RESPONSE OF CAATINGA VEGETATION TO DECREASING LEVELS OF CANOPY COVER[1]

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ABSTRACT - Although clearing of the caatinga forest is conducted primarily to open areas for crop production and to harvest wood, vegetation manipulation is being promoted as a means of increasing forage availability to livestock. Response of caatinga vegetation to various levels of canopy cover removal is being studied in two experiments at the CNPC, Sobral, CE, Brazil. Complete removal of the tree canopy resulted in a six to eightfold increase in first year production of herbaceous vegetation. This magnitude of increase was also true for canopy covers of 20% - 30% and 50% - 60%. Caatinga species coppice readily following cutting and, therefore, canopy cover for the cleared treatment (complete removal) was equal to that of the control (approximately 95%) by the end of the fourth year posttreatment. As a result, herbaceous vegetation and leaf litter yields for the two treatments were similar, too. Sabiá (*Mimosa caesalpiniaefolia*), a tree species which produces palatable browse and valuable wood, responded very favorably to clearing. Not only did many new plants establish, but by the fourth year posttreatment sabiá coppice on the cleared areas produced as much as ten times more foliar biomass than did the intact trees on the control area. The high herbaceous vegetation yields under a thinned canopy and the favorable responses to cutting of tree species such as sabiá indicate that a multiple use approach involving selectively thinned caatinga could be developed whereby production of the naturally renewable wood and forage resources would be optimized.

Index terms: vegetation manipulation, coppice, *Mimosa caesalpiniaefolia*.

RESPOSTA DA VEGETAÇÃO DA CAATINGA A VÁRIOS NÍVEIS DE RALEAMENTO

RESUMO - Muito embora o desmatamento da caatinga seja conduzido visando principalmente a abertura de novas áreas para produção de alimentos e para utilização da madeira, sua manipulação está sendo indicada como uma maneira de aumentar a disponibilidade de forragem. A resposta da vegetação da caatinga a vários níveis de desmatamento está sendo estudada em dois experimentos no Centro Nacional de Pesquisa de Caprinos, em Sobral, Ceará. A remoção total da copa das árvores produziu um aumento de seis a oito vezes na produção do estrato herbáceo durante o primeiro ano. Esta mesma intensidade de resposta foi obtida com a manutenção dos níveis da copa das árvores entre 20% e 30% e entre 50% e 60%. A regeneração das espécies cortadas foi rápida, e o nível de cobertura da copa para o tratamento com desmatamento total foi praticamente igual (aproximadamente 95%) ao das áreas não desmatadas (controle) quatro anos após o desmatamento. Como resultado dessa regeneração, a produção de biomassa do estrato herbáceo e a produção de folhas das árvores também foram similares entre os dois tratamentos. O desmatamento não somente favoreceu o estabelecimento de novas plantas, mas também a produção de biomassa originária da regeneração das áreas desmatadas foi cerca de dez vezes superior à produção das árvores da área-controle. A alta produção do estrato herbáceo durante o primeiro ano e a resposta de espécies desejáveis como sabiá (*Mimosa caesalpiniaefolia*) ao desmatamento indicam que a utilização de um sistema de manipulação seletivo da caatinga pode ser desenvolvido.

Termos para indexação: manejo de caatinga, rebrote, sabiá, *Mimosa caesalpiniaefolia*.

INTRODUCTION

The heterogeneous caatinga vegetation type of Northeast Brazil is composed of multiple-stemmed, deciduous trees and shrubs with an understory of annual forbs and grasses. In terms of goat and sheep production, the caatinga generally serves as the year-around forage resource. Herbaceous plants supply the bulk of the forage consumed by free ranging goats and sheep during the wet season. As the dry season progresses, herbaceous vegetation availability becomes limiting and the dried leaves of the deciduous trees become an important diet component. By the end of the dry season, these dried tree leaves may compose as much as 70% of a goat's or sheep's diet (Pfister 1983, Kirmse 1984).

