomass of sabia, mororo and catingueira remained relatively constant from February through July, probably due to goat browsing and insect damage (in the case of catingueira). Leaf fall began in August but coppice shoots of all species except marmeleiro retained some leaves (visual estimate: 10 to 20% of July's biomass estimates) until the end of the dry season. Coppicing stools shed their leaves from bottom to top and, 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 (Fig. 2.1). Collectively, foliage of pau branco, marmeleiro and catingueira consistently composed over 90% of the total biomass. In contrast, foliage on 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.

Dietary Selection

There were significant (P<.05) treatment-by-period interactions for browse, forbs and grasses in the goats' diets. The relative amounts of any one of these items in the goats' diets varied substantially across treatments and throughout the year (Table 2.1).

Table 2.1. Relative botanical composition (%) of diets of goats on manipulated caatinga and the control for six sampling periods in 1985, northeastern Brazil.

	February				April				May			
	Clear	25% cover	55% cover	Control	Clear	25% cover	55% cover	Control	Clear	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
Maniçoba	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

Table 2.1. (continued)

	July				September				December[1]			
	Clear	25% cover	55% cover	Control	Clear	25% cover	55% cover	Control	Clear	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
Maniçoba	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

[1]Herbaceous species were generally not identifiable to the species level in December.

Although the treatment-by-period interaction was not significant (P>.05) for dietary leaf:stem ratios, the treatment effect was not significant while the period effect was significant. These analyses reflect the seasonal fluctuations in selectivity by goats.

For both February and April, goats selected low to intermediate amounts of browse on the treated pastures compared to high amounts on the control (Table 2.1). Sabia and manicoba (Manihot glaziovii Muell. Arg.) were the favored browse species for all treatments. In February, goats selected from 25 to 50% of their diets as grasses on the treated pastures compared to 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% of the diets. 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 in both May and July (Table 2.1). 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 when climbing vines were also heavily consumed. 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. 2.2). Over 21% of the goats' 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.

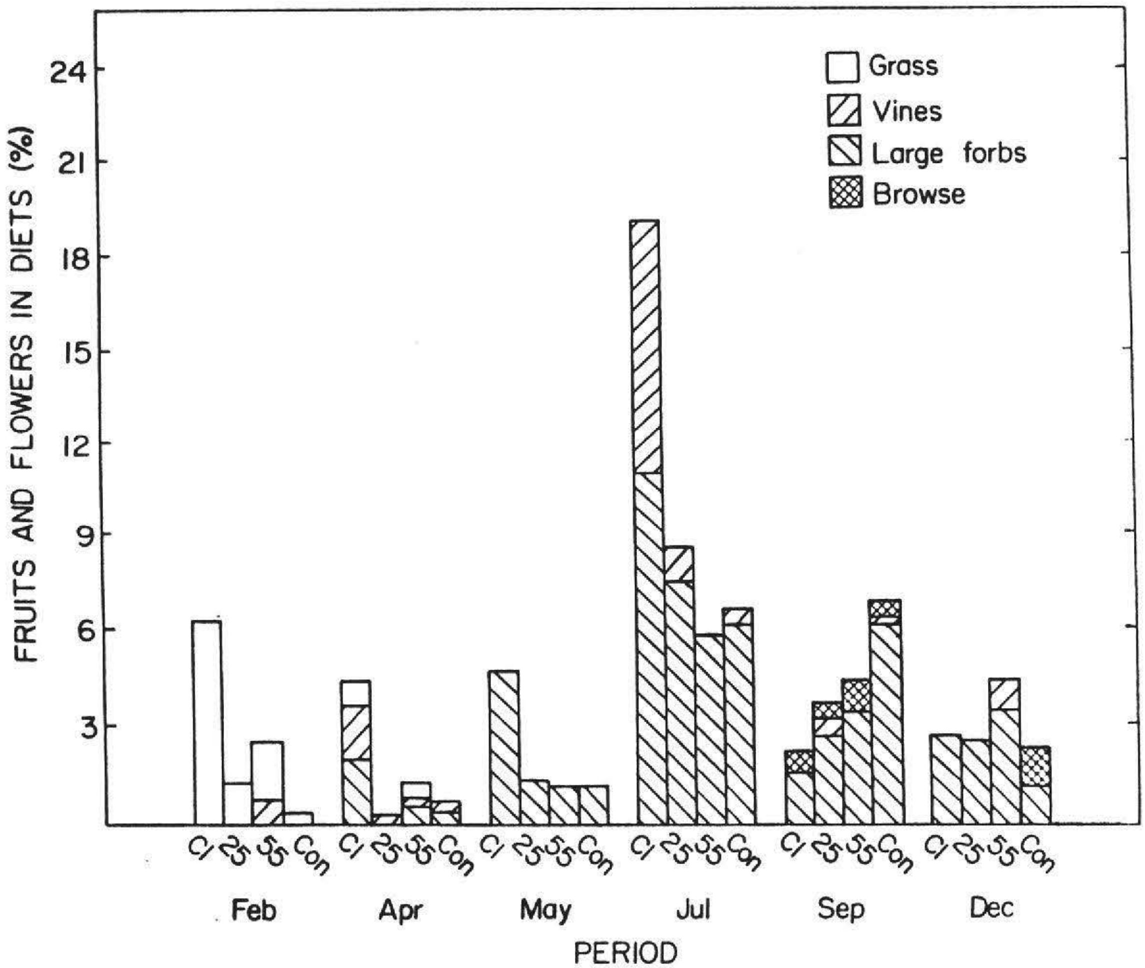

Figure 2.2. Relative amounts of fruits and flowers in the diets of goats utilizing the cleared (Cl), 25% cover (25), 55% cover (55) and control (Con) pastures.

The amounts of browse selected were generally high for all treatments during the two dry season collections (Table 2.1). 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 were 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 also utilized on the treated pastures. Variable amounts of dry herbaceous vegetation were consumed through the dry season although most of it was stem material.

Discussion

The SRD goats used in this study were opportunistic foragers and appeared to prefer herbaceous vegetation when readily available and in green, leafy form. Goats consistently consumed more herbaceous material than browse during the wet and transition seasons. Only on the control areas in February and April when available herbaceous standing crop was less than 170 kg/ha, was browse more heavily utilized than herbaceous vegetation. Surprisingly, goats consumed more herbaceous material than browse during the transition period (July) when the herbaceous vegetation was mature and senescing. All available browse on both treated and control pastures was green at this time. Browse consumption was high on all pastures for the last two collection periods. Leaf:stem ratios of available herbaceous vegetation were extremely low and all herbaceous material was dry and of lower forage quality (Table 2.2).

Amounts of the various components of the herbaceous vegetation consumed by the goats showed large seasonal variation. The use of grasses was highly seasonal since availability of green, good quality grass was mostly limited to the early wet season. In February, grasses represented only 8% of the total available herbage biomass on the treated pastures, yet nearly 35% of the goats' diets was grass parts. Although grass yields tended to be higher for subsequent collections, grass was never again a major dietary component. Pfister and Malechek (1986) also reported highly 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 2.2) 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 considered undesirable by local researchers and livestock producers as they are generally unacceptable to cattle, which are economically more important.

Table 2.2. Crude protein content (%) 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.	-	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).

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

Fruits and flowers of herbaceous plants were particularly important dietary constituents during the transition period (Fig. 2.2) when the large forbs and vines were mature and availability of green leafy material was declining. Fruits and flowers are generally high in nutrients (Everitt and Alaniz 1981, Pfister and Malechek 1986); however, hand-harvested samples of many of the fruit and flower types consumed in this study had nutritional values similar to those of other herbage types available at that time (Table 2.2). Consumption of this component declined as the dry season advanced. Fruits and flowers of woody species never were an important dietary constituent.

The amount of the five major browse species consumed on the various pastures depended greatly on availability, acceptability to goats, season and form (green foliage or leaf litter). Sabia was the browse species most consistently eaten by goats regardless of season or treatment (Table 2.1). This ubiquitous, leguminous tree was highly sought as green foliage throughout the year and as 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. There were other browse species which appeared to be more palatable, namely jurema branca (Pithecolobium dumosum Benth.) and algodao brava (Bombax vitifolium Wild.), but the density of these species was so low that they were never important dietary constituents.

The other major browse species varied greatly in dietary use (Table 2.1). 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. The consumption of pau branco foliage, which is generally considered to be unacceptable to goats, increased substantially 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 more than small quantities.

The heavy use of manicoba was somewhat surprising although its use was limited to the wet season (Table 2.1). 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.

The traditional classification of goats as a browse preferring species (McMahan 1964, Davis et al. 1975, Wilson et al. 1975, Van Soest 1982) is not applicable to the native animals used in this experiment. Moreover, any number of studies can be cited that classify goats as preferring herbaceous plants (Knight 1965, Somlo et al. 1981, Lopes and Stuth 1984) or as animals that readily consume both herbaceous plants and browse (Malechek and Leinweber 1972, Nge'the and Box 1976, Bryant et al. 1979, Pfister and Malechek 1986, Kirmse et al. 1986a). Dietary selection by goats depends on numerous factors including breed, previous experience, stocking rate, season of year, relative species composition of the available vegetation and various environmental factors (Arnold and Dudzinski 1978). The goats used in this study were opportunistic foraging animals that selected extremely variable diets as dictated by vegetation treatments and season of use.

Stand Manipulation

Forage conditions for goats appear to be improved as a result of stand manipulation. Herbaceous production is increased, green foliage from coppice shoots is available far into the dry season and moderate levels of dry season leaf litter are also present. Herbage availability, including herbaceous standing crop and green and dry browse, is relatively high throughout the year on manipulated caatinga. In dense stands of caatinga, availability of herbaceous vegetation is 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 this study indicate that thinning has the most potential as a management scheme for livestock producers 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 any browsing damage but they also provide a extremely important dry season reserve of palatable leaf litter.

Aside from the potential forage benefits, the 55% cover treatment provides for wood production opportunities. Forage and wood are two 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 caatinga has a more than adequate mix of tree species (e.g., sabia and mororo) that yield both valuable wood and palatable foliage and, therefore, 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 one or two years to protect the coppicing plants from browsing.

Management of thinned stands of caatinga for sustained high yields of forage and wood, however, is complicated by the fact that economic control of undesireable coppice shoots and seedlings 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. 1986). 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 two dominant tree species in northern Ceara, pau branco and marmeleiro, are relatively unacceptable to livestock, biological control of them with livestock is not practical. Other methods of control (e.g., burning or chemicals) 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.