Dense stands of trees greatly limit herbaceous production (Araújo Filho & Gadelha 1984, Kirmse 1984 and Mesquita 1985) probably due to low levels

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of light reaching the forest floor. Most of the system's herbage production, in the form of tree leaves, is out of reach of browsing livestock during the wet season. Nearly all of these leaves, however, become available to livestock during the dry season when the leaves are shed. This material is commonly referred to as leaf litter. Several of the tree species do not produce palatable browse and, therefore, much of a year's leaf production goes unutilized by livestock.

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 Northeast. For the purposes of this paper, 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.

As in many other tropical woodland and forest regions, clearing caatinga is normally conducted for agronomic purposes. Termed slash-and-burn cultivation, field preparation involves hand-clearing of suitable areas of woody plants, stacking and removing marketable wood and burning the slash. This operation is conducted during the dry season with the follow-up burning treatment being a spotty but general fire covering as much of the cleared area as possible. Size of the cleared areas is usually relatively small (less than 5 ha) due to intensive labor requirements (Queiroz 1985).

A less common practice is to clear forest stands for the harvest of marketable wood as well as for grazing management purposes (Primov 1984, Queiroz 1985). Clearing for these purposes is generally conducted in mature, relatively dense stands of caatinga. In such cases, offtake of marketable wood is sufficient to cover labor and transport costs. Also elimination or reduction of a dense tree canopy greatly increases herbaceous production and, therefore, forage availability during the wet season. Where areas are being cleared for grazing management purposes, the slash is burned in order to eliminate its potential effects on livestock movement and herbaceous production. The slash, however, is piled in order to localize the effects of fire.

Selective wood harvesting is also a common practice. When needs for fence posts or construction materials arise, the desired trees are selected and cut. This sporadic and spotty harvest may appear to have little serious effect on the system but it may be substantially modifying relative species composition.

Since caatinga manipulation is an integral part of land use or exploitation in the Northeast, caatinga vegetation responses to various levels of tree canopy removal were studied.

MATERIALS AND METHODS

Two related studies concerning vegetation responses to manipulation are being conducted at the CNPC, Sobral, CE, Brazil. Generally, the soils of the study sites are relatively shallow Red and Yellow Podzols with some Non-Calcic Brown soils. Bedrock is of precambriam origin. Topography is gently undulating with both well drained and poorly drained areas present. Vegetation cover of the area is a mature, dense stand (95% canopy cover) of caatinga composed of many of the plant species typical of the caatinga of northern Ceará state. Principle tree species on the study area are pau-branco (*Auxemma oncocalyx* Taub.), sabiá (*Mimosa caesalpiniaefolia* Benth.), catingueira (*Caesalpinia pyramidalis* Benth.), marmeleiro (*Croton hemiargyreus* Muell. Clrg.), mororó (*Bauhinia forficata* Link) and mofumbo (*Combretum leprosum* Mart.). Important annual herbaceous plants include *Hyptis* spp., *Bainvillea* spp., *Phaseolus* spp. and jitirana (*Ipomoea* spp). Dominant annual grasses are *Paspalum* spp., *Panicum* spp. and *Brachiaria mollis*.

A 6.5 ha site was selected during the 1981 dry season with the objective of comparing vegetation responses to clearing. For the remainder of the paper, this study will be referred to as experiment 1. Prior to the rains of 1982, the site was divided into three blocks and half of each block was cleared and fenced. After the marketable wood was removed, the slash was piled and burned. All grazing was excluded from the vegetation sampling areas for the duration of the study.