Although thinned stands of caatinga might produce favorable conditions for goat production, comparisons of nutritional aspects of goat diets between undisturbed, cleared and thinned caatinga will best address treatment differences. Response of cattle to stand manipulation must also be determined before conclusive statements can be made about multiple use management of the caatinga. Of all livestock species, cattle hold the highest socio-economic importance and can no longer be ignored in production system studies.

CHAPTER III

NUTRITION OF GOATS AS INFLUENCED BY THINNING AND CLEARING OF DECIDUOUS WOODLAND IN NORTHEASTERN BRAZIL

Knowledge of the botanical components that constitute animals' diets (Chapter II) are but an initial step to understanding the effects of stand manipulation on animal production. The second step involves nutritional assessment of these diets, both qualitatively and quantitatively. This chapter reports on the seasonal nutrient content of diets and on seasonal forage and energy intake of goats on cleared, thinned and undisturbed stands of caatinga.

Methods

The study area was the same 8-ha site described in Chapter II. Details of extrusa-sample collection on the treatment pastures and preparation of these samples have also been covered in Chapter II. Additionally, the following procedures were necessary to determine diet quality and intake.

The freeze-dried subsamples of the extrusa samples collected daily by the fistulated goats were ground in a Wiley mill to pass a 1-mm screen. The subsamples were subsequently pooled by animal over each of the 3-day collection periods. These composited samples were then used for the sequential determination of neutral detergent fiber (NDF) and permanganate lignin (Van Soest and Wine 1968, Goering and Van Soest 1970). The samples were also analyzed for nitrogen (AOAC 1970) and *in* vitro organic matter digestibility (IVOMD) using the Moore modification of the Tilley and Terry technique (Harris 1970). The rumen fluid used for the inoculation of the fermentation tubes was taken from rumenally fistulated goats ranging freely in pastures of caatinga vegetation. Locally grown forage sorghum (Sorghum bicolor L.) with a known in vivo digestibility was used as one of the standards. Samples of wheat (Triticum aestivum L.) straw and maple (Acer glabrum Torr.) leaves analyzed for IVOMD at the Range Nutrition Laboratory at Utah State University were also used as standards.

Total fecal collections were made to derive organic matter intake (OMI) on the pastures. Ten mature, SRD goats in each treatment were fitted with fecal collection bags and grazed in common with the fistulated goats during each of the above-mentioned periods. Feces were collected and weighed twice daily for four consecutive days. Subsamples were taken for the gravimetric determination of fecal organic matter output. IVOMD results obtained from the analysis of the diet samples were used in conjunction with the estimates of fecal organic matter output (FO) to calculate OMI:

$$OMI(g/day) = \frac{FO(g/day)}{1-IVOMD}$$

Gross energy of the diet samples and feces were determined by complete oxidation in a Parr adiabatic bomb calorimeter (Harris 1970). Digestible energy (DE) intake was calculated as:

$$\text{DE intake} = (\text{g/day of OMI})(\text{Kcal/g of diet sample on OM basis}) - (\text{g/day of FO})(\text{Kcal/g of feces on OM basis}).$$

Available forage biomass was measured at the time of each collection period, as described in Chapter II. Plant parts that were important dietary components were also selectively 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. Nitrogen and fiber components of these ground samples were determined as previously described.

The experimental design was a split-plot in time with an incorporated randomized complete-block design. There were two blocks with four treatments on which successive measurements were made at six times through the study year. Data analysis was conducted using the statistical package Rummage (Bryce et al. 1980). Least squares analysis was performed and the protected LSD procedure was used to detect differences among significant treatment means (Steele and Torrie 1960).

Results and Discussion

Nutrient Contents of Diets

NDF. Goats on the control pastures selected diets higher ($P<.1$) in NDF content than did goats on the treated pastures (Table 3.1). However, differences in NDF content among the reduced canopy treatments were not significant ($P>.1$). The overall higher dietary NDF level for the control was accentuated in May and July (late wet season to early dry season). It appeared that low forage availability on the control pastures (Fig. 2.1) forced goats to consume more fibrous diets earlier in the course of the study than on the treated pastures. Moreover,

Table 3.1. Dietary NDF and lignin contents (%)(means ± S.E.) for goats grazing manipulated and undisturbed stands of caatinga.

Collection Periods	NDF				Lignin			
	Cleared	25% cover	55% cover	Control	Cleared	25% cover	55% cover	Control
February	46.7±1.7	46.0±2.6	46.6±2.9	42.5±2.3	9.2± .4	11.4±1.3	11.4±1.1	10.0± .9
April	41.1± .9	38.9±1.4	40.5±1.7	41.4±2.5	10.6± .5	10.3± .7	10.6± .7	12.2± .5
May	39.6±2.1	39.4± .9	37.8±1.2	44.1±2.4	10.3±1.0	10.5±1.4	9.9±1.2	14.7±2.0
July	38.2± .7	41.4±1.2	40.2±1.1	44.5±1.0	12.5±1.0	14.3±1.2	12.7± .9	16.1± .7
September	41.4± .7	45.0± .8	46.1±1.1	46.4±1.8	14.9± .7	17.2±1.1	15.2± .9	16.5±1.5
December	46.9±1.6	45.1± .7	43.3± .8	45.5±1.5	11.5± .5	10.2± .5	10.0± .6	10.7± .7
Means	42.3± .7^{a}	42.9± .7^{a}	42.4± .8^{a}	44.1± .8^{b}	11.5± .4^{a}	12.5± .6^{a}	11.6±.5^{a}	13.0± .6^{a}

$^{a-b}$Means within the same row of the same fiber component followed by a common letter are not significantly different (P>.1).

what little acceptable forage remained on the control pastures (that had not been consumed in February or April) was mature by May. Forage conditions might have been further aggravated by the fact that shade grown plants generally have elevated cell wall content (Wilson 1981, Van Soest 1982). The reduced availability of low fiber forage probably lessened the ability of the goats on the control pastures to selectively forage. The greater amount of available forage on the cleared and thinned pastures (Fig. 2.1) apparently presented conditions for a higher degree of selectivity.

In February, the NDF contents of goats' diets from the treated pastures were relatively high. The high NDF levels were related to the comparatively high amounts of grass in the diets of goats on the treated pastures (Table 3.2). Grasses, especially tropical species, contain much higher NDF levels than do browse leaves or forbs (Short et al. 1974, Van Soest 1982). Only on the treated pastures in February were grasses a major dietary component.

Lignin. No overall differences ($P>.1$) in lignin content of diets were found among the four treatments (Table 3.1). Lignin content of diets followed the same trends by treatment as did NDF content until December. The marked decline in dietary lignin content between September and December appears to be an anomally since there was not a substantial shift in the botanical composition of the diets (Table 2.2) or a decrease in the lignin content of the available forage (Table 3.3). Other dry season studies in the caatinga vegetation zone have shown similar trends, with lignin levels peaking in the early to mid dry season period and decreasing thereafter (Kirmse et al. 1986a,

Table 3.2 Major forage classes (%) in diets of goats on cleared, thinned, and undisturbed caatinga for six sampling periods in 1985, northeastern Brazil.[1]

	February				April				May			
	Cleared	25%	55%	Control	Cleared	25%	55%	Control	Cleared	25%	55%	Control
Browse	20.5[a]	37.8[a]	45.5[ab]	66.8[b]	11.5[a]	26.9[a]	28.4[a]	63.4[b]	9.5[a]	24.4[a]	26.3[a]	19.5[a]
Forbs	28.8[a]	33.2[a]	29.5[a]	26.3[a]	76.6[a]	65.5[a]	62.3[a]	29.5[b]	79.9[a]	60.8[a]	62.6[a]	66.0[a]
Grass	50.7[a]	29.2[ab]	24.9[ab]	6.9[b]	11.5[a]	7.6[a]	7.6[a]	7.1[a]	10.6[a]	14.5[a]	11.0[a]	14.5[a]
	July				September				December			
	Cleared	25%	55%	Control	Cleared	25%	55%	Control	Cleared	25%	55%	Control
Browse	24.5[a]	47.1[a]	37.9[a]	25.8[a]	83.9[a]	72.8[a]	71.5[a]	68.9[a]	45.3[a]	67.0[a]	56.3[a]	63.9[a]
Forbs	71.5[a]	50.5[a]	56.8[a]	69.7[a]	15.9[a]	26.6[a]	28.0[a]	29.5[a]	54.6[a]	32.8[a]	43.5[a]	36.0[a]
Grass	4.0[a]	2.4[a]	5.4[a]	4.5[a]	T[2a]	T[a]	T[a]	1.6[a]	T[a]	T[a]	T[a]	T[a]

[1]This table is adapted from a more complete description of dietary selection in Chapter II.

[2]T indicates that the dietary component constituted less than 1% of the diet.

[a-b]Means of a dietary component within each period followed by a different letter are significantly different ($P<.05$).

Table 3.3 Crude protein (%) and lignin (%) content of plant species that were important constituents of the goats' diets from the late wet season through the late dry season.

	May		July		September		December	
Plant Species	CP	Lignin	CP	Lignin	CP	Lignin	CP	Lignin
Herbaceous								
leaves, *Bidens* spp.	17.5	8.0	-	-	-	-	-	-
leaves, *Hyptis* spp.	15.2	-	12.2	13.5	-	-	-	-
leaves, *Melanthera* spp.	16.6	5.1	-	-	-	-	-	-
leaves, *Ipomoea* spp.	16.8	15.4	14.6	17.9	-	-	-	-
leaves, herbaceous plants pooled	-	-	-	-	8.4	12.7	8.0	10.8
stems, herbaceous plants pooled	-	-	-	-	3.2	19.4	3.4	18.4
Browse								
green foliage, sabia coppice	17.0	15.5	15.5	19.2	14.4	15.7	13.3	19.2
leaf litter, sabia tree	-	-	-	-	7.8	23.5	10.9	24.0
leaf litter, catingueira tree	-	-	-	-	11.2	10.7	9.8	10.4

Pfister and Malechek 1986). None of these studies, including my study, was designed to explain these trends in lignin levels, and the reasons for the decline in dietary lignin content are not understood.

Crude Protein. Crude protein (CP) content of the goats' diets was similar (P>.1) for all treatments (Table 3.4). CP content remained in the 13 to 15% range through July for all treatment levels and subsequently dropped off sharply in September and December. Levels on the control pastures remained surprisingly high in May and July when forage availability was very low (Fig. 2.1). Caatinga plant species are generally high in CP when green (Table 3.3), and free-ranging goats appeared to be able to select diets relatively high in CP even at comparatively low levels of forage availability.