In the dry season of 1984, another nearby site was located in order to compare vegetation responses to various levels of tree canopy removal. Hereafter, this study will be referred to as experiment 2. Four treatment levels were designated: 1) clearing or 0% tree canopy cover; 2) thinning to a 20% - 30% tree canopy cover; 3) thinning to a 50% - 60% tree canopy cover; and 4) control of 95% tree canopy cover. The 8 ha study site was divided into two blocks based on vegetation and related soil differences. Within each block, the four 1 ha plots were randomly allocated to one of the four treatment levels. All woody plants were cut on the designated cleared plots. For the 20% - 30% cover and 50% - 60% cover treatments, all woody species which produce nonpalatable foliage (to sheep and goats) were cut. To attain the desired 50% - 60% cover treatment level, very few trees which produce palatable foliage were cut and the final tree density was approximately 1000 trees/ha. A significant number of such trees were cut on the 20% - 30% cover plots as reflected in the final tree density of about 450/ha. For all treatment levels, marketable wood and large slash material were removed from the site. The remaining slash (10,000 kg/ha) was not burned but left evenly distributed over the sites. Stumps of the cut trees did not receive further treatment.

Vegetation responses measured were:

1. Percent cover of coppicing woody plants on the manipulation, or reduced cover; treatments was estimated

using the line intercept method. Cover estimates were made in May 1984 and May 1985 for experiment 1 and in June 1985 for experiment 2.

2. Sampling for peak herbaceous standing crop was conducted at the time of flowering of the major forb species in May 1982, May 1984 and May 1985 for experiment 1 and in May 1985 for experiment 2.

3. Leaf litter biomass and composition were estimated shortly following leaf fall for most of the woody plants in the dry seasons of 1982, 1984 and 1985 for experiment 1 and in 1985 for experiment 2.

4. Coppice production was also estimated for the manipulation treatments in experiment 2 in August 1985. Within eight quadrats (4 m x 25 m) per treatment all coppice foliage was hand-harvested by species and subsamples were ovendried and weighed.

5. In experiment 1, the increased prevalence of sabiá, during the regeneration of cleared caatinga was studied. In June 1985, the density of sabiá seedlings was estimated using a quadrat method and a volumetric procedure was used to estimate foliar biomass per seedling. The resulting foliar biomass/ha value was then subtracted from total sabiá leaf litter biomass, obtained from the dry season leaf litter harvest, to yield a figure approximating coppice foliar production.

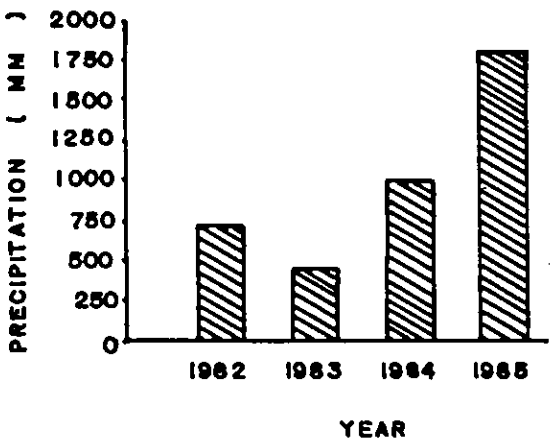

FIG. 1. Annual precipitation on the study site for the experimental period, 1982-1985. The 22 year average (1964-1985) in Sobral, Ceará, is 805 mm.

RESULTS

Year to year variation in rainfall was high during the period of these studies (Fig. 1). Relative to Sobral's 53 year average of 832 mm, annual precipitation measured on the study site ranged from 450 mm in 1983 to 1800 mm in 1985. In 1985, 1630 mm of precipitation was recorded during the growing season, January through May.

First year posttreatment responses to manipulation

All levels of tree canopy removal responded similarly the first year following manipulation in terms of peak yields of herbaceous vegetation. In experiment 1, removal of the woody canopy resulted in a sixfold increase in standing herbaceous vegetation (Table 1). In experiment 2, all treatment levels resulted in a seven to eightfold increase in herbaceous vegetation yields when compared to the control (Table 2). There were no significant differences in yields between the three manipulation treatments. A major portion of the increased herbaceous vegetation production on the manipulation treatments for both experiments 1 and 2 was in the form of stem biomass. With a common leaf: stem ratio of approximately .5, two-thirds of the herbaceous vegetation production was in the form of stems for all manipulation treatments.