Dietary CP levels of this study, however, are substantially lower than the findings of a study conducted by Pfister and Malechek (1986) in an adjacent stand of undisturbed caatinga woodland. They reported dietary CP for goats ranging from 25% in the early wet season to 12% by the end of the dry season. A number of differences between the two studies are noteworthy: 1) Pfister and Malechek's (1986) study was conducted during a drought year; 2) a dry season rainshower during the course of their study stimulated woody plants to leaf-out for a short period of time, elevating dietary CP levels substantially and 3) their study was conducted on a larger more heterogeneous area (40 ha).

In respect to the first point, it is generally reported (Anderson and Scherzinger 1975, Van Soest 1982) that in range ecosystems forage quality is higher in dry years than in normal to wet years. Poor growing conditions during dry years result in high nutrient

Table 3.4. Dietary CP and IVOMD (%) (means ± S.E.) for goats grazing in manipulated and undisturbed stands of caatinga.

Collection Periods	CP				IVOMD			
	Cleared	25% cover	55% cover	Control	Cleared	25% cover	55% cover	Control
February	15.8±.3	15.3±.3	15.4±.5	15.1±.2	58.2±2.0	53.5±2.2	53.2±2.8	57.3±2.3
April	13.6±.2	14.8±.3	14.9±.4	14.6±.4	54.6±1.7	55.3±2.5	57.2±2.3	53.7±2.3
May	13.3±.6	14.0±.3	14.0±.5	14.8±.9	55.1±1.8	51.0±1.6	51.5±1.2	43.0±2.8
July	15.1±.3	15.0±.2	14.2±.3	14.2±.4	50.6± .6	49.4±1.0	48.9±1.4	45.6±1.4
September	12.1±.3	10.7±.5	10.3±.3	8.6±.2	35.7±2.4	37.6±1.0	37.6±1.2	36.9±1.6
December	8.1±.3	8.3±.2	8.5±.3	7.9±.2	30.6±1.4	33.4± .8	33.4±1.6	30.3±1.3
Means	12.9±.4[a]	13.0±.4[a]	12.9±.4[a]	12.5±.5[a]	47.5±1.7[a]	46.7±1.4[a]	46.9±1.5[a]	44.5±1.6[a]

[a-b] Means within the same row and treatment comparison followed by a common letter are not significantly different (P>.1).

concentrations in plant tissues as low amounts of biomass are produced. Also, in dry situations, cessation of plant growth occurs before maturation and, consequently, the dead plant has an atypically high proportion of vegetative growth with a high concentration of nutrients. As a result, nutritive value of available forage is relatively high during both the growing and dormant seasons. It cannot be certain that this would apply to a grazing system, such as the caatinga, where browse is often a major dietary component. The second point relates to the fact that the ephemeral shower caused an increased availability of good quality forage during the dry season when nutritive value of forage is usually decreasing. Third, the larger more heterogeneous pasture probably allowed the animals a greater opportunity for selective grazing. Finally, a combination of these factors would allow foraging animals to select diets of comparatively high nutrient content during both the wet and dry seasons.

The dietary CP levels of my study more closely compare to results reported by Kirmse et al. (1986a,b). These studies were conducted in stands of caatinga woodland during a year of average rainfall with no dry season showers. Moreover, the studies by Kirmse et al. (1986a,b) were conducted on small homogeneous plots.

The decline in dietary CP levels in the dry season of my study was expected as the goats increasingly relied on dry herbaceous material and leaf litter as forage. The CP content of the available forage also declined substantially over the course of the dry season (Table 3.3). Proportionally, the decline in dietary CP content was similar to that reported by Kirmse et al. (1986b) and Pfister and Malechek (1986).

Dietary levels of CP exceeded mmaintenance requirements for goats for all treatments up to the December collection (NRC 1981).

Digestibility. Differences in IVOMD among treatment levels were not significant (P>.1) (Table 3.4). As with fiber components, IVOMD for the three reduced canopy treatments was similar over the course of the study while the values for the control deviated noticeably from the general trend in May and July.

Van Soest (1982) reported that lignin is the main factor limiting digestibility in forages and that lignin content is inversely correlated to digestibility. In the case of this study, however, IVOMD was not correlated to dietary lignin levels. Although the trends in IVOMD and dietary lignin content were inversely correlated through September, they both decreased in December. These results suggest that factors in addition to lignin might be the primary determinants of digestibility (e.g., phenolics and levels of forage intake). Moreover, permanganate lignin estimates may not be indicative of true lignin and its binding potential (Van Soest 1982). This is particularly relevant to the caatinga where the sources of lignin, and perhaps the levels of phenolics, differ seasonally.

The dry season estimates of IVOMD for this study were considerably lower than those for the study by Pfister and Malechek (1986). The same reasons as previously mentioned in the CP section might partially explain the differences in the IVOMD estimates. Additionally, the dissimilarities could be attributed to a procedural difference in the in vitro method used. In the case of the study by Pfister and Malechek (1986), rumen inocula were obtained from pen-fed goats in Utah maintained on an alfalfa hay diet. Rumen liquor source in our study was from free-ranging SRD goats. This method of maintaining inoculum donor goats was used so that the donor and experimental animals would be experiencing similar forage conditions and nutritional limitations. In this manner, the in vitro esimates based on rumen fluid from free-ranging donors should have been representative of the field situation as experienced by the experimental goats. The relatively poor nutritional status of donor goats foraging in a caatinga pasture during the dry season could have adversely affected microbial populations and, therefore, resulted in reduced IVOMD estimates.

Estimates of in vitro digestibility from our study are similar to the findings of the dry season experiment conducted by Kirmse et al. (1986b). The similarity in experimental and environmental conditions once again might explain the favorable comparison of these two studies. In addition Kirmse et al. (1986b) conducted their digestibility determinations in Brazil using free-ranging donor animals as their source of rumen inocula.

Intake

Organic matter intake (OMI) reported in either absolute (g/day) or relative (% body weight, BW) terms was significantly ($P<.05$) greater for the reduced canopy treatments than for the control (Table 3.5). There were no differences ($P>.05$) among the reduced canopy treatments. Forage organic matter intake ranged from 2.1 to 2.3% BW on the treated pastures compared to only 1.8% BW on the control.

The low OMI estimates for the control were most likely related to the relatively low availability of forage (Fig. 2.1). Herbaceous

Table 3.5. OMI (means ± S.E.) for goats grazing cleared, thinned and undisturbed stands of caatinga.

	Mean[1] Body Weight (kg)	%BW				g/day			
		Cleared	25% cover	55% cover	Control	Cleared	25% cover	55% cover	Control
February	30.8	2.2±.06	1.7±.11	1.7±.10	1.7±.08	630±86	600±68	605±66	565±46
April	29.7	1.9±.13	1.9±.11	1.9±.08	1.6±.09	572±67	617±55	612±63	428±60
May	29.6	2.1±.09	1.8±.06	1.8±.09	1.4±.10	624±52	531±52	561±43	420±40
July	32.6	2.6±.07	2.6±.17	2.4±.09	1.8±.11	857±66	837±91	762±70	606±63
September	37.9	2.6±.10	2.6±.08	2.4±.08	2.3±.08	948±62	1092±80	899±78	866±56
December	36.3	2.2±.13	2.3±.07	2.3±.10	1.9±.11	788±38	821±46	807±56	689±43
Means		2.3±.05^{a}	2.2±.06^{a}	2.1±.05^{a}	1.8±.05^{b}	737±30^{a}	750±37^{a}	707±30^{a}	596±30^{b}

[1]This column represents the mean body weight by collection period of 20 goats used for the collection of feces. Mean body weights within a period were similar across all treatments as the goats were blocked by weight in the process of randomly allocating them to the treatments.

$^{a-b}$OMI means (expressed either as %BW or g/day) followed by a different letter are significantly different (P<.05).

standing crop was low throughout the year and browse availability was relatively low until the dry season after leaf fall. However, most of the dry leaves were unacceptable to goats since the two dominant tree species (pau branco and marmeleiro) do not produce palatable foliage. Approximately 60% of the total leaf litter biomass on the control pastures was contributed by pau branco and marmeleiro. Grazing pressure during each of the collection periods was probably higher than reasonably supportable by the control pastures.

On the average, OMI estimates compare fairly well with the results of other studies in the caatinga vegetation zone (Pfister and Malechek 1986, Kirmse et al. 1986b) and in other semiarid tropical regions (Kearl 1982). Contrary to what might be expected, however, OMI estimates for my study tended to be lower in the wet season than in the dry season. The reasons for this appear to be related to environmental characteristics of the caatinga vegetation rather than to any forage availability or quality considerations.

As previously mentioned, the inland region of northeastern Brazil is characterized by cycles of wet and dry periods. During stretches of drought, such as the five year drought of 1979 to 1983, low forage availability is usually considered the major factor limiting small ruminant nutrition and forage intake (Pfister et al. 1983, Queiroz 1985). The relatively small amount of forage produced during the short wet seasons is not sufficient to maintain sheep and goats through to the end of extended dry seasons. An unrelated set of factors, however, may be limiting nutrition and production of small ruminants during wet years.

During a period of wet years, the most recent one beginning in 1984, soils are saturated and even inundated during much of the extended wet season. These excessively wet conditions are the cause of three major factors affecting small ruminant nutrition and intake: 1) severely compromised animal health conditions; 2) an increase in numbers of biting flies and mosquitoes and 3) poor foraging conditions. Pasture and corral areas never dry and conditions are ideal for stress-related, communicable health disorders. The most common of these are intestinal parasites, pneumonia and foot rot. These health disorders are chronic in most herds even when treated. The poor health status casues a malaise in small ruminants which adversely affects intake and can result in death for all age groups (Santa Rosa et al. 1986).

The excessively wet conditions also favor insects such as biting flies and mosquitoes. During months of highest populations (February through April), goats forage frenetically in an attempt to escape from the hordes of flies and mosquitoes. Most choose foraging sites where insect numbers are lower (e.g., open areas) or seek low hanging tree branches or coppice shoots to lie under. Although never quantified in this study, field observations indicated that foraging time was restricted as the goats spent an inordinate amount of time lying down in an attempt to protect their sensitive legs. Dietary selection was also probably affected by the frenetic feeding behavior.

Finally, goats, and to some extent sheep, are intolerant of wet conditions. Not only do they stop eating and seek shelter when rain falls, but they also do not enter areas that have tall, wet vegetation or that have standing water. This intolerance of wet conditions greatly limits both foraging time and potential foraging sites.

The combination of these factors apparently has a severe effect on the nutrition and intake of small ruminants in the caatinga vegetation zone. Even at the CNPC, where animal management is relatively intensive, malnutrition was a common cause of death in the 1985 wet season (Santa Rosa et al. 1986). The health status of the goats used in this experiment was generally good but biting flies, mosquitoes and wet conditions markedly affected their foraging behavior.

Weight responses of the nonfistulated goats used in this experiment further illustrate the poor conditions of the wet season of 1985 (Fig. 3.1). During most of the year these animals were pastured on an undisturbed caatinga area contiguous to the study area. These weight responses are not related to treatment effects but simply reflect the growth conditions in 1985. The animals merely maintained their weight during the wet season and gains did not occur until the early to mid dry season period. These weight responses also demonstrate what is common knowledge to local producers: fastest rates of growth for small ruminants occur during the early dry season, especially during wet years.

As was the case for OMI, daily digestible energy intake was significantly ($P<.05$) higher for the three reduced canopy treatments than for the control (Table 3.6). Average DE intake adjusted for BW on the three treated pastures was 47.3 Kcal/kg BW while it was only 36.0 Kcal/kg BW on the control pastures.

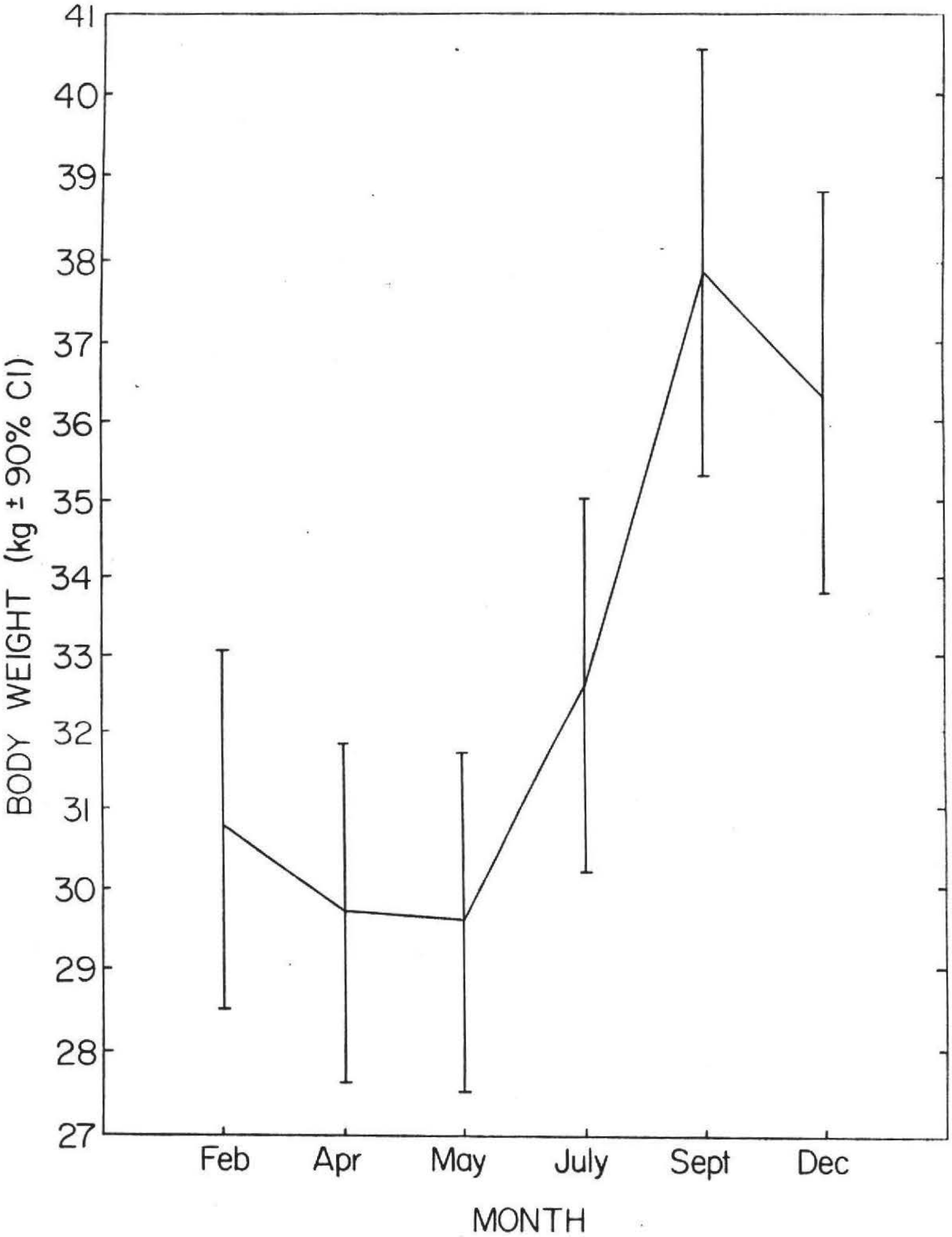

Figure 3.1. Average weight of the nonfistulated goats on six dates in 1985. These animals spent about 80% of the year on a pasture of undisturbed caatinga vegetation and approximately 20% of the year on the study area.

Table 3.6. DE intake (means ± S.E.) for goats grazing cleared, thinned and undisturbed stands of caatinga.

	Mean[1] Body Weight (kg)	kcal/kg BW				kcal/day			
		Cleared	25% cover	55% cover	Control	Cleared	25% cover	55% cover	Control
February	30.8	59.3±1.6	43.2±3.4	41.7±2.4	45.3±2.4	1715±236	1507±215	1488±161	1360±127
April	29.7	46.3±3.1	50.6±2.9	51.3±2.1	38.6±2.1	1395±164	1603±143	1613±165	1057±149
May	29.6	51.4±2.1	41.0±1.6	42.9±2.1	27.0±1.9	1559±130	1199±118	1314± 99	810±78
July	32.6	65.1±1.6	62.7±4.2	55.3±2.1	39.7±2.3	2126±163	2008±218	1766±163	1340±139
September	37.9	45.0±1.7	46.1±1.6	42.6±1.4	36.1±1.3	1628±107	1944±143	1586±138	1371±88
December	36.3	33.8±2.0	35.8±1.1	37.7±1.7	29.5±1.6	1230±59	1274±72	1339±94	1060±65
Means		50.1±1.6^{a}	46.5±1.5^{a}	45.3±1.1^{a}	36.0±1.1^{b}	1609±68^{a}	1589±72^{a}	1517±58^{a}	1166±52^{b}

[1]This column represents the mean body weight by collection period of 20 goats used for the collection of feces. Mean body weights within a period were similar across all treatments as the goats were blocked by weight in the process of randomly allocating them to the treatments.

[a-b]DE intake means (expressed either as kcal/kg/BW or kcal/day) followed by a different letter are significantly different (P<.05).

DE intake followed the same trends as did OMI until September when DE intake dropped sharply while OMI remained relatively high. Daily forage intake was high but IVOMD was low in September and December. The effect that the reduced digestibility had on estimates of DE intake in September and December suggested that IVOMD might have been highly correlated to digestible energy intake (Rittenhouse et al. 1971). This did not prove to be the case as the equation expressing the relationship between DE intake and IVOMD ($Y=16.91 + .59x$) has a low coefficient of determination ($r^2=.33$). The low r^2 value appears to be largely a result of the May to July period when DE intake increased substantially and digestibility decreased. Pfister and Malechek (1986) also noted a low correlation between DE intake and digestibility.

DE intake on the control pastures was not sufficient for maintenance during any season of the year (NRC 1981, Kearl 1982). July was the only period for which DE intake on the treated pastures was above the requirements for maintenance plus low to medium activity. This corresponds with the weight responses of the nonfistulated goats. These results support the conclusion that the conditions of the 1985 wet season were not conducive for growth and that favorable environmental and forage conditions were limited to the early dry season.

In summary, the generally higher levels of available forage on the cleared and thinned pastures did not result in the goats selecting a diet higher in nutritive value on the treated pastures than on the control. Instead, the forage conditions on the treated pastures allowed the goats to attain higher levels of intake. The reported

(Araujo Filho and Gadelha 1984) superiority of manipulated caatinga in terms of livestock production (kg/ha), therefore, is probably a result of relatively high forage intake rather than a positive effect on overall dietary nutrient content.

The thinned treatments compare favorably with the cleared treatment in terms of forage production, dietary nutrient content and intake. This is an important result in light of the fact that thinned caatinga has the added benefit of wood production. Not only do many caatinga tree species yield palatable foliage but they also produce valuable wood which is used as fuel, fence posts and construction material. Wood is a very important component of the economy of northeastern Brazil and demand surpasses supply (FAO 1981). Thinned woodland could provide the conditions where relatively high levels of both livestock production and wood production are realized.

CHAPTER IV

ABOVEGROUND PRODUCTION IN CLEARED AND THINNED STANDS OF SEMIARID TROPICAL WOODLAND, BRAZIL

Earlier chapters of this dissertation and other studies (Araujo Filho et al. 1982, Kirmse et al. 1986a) have reported the effects of thinning and clearing on herbaceous vegetation production and browse biomass available to small ruminants. However, information is not available on how reduced canopy treatments affect total aboveground biomass production and, in particular, wood production. Knowledge of the effects of intensity of thinning on all major components of total biomass production is needed for effective evaluation of vegetation manipulation and development of management recommendations for the caatinga. This chapter reports on how differing thinning intensities affect biomass production of both wood and forage.

Methods

On the same study area described in Chapter II, estimates of aboveground production were derived for four vegetation components: 1) total herbaceous biomass; 2) total foliar biomass of woody plants; 3) foliar and wood biomass of coppice shoots; and 4) wood biomass of intact trees. The 1-ha experimental pastures were grazed by goats (Chapter II); therefore, the first three production components were measured inside 40 x 50 m exclosures constructed in each pasture. Wood production by intact trees was determined in unprotected quadrats located in the grazed pastures.

Because of the large number of herbaceous species in the study area (over 60) and the asychrony of their phenologies, peak standing crop could not be equated with total production. Therefore, in an effort to estimate total herbaceous production, herbaceous biomass sampling was conducted twice during the growing season of 1985. A March sampling period coincided with the maturation of a group of early maturing forbs and grasses, while the second sampling period was in late May when the dominant large forbs were flowering. The sampling procedure involved harvesting all herbaceous vegetation within 25, randomly placed, 0.3 sq m quadrats in each exclosure. Plant material was clipped at ground level, was separated by species, individually sacked, dried in a forced air oven at 60°C for 48 hours and weighed. This dried material was later separated into leaf and stem components and weighed.