TABLE 1. Peak herbaceous standing crop ($kg.ha^{-1}$) in May 1982, 1984 and 1985 and woody plant leaf litter and total leaf litter biomasses ($kg.ha^{-1}$) in early December 1982, 1984 and 1985 for the cleared and control treatments in Experiment 1.

	May		December			
	Herbaceous		Woody leaf litter		Total[1]	
	Cleared	Control	Cleared	Control	Cleared	Control
1982	3412 a	564 b	1077 a	2715 b	2532 a	2897 a
1984	1234 a	508 b	2660 a	2652 a	3413 a	3113 a
1985	202 a	141 a	3342 a	2807 a	3428 a	2999 a

[1] Includes all current year's production of vegetal material found on the forest floor in early December: seeds and leaves of woody plants as well as dead herbaceous plants.

ab Means in the same row and in the same vegetation type category, followed by a different letter, are significantly different.

TABLE 2. Peak herbaceous standing crop (kg . ha^{-1}) in May 1985 and woody plant leaf litter and total leaf litter biomasses (kg . ha^{-1}) in December 1985 for the four treatments in Experiment 2.

	May	December	
	Herbaceous	Woody leaf litter	Total[1]
Cleared	1896 a	966 a	1688 a
20% - 30% Cover	1675 a	928 a	1712 a
50% - 60% Cover	1767 a	1003 a	1765 a
Control	223 b	1891 b	2073 a

[1] Includes all current year's production of vegetal material found on the forest floor in December: seeds and leaves of woody plants as well as dead herbaceous plants.

[ab] Means in the same column, followed by a different letter, are significantly different ($P < 0.05$).

Total leaf litter biomass, including both the dead herbaceous plants and dried leaves of woody plants, was similar for all treatments within experiments 1 and 2 (Tables 1 and 2). Biomass of dried leaves of woody plants, however, was significantly ($P < .05$) higher on the control than on the treated plots for both experiments 1 and 2. It should be noted that in experiment 2, the dominant coppice species retained a portion of their leaves (visual estimate: 10% - 20% by weight) to the end of the 1985 dry season. Therefore, woody plant leaf litter biomass and total leaf litter biomass determinations for the manipulation treatments in experiment 2 are underestimated.

Total foliar production from coppice was similar for the cleared (1131 kg/ha) and 20% - 30% cover (1029 kg/ha) treatments but the coppice foliar yield was significantly ($P < .05$) lower for the 50% - 60% cover treatment (497 kg/ha) than for the other two. The high foliar biomass estimate for the 20% - 30% cover plots may have been due to some unusually large pau-branco coppice shoots that happened to fall within the quadrats.

Longer term responses to clearing

Caatinga woody plants coppice readily and grow rapidly following cutting. Canopy cover was 30% by the end of the first year posttreatment (1985) for the cleared treatment in experiment 2 (Fig. 2). In experiment 1, canopy cover was 78% by the end of the third year posttreatment (1984) and increased to 96% by the end of the fourth year (1985).

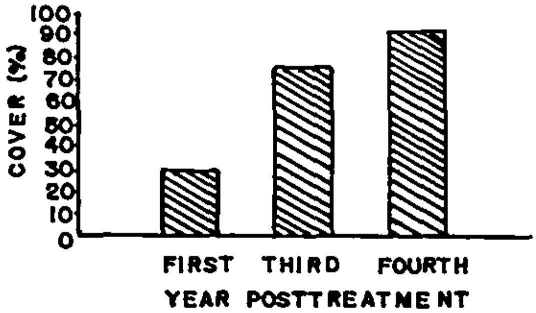

FIG. 2. Percent canopy cover of coppice on the regenerating clearfelled caatinga studies. First year posttreatment is from experiment 2 and the third and fourth years posttreatment are from experiment 1.