Total foliar production of woody plants was estimated shortly after the completion of leaf fall (early December). All fallen leaves of woody species were collected from the ground using the same quadrat method described for sampling herbaceous vegetation. It was considered possible to estimate foliar production in the form of fallen leaves because the drought-deciduous, woody species of the study area normally shed all of their leaves by mid dry season.

Production of leaves and wood by coppicing stools was estimated in August 1985, shortly before the commencement of leaf fall. Foliage and stems of all coppice shoots were hand-harvested by species within four quadrats (4 x 25 m) in each exclosure. Leaves and stems were weighed separately in the field. Subsamples were oven-dried to determine moisture content and yields were then adjusted to a dry matter basis. Foliar production by intact trees on the thinned areas was calculated by subtracting appropriate coppice foliar biomass estimates from total foliar biomass estimates.

Wood production (including stem wood, branches and bark) of trees was measured in randomly located quadrats established in each pasture. The number of quadrats and quadrat size for each treatment were as follows: three 20 x 20 m quadrats in each 25% cover pasture, three 15 x 15 m quadrats in each 55% cover pasture and two 8 x 8 m quadrats in each control pasture. The variable quadrat sizes and numbers were used to accomodate the differing density and uniformity of the stands.

Towards the end of the 1984 dry season, the diameter at 1.3 m aboveground (dbh) and height of all tree stems (2.0 m or more in height) within the quadrats were measured. Each stem was marked by securing a numbered metal tag to the tree at 1.3 m. The stems were remeasured one year later, in November 1985.

During the 1985 dry season, the dbh and height of 20 to 25 individual stems of each of the five major tree species, with a wide range of sizes, were measured in an adjacent stand. The trees were subsequently felled, allowed to air dry and then weighed. Subsamples were taken and dried in a forced air oven to determine percent dry matter. These data were used to develop regression equations relating oven-dry stem and branch biomass to dbh and height.

Several forms of regression equations were evaluated for their predictive ability. The particular equation selected in each case was based on the highest r^2, the lowest S.E. and an examination of the residuals. In deriving the equations in Table 4.1, dbh and height were used alone and in various combinations with each other. For all five species, the traditional $dbh^2 \cdot ht$ variable, either in a linear regression model or a log-log transformation, resulted in the best predictive equations. For mororo, a log-log transformation was selected because of its lower S.E. The constant was not included in the regression equation for catingueira as it did not prove to be a significant part of the equation.

Total wood production and wood production by species for 1985 was calculated as the difference between 1985 and 1984 wood biomass estimates. Wood biomass estimates for 1984 and 1985 included the minor tree species. Biomass estimates of the minor species were based on matching the principal tree species and minor species that were most similar in form. The appropriate regression equations were subsequently used to calculate the biomass of the various minor species.

Statistical analysis of data was done using the statistical package Rummage (Bryce et al. 1980). Least squares analysis of variance was performed and the protected LSD procedure was used to detect significant differences among treatment means.

Results

Herbaceous Vegetation

Each of the three reduced canopy treatments resulted in a seven- to eightfold increase in total herbaceous vegetation yields when compared to the control (Table 4.2). Most of this difference was due to species that matured late in the growing season. Peak standing crop of

Table 4.1. Regression models, coefficients of determination (r^2) and S.E. used to estimate wood biomass of the five major tree species. (Y is in kilograms, dbh in centimeters and ht in meters.)

Species	Regression equation	r^2	S.E.
marmeleiro (n=21)	$Y = .886 + .0484\,(dbh^2 \cdot ht)$	.971	.339
pau branco (n=22)	$Y = 8.730 + .0414\,(dbh^2 \cdot ht)$	.984	3.108
mororo (n=21)	$\log_{10} Y = -2.480 + .9270\,(\log_{10} dbh^2 \cdot ht)$	.952	.051
sabia (n=25)	$Y = 4.020 + .0339\,(dbh^2 \cdot ht)$	.952	.950
catingueira (n=25)	$Y = .0626\,(dbh^2 \cdot ht)$	.994	1.288

Table 4.2. Production of herbaceous vegetation (kg/ha) for the three reduced canopy treatments and the control for the March collection of early maturing plants and for the May collection of late maturing plants. Percent stem and percent grass of the combined total of March and May collections are also presented.

Treatment	March early maturing plants	May late maturing plants	Total	% stem	% grass
Cleared	309a	1649a	1958	62	14.6
25% cover	252a	1593a	1845	64	11.6
55% cover	266a	1660a	1926	62	10.5
Control	38b	221b	259	47	1.7

[a-b]Means in the same column followed by a different letter are significantly different ($P<.1$).

the early maturing grasses and forbs represented only 15% of the total production of herbaceous vegetation for any one of the treatments. While tree canopy reduction resulted in large increases of forb yields, the major portion of the increase was in the form of stem biomass (Table 4.2). Nearly two-thirds of the total production was stems for each of the three treatments compared to less than one-half for the control.

Opening the tree canopy was especially favorable to grasses (Table 4.2). Only 1.7% by weight of the herbaceous vegetation on the control was grasses while grasses yielded over 10% of the total herbaceous production on the cleared and thinned areas. Much of this increased grass production was due to relatively high yields of *Brachiaria mollis*.

Woody Plant Foliage

Foliar production by coppice shoots was similar (P>.1) for the cleared and 25% cover treatments (Table 4.3). Coppice foliar yield was about 50% lower for the 55% cover treatment than for the other two. The leaf:stem ratio of coppice shoots was about 0.5 for all three treatments.

Total biomass of fallen leaves of woody plants collected in December was significantly (P<.1) higher on the control than on the treated areas (Table 4.3). There were no differences (P>.1) among the reduced canopy treatments. Foliar biomass figures for the treated areas, however, are underestimates since the dominant coppice species retained a portion of their leaves (visual estimate: 10 to 20% of July's biomass estimates) to the end of the 1985 dry season. For the

Table 4.3. Total foliar biomass (kg/ha) of woody plants for manipulated and undisturbed stands of caatinga in northeastern Brazil.

Treatment	Coppice August collection	Total December collection	Adjusted Total	Tree[1] Foliage
Cleared	1131[a]	966[a]	1131	0
25% cover	1070[a]	1058[a]	1214[2]	144
55% cover	497[b]	1003[a]	1075[2]	578
Control	0	1891[b]	1891	1891

[1]Values in this column represent the difference between the adjusted total for foliar production and coppice foliar production.

[2]Represent adjusted values whereby 15% of the coppice production figures were added to the total production estimates from the December collection.

[a-b]Means in the same column followed by a different letter are significantly different (P<.1).

cleared areas, comparison of the December (966 kg/ha) and August (1131 kg/ha) estimates indicates that the December value is underestimated by about 15%. This 15% difference probably represents the amount of foliage retained on the coppice shoots when fallen leaves were measured in December. In order to obtain an adjusted estimate of total foliar production from trees as well as from woody plants for the two thinned treatments, 15% of the foliar biomass estimate for coppice measured in August was added to the December yield values. These adjusted totals are shown in the third column of Table 4.3. The difference between the adjusted total and coppice foliar biomass for the thinned treatments represents foliar biomass of trees (Table 4.3).

Coppice Wood Production

Total wood production by coppice shoots was similar for the cleared and 25% treatments but was significantly ($P<.1$) lower for the 55% cover treatment (Table 4.4). The differences among treatments in stem production of pau branco and marmeleiro coppice were not significant ($P>.1$) because of high standard errors. Relatively few sabia and catingueira trees were cut on the 25% cover and 55% cover areas; therefore, wood production from sabia and catingueira was significantly less for these treatments than for the cleared treatment.

Tree Wood Production

Wood production from intact trees was calculated using two different methods because some sample stems were lost through the course of the study. A total of 13 sample stems (2% of all sample stems) fell or were blown over during the 1985 wet season.

Table 4.4. Wood production (kg/ha) by coppice shoots on manipulated stands of caatinga in northeastern Brazil.

Treatment	Pau branco	Marmeleiro	Catingueira	Sabia	Others[1]	Total
Cleared	819a	330a	321a	311a	236a	2017a
25% cover	829a	670a	115b	65b	351a	2030a
55% cover	420a	306a	15b	19b	261a	1021b

[1]Mororo was an inconsistent and minor component of coppice stem production; therefore, it was included along with other minor species in the "Others" column.

[a-b]Means in the same column followed by a different letter are significantly different ($P<.1$).

Unfortunately, 10 of these stems were lost from the 25% cover treatment in a single replicate (Block 1). Three major factors appear to have contributed to this loss. First, most caatinga woody species are typically very shallow rooted (Queiroz 1985). Second, the soils in Block 1 had poor surface drainage and were inundated during much of the extremely moist wet season of 1985 (whereas Block 2 had good surface drainage). Finally, in denser stands, tree canopies are generally intertwined and the poorly rooted trees are probably supported by their cohorts. Apparently, Block 1 of the 25% cover treatment was the only area seriously affected by this problem because of the unfortunate combination of waterlogged soils and a relatively low density of shallow-rooted trees.

Using the first method of calculation (Method I), the production estimate for an individual stem that fell over was equal to the negative of its biomass estimate in 1984. These estimates were entered in the subsequent data analyses as negative productions. For the second calculation method (Method II), the stems that fell over were ignored and never entered into any data analyses.

Tree biomass estimates at the end of the 1984 dry season were 16,196 kg/ha, 37,815 kg/ha and 124,921 kg/ha for the 25% cover, 55% cover and control pastures, respectively. For the 1985 wet/dry season cycle, significant ($P<.1$) differences in wood production existed among the treatments and the control regardless of the calculation method used (Table 4.5). When lost stems were not used in the data analysis (Method II), the production estimate for only the 25% cover treatment was substantially altered in comparison to the estimates using Method

Table 4.5. Wood production (kg/ha) (means ± S.E.) by intact trees for the three canopy levels. Two methods of calculating production are presented.[1]

	Pau branco	Marmeliero	Catingueira	Sabia	Mororo	Others	Total
METHOD I:							
25% cover	0	0	390±506	271± 80	46±12	126±242	824±387a
55% cover	0	0	2026±616	330±224	160±33	140±129	2656±454ab
Control	1280±335	684±383	2249±974	401±176	112±71	412±177	5136±624b
METHOD II:							
25% cover	0	0	858±290	271± 80	46±12	332±209	1507±310a
55% cover	0	0	2026±616	415±182	160±33	140±129	2740±520ab
Control	1280±335	751±443	2249±974	401±176	112±71	405±178	5197±637b

[1]Wood production was calculated using two method because some sample stems fell over through the course of the study. Using Method I, the production estimate for the lost stem was equal to the negative of its initially estimated biomass. For Method II, the stems that fell over were ignored and never entered into data analyses.

[a-b]Means in the same column followed by a different letter are significantly different (P<.1).

I. For both methods, however, wood production on the 25% cover pastures was significantly ($P<.1$) less than that on the control and similar ($P>.1$) to that on the 55% cover pastures. The 55% cover treatment was not different ($P>.1$) from the control.

Total Aboveground Production

Total production ranged from 5106 kg/ha for the cleared treatment to 7347 kg/ha for the control, while production for the two thinning treatments was slightly less than the control (Fig. 4.1). Total aboveground production estimates appear to be similar for all treatments regardless of which method was used in the calculation of tree production. In comparison to the control, the high yields of herbaceous vegetation and coppice material on the reduced canopy treatments partially compensated for the low or nonexistent wood production from intact trees.

Discussion

Increase in herbaceous production in response to reduced tree canopy is a well-documented response (Pratt and Knight 1971, Beale 1973, Walker et al. 1972, Pratchett 1978, Araujo Filho et al. 1982, Kirmse et al. 1986a). Moreover, the magnitude of increase for the cleared treatment over the control in the present study was similar to that reported by Araujo Filho et al. (1982) and Kirmse et al. (1986a). The response of herbaceous vegetation to heavy thinning intensities has been quantified in a study by Silva and Araujo Filho (1984) in southern Ceara. They compared cleared caatinga to four levels of thinning ranging from 9 to 32% tree canopy cover and found no differences in

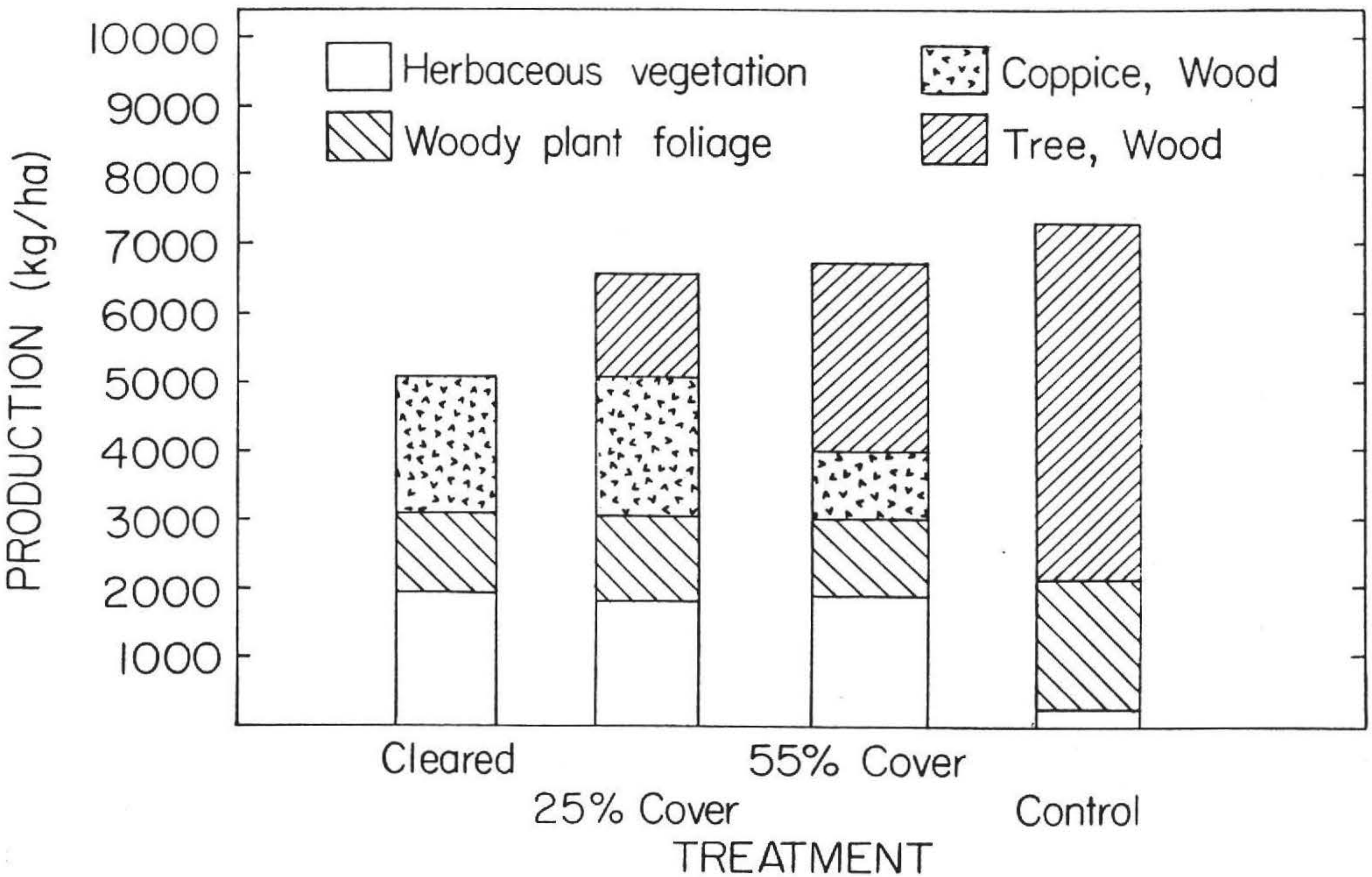

Figure 4.1. Total aboveground production of manipulated and undisturbed stands of caatinga in northeastern Brazil.

herbaceous vegetation production among the treatments. The results of our study support their findings and extend the inference that the decline in herbaceous production towards control levels does not begin until some canopy cover higher than 55%. One of the practical significances of these results is that for livestock producers interested in maximizing herbaceous vegetation production, clearfelling an entire caatinga stand is not necessary. Moderate to light levels of stand thinning would be adequate.

Caatinga trees coppice readily after cutting. Even though all intact trees were removed, foliar production from woody plants for the cleared treatment was about 60% of that for the control (Table 4.3). Wood production was considerably reduced by clearing but still attained nearly 35% of that for the control (Table 4.5). Moreover, nearly 50% of the total foliar production on the cleared areas was produced within the first month of the growing season (Chapter II). The exceptionally high early growth rates of coppice shoots is well-documented (Evans 1982, Blake 1983, Evans 1984, Crowther and Evans 1984). The initial, rapid growth of coppice, compared to planted trees or seedlings, is presumably due in part to the advantage conferred by the large parental root system. On the cleared areas of this study, seedling density was approximately 20,000 plants/ha, yet total seedling biomass was less than 200 kg/ha. Coppice systems do not raise site production potential, however, as coppice stands generally show earlier culmination of mean annual increment than do planted stands (Sharma 1979, Crowther and Evans 1984). Following the initial years, the growth increment of coppice shoots becomes similar to that of planted trees.

Mean annual increment of foliar production of coppice for caatinga species appears to culminate early. Kirmse et al. (1986a) estimated foliar production during first year post-clearing at 1077 kg/ha, which compares favorably with the estimated 1131 kg/ha for this study. Foliar production from woody plants on the cleared plots established by Kirmse et al. (1986a) was similar to that of adjacent undisturbed plots by the end of the third year posttreatment (Schacht et al. 1986). Production on the cleared plots appeared to level off at this point as the fourth year posttreatment production estimate was similar to that of the third. Wood production was not estimated on either the cleared or control plots.

Wood production estimates of coppicing woody plants of very dry and dry tropical forests (Holdridge 1966) such as the caatinga of Brazil, are unavailable except for the results of this study. Even on a worldwide basis, information on coppice production is scarce. Uhl et al. (1982) reported a biomass of 6,130 kg/ha of coppice stems three years after clearfelling tropical moist forest in southern Venezuela. Mean annual growth, therefore, would be approximately 2,000 kg/ha. Similarly, Crowther and Evans (1984) reported mean annual increments of 2,500 to 6,000 kg/ha over a 15 to 20 year coppice rotation for several temperate hardwood species in Great Britain (i.e., ash, oak, Sweet chestnut, willow and poplar). These production estimates compare well with the findings of the present study. The cited estimates, however, are mean annual increments based on three or more years of growth whereas our estimate is based on only the initial year's growth. Presumably, annual increments of growth will increase for a few years before levelling off (Sharma 1979, Crowther and Evans 1984). Compared to other forest systems, wood production by coppice growth in stands of caatinga might be high.

Coppice production was significantly different ($P<.1$) for the two thinning treatments. Most of this disparity was related to the comparatively high yields of pau branco and marmeleiro coppice on the 25% cover areas (Table 4.4). The number of coppicing stools in each quadrat was similar for the two thinning treatments (21 marmeleiro and 8 pau branco stools for the 25% cover treatment and 23 marmeleiro and 8 pau branco stools for the 55% cover treatment). Therefore, the relatively high coppice yields on the 25% cover areas were due to the high biomass production per stool. The only major difference between the two treatments was the number of standards (remaining trees) and, consequently, the amount of shading. Crowther and Evans (1984) stated that too great a number of standards overshades and depresses growth of coppice. For the three reduced canopy treatments, comparison of coppice biomass yields of pau branco and marmeleiro (the two major species cut on all treated areas) suggests that density of standards affected coppice production. This analysis, however, is not supported by the fact that herbaceous vegetation production was similar on all treated areas. Further research is obviously needed to study understory/overstory relationships in manipulated stands of caatinga.

In terms of the intact trees on the control and thinned stands, the drop in wood production per unit area measured on the thinned pastures was expected. The removal of trees by thinning immediately reduces leaf area and, consequently, the productive capabilities of the tree component of the stand (Evans 1982). According to the theoretical pattern of increment recovery the initial drop in production per unit area is followed by a resurgence in growth as the remaining trees respond to the extra space by increased production of new foliage and roots. Performance and recovery of a thinned stand, however, is dependent on many variables, including stand density and climate. As a result, the longer term response of the standards in the thinned stands of this study can only be speculative at this time. The potential competitive effect of coppice also complicates any attempt to predict the pattern of increment recovery.