As already stated, peak herbaceous vegetation yield in experiment 1 was six times higher on the cleared areas than the control for the first growing season following treatment. Peak herbaceous standing crop yields were still significantly higher ($P < .05$) on the cleared plots in 1984, third year posttreatment, even though herbaceous plant production had greatly decreased in absolute terms from the first year (Table 1). By 1984, however, total leaf litter and woody plant leaf litter biomasses were similar for the two treatments. The two treatments were similar by 1985 in terms of both peak herbaceous vegetation production and total leaf litter biomass. In addition, the sum of the peak herbaceous vegetation production and woody plant leaf litter was similar for the two treatments for each of the three years measured.

No long term changes in relative species composition of herbaceous vegetation were noted. The major difference in relative species composition of the leaf litter for the two treatments involved the dramatic increase in the amount of the sabiá leaf component (Fig. 3). Sabiá leaves composed only 2% of the total leaf litter biomass on the control in 1984 and 1985 whereas for the cleared treatment sabiá leaves were 20% (652 kg/ha) and 31% (1061 kg/ha) of the total in 1984 and 1985, respectively. These increased yields can be attributed to production by sabiá seedlings and coppice shoots on the cleared treatment. In June 1985, the yield of leaves of sabiá seedlings was estimated to be 267 kg/ha. Subtracting this amount from the total sabiá leaf litter biomass (1061 kg/ha) obtained from the 1985 dry season harvest, an estimate of sabiá leaves from coppice of 794 kg/ha is derived. Therefore, approximately 25% of the total sabiá foliar biomass was from seedlings

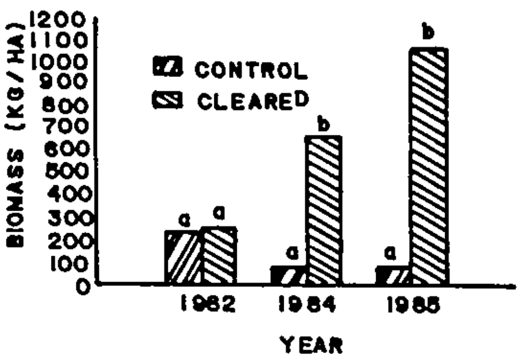

FIG. 3. Sabiá foliar biomass on the cleared and control treatments of experiment 1 in 1982, 1984 and 1985. Different letters above bars from the same year indicate significant differences ($P < 0.05$)

and 75% from coppice. In addition, a comparison of sabiá leaf litter biomass for the control (76 kg/ha) with the derived coppice production estimate for the cleared treatment, indicates that four-year-old sabiá coppice produced as much as ten times more foliar biomass that did mature, intact trees on the control.

DISCUSSION

One of the major outcomes of these studies is that peak herbaceous vegetation yields were similar for all three manipulation treatments. Therefore, for the caatinga type studied, understory herbaceous production does not drop off until some canopy cover level higher than 50% - 60% is attained. Light is apparently not a limiting factor in terms of herbaceous production for either the 20% - 30% cover or 50% - 60% cover levels.

In comparing the first year peak herbaceous vegetation yields for experiments 1 and 2, it should be noted that 1982 was an 'average' year in terms of precipitation whereas 1985 was an extremely wet year. The relatively low peak herbaceous vegetation yields in 1985 might be related to waterlogged soils.

The only major vegetational component that differentiated the three manipulation treatments was total coppice foliar production. The significantly lower production for the 50% - 60% cover treatment level was apparently due to the relatively low number of coppice shoots per unit area of land. In terms of total leaf litter biomass produced by woody plants, however, there were no differences by manipulation treatment due to the addition of foliar production by trees on thinned plots. Therefore, these three treatments, as well as the control, are all producing equal amounts of potential forage but making it available to grazing livestock in different forms and at different times of the year.