Total aboveground biomass production for the cleared treatment was 30% less than that for the control and about 25% less than that for the two thinned treatments. The comparatively low production estimate for the cleared treatment appears to be related to its lack of an intact tree component. In fact, estimates of biomass production are similar for the cleared and 25% cover treatments if wood production by intact trees is ignored. Although the differences between the cleared and thinned treatments might not be significant, they do represent important considerations for a silvipastoral system. The results of this experiment indicate that herbaceous vegetation production and, to some degree, coppice production in thinned stands of caatinga woodland could be maintained at similar levels to that of a cleared stand. The added benefit of a thinned stand is that relatively high production of understory vegetation can be realized under a stand of trees which produce valuable wood. The differences between the 25% cover and 55% cover treatments also suggest that the amounts of the various production components (e.g., wood production by intact trees and foliar production by coppice) could be varied by the level of thinning. Apparently, thinned treatments allow for more production options than either the cleared treatment or the control, and this can be done without a reduction in total biomass production.

Comparison of this study's biomass and production estimates for caatinga forest with those of forests on a worldwide basis (Cannell 1982, Satoo and Madgwick 1982) suggests that caatinga forest ranks moderately low in terms of yields of total aboveground biomass. There is a lack, however, of biomass estimates from tropical dry forest or very dry forest types. Therefore, effective comparison of the caatinga with similar forest types is not possible.

Conclusion

The primary purpose of this study was to determine the response of caatinga vegetation to a simple form of stand manipulation, i.e., reduction of canopy cover, and to use these results as a basis for further applied research. The rural inhabitants of northeastern Brazil rely heavily on the wood and livestock produced in the caatinga vegetation zone. The current exploitive system is a multiple-use approach that involves very little management of the renewable resources. Effective management practices must be developed to assure long-term forage and wood production as well as ecosystem stability.

The results of this experiment indicate that simple stand manipulation practices can be used to alter the routes by which biomass is produced without greatly affecting total production. This has much practical significance to local producers who are interested in increasing forage production above those levels found in 'undisturbed' caatinga. From the limited scope of this experiment, it appears that thinned caatinga has potential as the basis of a production system for the silvipastoralists of the caatinga vegetation zone. This agroforestry approach would allow for high levels of forage production while maintaining moderate to high levels of wood production. Before a technical package will be ready for extension to producers, however, many fundamental aspects of stand management must be researched. The most basic of these is the long-term productivity and stability of manipulated stands of caatinga vegetation.

CHAPTER IV

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

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. During this period of time, available herbaceous biomass was generally seven to eight times higher on the treated pastures than on the control and biomass of available browse was about four times greater. After leaf fall, total available forage was similar for all four treatments but about 90% of the available forage on the control was leaf litter. For the reduced canopy treatments there was a mixture of leaf litter, dry herbaceous plants and green foliage from coppice shoots.

Dietary selection 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 throughtout 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. The dissimilarities in dietary selection during the wet season did not result in differences in overall nutrient content among the treatments. However, forage intake and digestibility energy intake were higher on the treated pastures than on the control. The relatively low availability of forage during much of the year was probably the cause of the low intakes on the control pastures.

For most aspects of this study, the thinned treatments compared favorably with the cleared treatment. Most noticeably, the high biomass yields of forage and high levels of forage intake by goats were similar for the cleared and thinned treatments. For the thinned treatments, however, these positive forage and animal responses were realized with the added benefit of 1500 to 2700 kg/ha of wood production by intact trees. Wood biomass yields by intact trees on the thinned pastures effectively augmented total biomass production by 25% above the total production level on the cleared pastures.

Wood production by intact trees was substantially higher on the control pastures than on the thinned pastures, but the difference between the control and 55% cover treatment was not significant ($P>.1$). The differences between the control and thinned treatments might decrease after the initial year, however, as the intact trees on thinned pastures develop larger crowns needed to support higher rates of production. In economic terms, the production of marketable wood should be higher on the thinned pastures as much of the wood production on the control is from woody species which have little or no market value.

Overall, the results of this experiment indicate that thinned caatinga has potential as the basis for a production system for the silvipastoralists of the caatinga vegetation zone. The approach would allow for high levels of forage production while maintaining moderate to high levels of wood production. This study did not define what thinning intensity would be the most appropriate but simply indicated what range of intensities might be suitable for a silvipastoral system. For example, from a wood production perspective, a lightly thinned or undisturbed stand might be the most attractive due to high wood biomass yields by intact trees. For a livestock producer, however, any one of the reduced canopy treatments are suitable as all three treatments resulted in favorable forage and animal responses. These simplified assessments of the results of this experiment suggest that stands of caatinga thinned at moderate to light intensities (50% canopy cover or above) would optimize production of forage and wood.

Management of these thinned stands as coppice systems is recommended. Coppice systems appear to be particularly well-suited to a silvipastoral system in the extensively managed caatinga vegetation zone. Because caatinga tree species coppice vigorously following cutting, natural regeneration of the stand is essentially assured with little, if any, managerial input. In addition, the early rapid growth of coppice shoots results in a sizeable part of the plant growing out of reach of livestock in one or two growing seasons. This greatly reduces the amount of time livestock would need to be excluded from recently harvested areas.

Management of thinned stands of caatinga, however, is complicated by the fact that economic control of undesireable coppice shoots and seedlings has not been realized. Rapidly growing coppice shoots have the potential of quickly recapturing a site and curtailing the growth of herbaceous plants. Methods of control, such as burning and chemicals, need to be tested as means of effectively controlling undesireable coppicing species.

Long-termed studies must be conducted to determine the appropriate silvicultural and pastoral practices that need to be incorporated into the management of thinned stands of caatinga. Such studies would also allow for economic analysis of the system. Inclusion of cattle in future studies is a necessity because of their socio-economic importance.

Thinning must also be further studied as a method of improving livestock performance during the mid to late dry season. This period has been identified as the most critical time of the year for livestock as the interrelated problems of low forage availability and quality result in weight losses and mortality. The results presented in Chapter 1 suggest that for stands of undisturbed caatinga, the amount of palatable, good quality forage during the dry season is proportionally a very small part of the total. Either supplementation or increased availability of nutritious forage would be necessary for goats to continue to grow beyond the first half of the dry season. It appears that thinning could be a means of increasing the availability of nutritious forage. As reported in Chapter 3, the comparatively high levels of forage intake on the thinned pastures during the dry season indicate that forage conditions are improved by thinning. These higher levels of intake appear to be a result of the increased availability of dry herbaceous plants and the availability of the persistant green foliage on the coppice shooots.

Finally, a better understanding is needed of how the amount, distribution and composition of available forage affects livestock performance. Meaningful relationships between livestock performance and characteristics of differing forage and community types must be developed so that decisions concerning range and livestock management can be made more effectively. This endeavor is particularly relevant to vegetation manipulation practices since such methods as clearing and thinning substantially alter the structure and composition of a plant community. If the relationship between livestock and potential forage was better understood, manipulation practices could be used to more effectively improve the forage situation.

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APPENDIX

Table A.1. Dry season trends in NDF, lignin and CP content (%) of major components of the available forage on 4 dates through the 1984 dry season for undisturbed caatinga. About 25 mm of rainfall was recorded on December 31, 1984.

Plant Species	NDF Oct 10	NDF Nov 29	NDF Dec 14	NDF Jan 3	LIGNIN Oct 10	LIGNIN Nov 29	LIGNIN Dec 14	LIGNIN Jan 3	CP Oct 10	CP Nov 29	CP Dec 14	CP Jan 3
Sabia	62.74	-	57.02	61.71	25.65	-	33.82	33.86	8.84	9.13	9.47	-
	54.29	-	57.63	63.87	21.29	-	35.34	37.01	8.59	8.72	9.01	-
	52.54	-	60.91	64.83	21.58	-	35.27	34.02	-	10.13	8.67	-
	-	-	56.98	-	-	-	28.90	-	-	-	-	-
$\bar{x}$	56.52	-	58.14	63.47	22.84	-	33.33	34.96	9.13	9.27	9.22	-
S	5.45	-	1.87	1.60	2.44	-	3.04	1.77	.73	.60	.47	-
Catingueira	43.59	41.68	40.03	48.16	9.53	9.54	10.11	11.85	10.98	10.31	9.54	10.00
	41.82	45.67	42.77	53.32	8.90	11.54	10.95	12.84	10.32	11.01	9.82	9.23
	39.37	41.77	43.52	51.12	8.77	9.64	11.17	11.63	10.27	9.37	9.90	10.22
	40.45	-	40.50	53.17	9.45	-	9.01	13.01	8.80	8.57	9.23	10.52
$\bar{x}$	41.31	43.04	41.71	51.44	9.16	10.24	10.31	12.33	10.09	9.82	9.61	9.99
S	1.82	2.28	1.70	2.41	.38	1.13	.98	.69	.92	1.07	.31	.55
Pau branco	54.32	57.87	58.49	62.43	17.07	17.86	20.06	18.98	7.24	7.3	8.19	7.19
	57.31	59.50	59.52	61.73	18.11	19.29	18.98	19.50	8.04	7.82	8.12	
	54.89	59.08	60.71	60.31	15.73	19.37	18.10	18.26	7.48	8.06	7.32	7.27
	54.70	59.42	56.96	59.54	15.73	19.31	15.59	18.97	7.23	7.76	7.58	8.41
$\bar{x}$	55.31	58.97	58.92	61.00	16.66	18.96	18.18	18.93	7.50	7.74	7.80	7.62
S	1.36	.75	1.59	1.31	1.15	.73	1.91	.51	.38	.32	.42	.68
Herbaceous leaves	44.75	43.87	48.4	41.61	11.3	13.64	11.57	12.53	9.46	10.69	10.47	-
	46.78	42.84	42.93	43.54	9.92	10.29	10.12	12.89	10.19	8.72	10.72	-
	46.45	40.78	50.23	38.05	12.07	11.63	9.95	11.79	9.55	8.33	11.61	-
	-	43.04	42.79	45.49	11.92	12.98	9.18	12.65	9.82	10.29	12.06	-
$\bar{x}$	45.99	42.63	46.09	42.17	11.30	12.14	10.21	12.42	9.76	9.51	11.22	-
S	1.09	1.31	3.80		.98	1.49	1.00		.33	1.16	.75	-
Mofumbo	41.43	47.71	44.70	51.50	18.41	22.54	16.98	23.41	7.54	6.41	7.85	6.14
	41.74	47.13	42.71	49.12	15.83	22.67	18.41	22.43	6.60	6.09	5.82	6.36
	40.09	44.69	47.01	50.07	15.60	22.35	19.52	21.59	6.54	6.40	7.30	6.29
	46.15	45.09	51.11		22.11	18.52	21.64		6.55	6.44	6.30	
$\bar{x}$	41.09	46.42	44.88	50.45	16.61	22.42	18.36	22.27	6.89	6.36	6.85	6.27
S	.88	1.32	1.76	1.07	1.56	.24	1.05	.85	.56	.19	.90	.09
Herbaceous Stems	74.73	76.90	77.38	77.70	21.76	23.83	19.16	20.58	5.28	5.55	4.78	4.05
	80.13	72.67	68.47	80.79	22.07	23.86	15.64	20.10	4.07	6.04	5.84	3.85
	-	75.14	73.20	77.90	-	23.97	13.18	19.05	-	5.97	5.35	4.93
	-	83.31	73.33	81.43	-	24.23	14.61	20.88	-	4.28	5.39	4.56
$\bar{x}$	77.43	77.01	73.10	79.46	21.92	23.97	15.65	20.15	4.68	5.46	5.34	4.35
S	3.82	4.55	3.64	1.93	.22	.18	2.55		.86	.82	.43	.49
Marmeleiro	54.82	-		66.60	20.86	-	-	25.50	6.92	-	-	7.95
	59.62	-	-	67.09	14.42	-	-	25.71	7.55	-	-	7.93
	51.25	-	-	64.02	21.69	-	-	26.17	6.40	-	-	7.34
	54.47	-	-	64.92	17.07	-	-	28.01	7.32	-	-	7.55
	55.04	-	-	65.66	18.51	-	-	26.35	7.05	-	-	7.69
	3.45	-	-	1.43	3.39	-	-	1.14	.50	-	-	.30

Table A.2. Seasonal trends in NDF, lignin and CP contents (%) for various herbaceous plant and browse species. The February and April values for browse are based on two or more samples and the S.E. is included in parentheses. All other values represent one sample only.

	February			April			May			July			August/September			December		
	NDF	Lignin	CP	NDF	Lignin	CP	NDF	Lignin	CP	NDF	Lignin	CP	NDF	Lignin	CP	NDF	Lignin	CP
COPPICE																		
Sabia, green	-	-	11.4(1.8)	35.7 (.3)	11.1 (.2)	11.7 (.1)	52.5	17.0	13.3	60.4	29.2	15.8	41.6	12.4	14.8	38.9	19.3	13.3
leaf litter													63.4	29.1	8.7	51.6	19.2	6.1
Catingueira green	36.2(2.5)	7.4 (.7)	16.6 (.8)	37.8(4.0)	8.6(1.1)	15.4(1.4)	36.8	7.3	12.6	37.7	9.3	13.7	37.1	6.9	17.4	33.3		11.3
leaf litter													44.6	10.7	11.7	39.2	8.9	9.8
Pau branco, green	69.8(1.2)	30.9(1.0)	19.4(1.2)	69.8(1.0)	22.3 (.8)	14.7(1.5)	63.5	24.7	14.08	62.2	20.3	12.2	57.2	13.8	13.2	49.7	15.8	10.0
leaf litter													69.7	17.9	6.4	56.3	-	7.6
Mororo, green	-	-	16.4(1.1)	35.3(2.8)	9.7 (.1)	14.7 (.1)	43.9	7.1	12.9	33.7	7.9	15.2	40.2	10.7	10.7	-	-	-
leaf litter													59.1	24.4	8.5	43.1	-	5.9
Marmeleiro, green	-	-	13.9 (.5)	45.7 (.6)	10.4 (.1)	9.2 (.1)	53.2	15.0	8.1	42.6	10.3	10.6	35.9	7.9	8.8	-	-	-
leaf litter													51.3	15.8	4.5	51.1	-	5.0
Marmeleiro branco, green				47.1 (.3)	11.0(1.4)	12.5 (.1)	42.2	10.5	11.2	36.2	8.5	10.6	34.8	6.7	8.4	-	-	-
leaf litter													42.4	9.8	3.9	-	-	-
Mofumbo, green													41.1	12.8	11.1	35.9	-	10.1
Algodao bravo, leaf litter													44.5	11.2	3.9	-	-	-
Cipo', green													47.4	9.9	-	-	-	-
Jurema branca, green													38.2	10.9	17.8			
Manicoba, leaf litter													44.4	15.2	18.3			
Pereira, green													41.7	7.5	5.7			
TREES																		
Sabia	-	-	14.1 (.6)	32.4 (.2)	10.4 (.2)	15.1 (.2)	49.8	18.8	19.6	45.3	19.0	15.7						
Catingueira	41.0(1.1)	8.2 (.4)	16.6 (.3)	43.9 (.8)	8.5 (.6)	15.2 (.2)	41.1	9.0	13.7	37.6	7.7	14.9	55.0	23.5	7.8	57.0		10.9
													46.9	11.6	9.5			
Pau branco	68.7 (.6)	29.4 (.1)	15.4 (.1)	68.4 (.2)	22.9 (.3)	13.0 (.3)	60.7	22.3	12.7	61.8	23.2	13.1				43.1		9.8
Mororo	-	-	13.5 (.1)	46.7 (.6)	10.4 (.6)	14.1(1.9)	43.6	14.1	16.1	57.1	19.4	12.8				55.0		8.0
Marmeleiro	-	-	13.4 (.2)	41.7 (.8)	10.9 (.4)	10.7 (.7)	46.7	14.9	11.2	39.6	9.4	10.2				48.1		7.4
Imburana										35.3	9.7	14.2				51.9		6.0
Marmeleiro branco										32.5	6.4	12.4						
HERBACEOUS																		
Hyptis spp. new leaves							48.9	23.3	15.2	43.9	18.5	12.3						
old leaves							37.8	13.5	10.7	-	-	-						
flowers							48.5	10.3	12.0	-	-	-						
Melanthera spp. new leaves							26.4	5.1	16.6	-	-	-						
old leaves							-	-	9.0	-	-	-						
flowers							42.9	9.4	12.1	-	-	-						
Bidens spp. new leaves							24.7	8.0	17.5	-	-	-						
old leaves							25.2	6.5	11.4	-	-	-						
seeds							55.2	13.7	12.6	-	-	-						
Ipomoea spp. leaves							37.4	15.4	16.8	55.5	17.9	14.6						
stems							59.8	12.7	5.9	-	-	-						
flowers							-	-	-	36.9	9.6	13.3						
Ruellia asperula: stems							66.2	10.2	4.3	-	-	-	-	-	-			
Ruellia asperula: leaves							38.2	9.2	13.3	-	-	-	-	-	-			
Fava de boi: seeds													61.4	1.6	28.1			
Fava de boi: seed pods													69.5	6.1	2.48			
Herbaceous plants pooled, leaves							-	-	-	-	-	-	59.8	12.7	8.4	48.3	10.8	8.0
Herbaceous plants pooled, stems							-	-	-	-	-	-	82.4	19.4	3.2	79.3	18.4	3.4
Herbaceous plants pooled, seeds							-	-	-	-	-	-	55.7	14.4	8.2	-	-	-

Table A.3. NDF, lignin and CP contents (%) for the major coppice species in August at three vertical strata: 0-1.6 m, 1.6-2.0 m and above 2.0 m.

	0-1.6 m			1.6-2.0 m			above 2.0 m		
	NDF	Lignin	CP	NDF	Lignin	CP	NDF	Lignin	CP
Sabia	49.7	15.7	14.4	33.5	9.0	15.2			
Catingueira	42.3	8.7	14.5	31.9	5.0	20.3			
Mororo	40.2	10.7	10.7						
Pau branco	55.5	15.9	11.6	54.3	9.6	13.3	61.9	16.0	14.6
Marmeleiro	38.2	8.3	7.8	31.9	7.1	9.4	37.6	8.2	9.3
Marmeleiro branco	33.3	6.2	8.1	40.6	8.6	-	30.5	5.2	8.6
Mofumbo				41.1	12.8	11.1	35.1	7.3	-

Table A.4. Herbaceous plant biomass (kg/ha) and leaf/stem ratios in May and December 1984 and 1985; and biomass of fallen tree leaves in December of 1984 and 1985. These values represent biomass estimates for the study area established by Robert Kirmse in the dry season of 1981.

Date and Replication	Uncleared			Cleared		
	Herbaceous	L/S	Fallen Tree Leaves	Herbaceous	L/S	Fallen Tree Leaves
May 1984						
A	856	-		1817	-	
B	341	-		650	-	
C	523	-		1234	-	
December 1984						
A	745	0.94	2281	1034	0.52	2510
B	273	1.26	3282	591	0.22	2496
C	383	0.31	2401	652	0.71	2975
May 1985						
A	194	0.54		80	0.50	
B	113	0.72		424	0.99	
C	116	0.55		103	0.47	
December 1985						
A	261	0.29	2638	115	0.43	3446
B	139	0.13	3105	68	0.64	2967
C	193	0.44	2691	56	0.42	3630

Table A.5. Biomass (kg/ha) (means±S.E.) of the major components of the tree leaf litter in December of 1984 and 1985 on the study site established by Robert Kirmse in the dry season of 1981.

Plant Species	Uncleared		Cleared	
	1984	1985	1984	1985
Sabia	71±29	75±17	652±86	1061±121
Pau branco	1305±108	1511±144	897±121	1015±132
Catingueira	326±39	237±32	191±41	122±31
Mofumbo	311±51	172±36	193±52	97±27
Others	642	816	728	1052

Table A.6. Seedling density (seedlings/ha) (means±S.E.) in May 1985 for the major woody species on the cleared plots of the study area established by Robert Kirmse in the 1981 dry season. Foliar biomass (kg/ha) of sabia is also presented.

Plant Species	Density	Foliar Biomass
Sabia	3533±586	267[1]
Mororo	5260±703	-
Pau branco	2167±304	-
Catingueira	1220±262	-

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Education: Graduated from Neligh Public High School, Neligh, Nebraska in 1967; received Bachelor of Science with a major in Environmental Science and Biology from Dana College, Blair, Nebraska in 1975; completed requirements for Master of Science with a major in Agronomy-Range Management at University of Nebraska in 1981; completed requirements for Doctor of Philosophy with a major in Range Science at Utah State University in 1987.

Professional Experience: 1986 - present, Range Animal Science Specialist, Consortium for International Development, University of Arizona, Tucson, Arizona; 1984-1986, Research Associate, Department of Range Science, Utah State University, Logan, Utah; 1982-1983, International Range Technician, Department of Range Science, Utah State University, Logan, Utah; 1979-1981, Research Assistant, Department of Agronomy, University of Nebraska, Lincoln, Nebraska; 1979-1981, Farm laborer, Ganz Land and Cattle Co., Alvo, Nebraska; 1978-1979, Wildlife Research Biologist, Peace Corps, Central African Republic; 1976-1978 Fisheries Extension Agent, Peace Corps, Central African Republic.