The 50% - 60% cover treatment would appear to be the best compromise towards reducing the effects of seasonal fluctuations in forage availability and quality typical of cleared and native caatinga. In fact, the 50% - 60% cover treatment has the combined advantages of newly cleared caatinga and mature intact caatinga: high herbaceous vegetation production as well as high yields of palatable leaf litter during the dry season. In addition, coppicing woody species which produce palatable foliage are susceptible to overgrazing on cleared areas; whereas when such palatable species remain intact in thinned stands they are not only protected from any grazing damage but they also provide an extremely important dry season reserve of palatable leaf litter.

Aside from the potential forage resource benefits, the 50% - 60% cover treatment assures a certain level of ecosystem stability that cleared caatinga does not. The most obvious example is that the tree canopy should reduce the impact of early wet season rains in terms of erosion. The canopy of the trees may also provide important shade for grazing livestock during midday.

The regeneration of manipulated caatinga to pretreatment conditions can be rapid. For the dense stand of caatinga studied in experiment 1, the vigorous and rapidly growing coppice on the cleared treatment attained a canopy cover equal to the control by the end of the fourth year. The rapidly increasing canopy cover greatly limited herbaceous vegetation production so that by the fourth year herbaceous production on the cleared areas had been reduced to the control level. Due to the vigorous growth of the coppice shoots, woody plant leaf litter biomass was similar for the two treatments by the third year. There appeared to be only two major differences in vegetation between the cleared treatment and control by the fourth year: 1) physiognomy of the stands as the coppice canopy was very dense and had an average height of 5 m to 6 m while canopy of the control was about 10 m in height, and 2) change in species composition of the woody plant component as sabiá increased in stems/ha and biomass/ha.

The emergence of sabiá seedlings as an important component of the cleared treatment is apparently related to the removal of the tree canopy. Sabiá, acting as an early seral species, was able to take advantage of the cleared situation and greatly increase its density and importance in the stand. In regard to the response of sabiá coppice, sabiá could be loosely compared to early seral species which root sprout readily under favorable conditions. The aboveground portion of such woody plants lose vigor and degenerate in the development of dense mixed stands, but when such a stand is clearfelled, the below ground portion responds with production of very vigorous coppice.

Until now, research has not dealt with the importance of wood production and how it interrelates with livestock production in the Northeast. Further research needs to be conducted in the area of agroforestry with a possible objective of developing a management scheme which optimizes production of the forage resource as well as production of marketable wood. Some form of thinned caatinga would certainly be the basis of such a system.

According to a possible scheme, woody plant species that do not produce palatable browse are selectively removed from the stand; thereby decreasing canopy cover and increasing herbaceous production without decreasing production of palatable leaf litter. This management would favor sabiá (or other desirable woody plants) which produces palatable forage and valuable wood. Sabiá could be periodically harvested (every ten years, depends on annual precipitation and soil types) for wood and subsequently allowed to coppice again in the absence of high stoking rate for at least two wet seasons. This scheme would potimize forage and wood production as well as ecosystem stability.

CONCLUSIONS

1. Reduction of the canopy cover of dense stands of caatinga can greatly increase herbaceous vegetation yields and, in the case of thinned caatinga, this increased production can be realized without seriously affecting production of palatable leaf litter. The first two years following cutting, coppicing woody plants also retain their leaves at least two months further into the dry season than do intact trees. In respect to livestock production, some form of thinned caatinga would appear to be the most consistent and dependable forage resource throughout the year as well as over years.

2. In terms of future management oriented research, resilience of both individual plant species and the entire ecosystem to periodic harvest needs to be studied. In addition, realistic control methods of the undesirable woody species must be developed. Perhaps the most important factor in need of investigation, however, is the technical and economic feasibility of proposed management schemes in light of local production and marketing systems.

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