DOI: 10.17138/TGFT(4)71-81

Research paper

Botanical composition of Caatinga rangeland and diets selected by grazing sheep

Composición botánica de un pastizal del ecosistema Caatinga y de dietas seleccionadas por ovejas en pastoreo

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Abstract

Sheep dietary selection from species-diverse Caatinga rangeland of semi-arid northeastern Brazil has not been documented. This study examined the botanical composition of the available forage and diets of Dorper x Saint Ines ewes on thinned Caatinga over-seeded with *Cenchrus ciliaris* and *Urochloa mosambicensis*. Sixty-three species from 23 families, dominated by shrubs and short trees of low forage nutritive value, were identified in the vegetation. The botanical composition revealed, on average, high presence of 29.2% Malvaceae and 13.0% *C. ciliaris*. Using the microhistological technique, sheep showed, on average, 59.6% preference for dicotyledons throughout the year. However, selectivity indexes indicated, on average, greater selection for Poaceae during the rainy season (1.5) and for dicotyledons in the dry season (1.8) with a year-round aversion for Malvaceae (0.3). These findings suggest that Caatinga vegetation management should include Malvaceae thinning and greater incorporation of grasses and herbaceous legumes to improve rangeland carrying capacity.

Keywords: Brazil, continuous stocking, dietary selection, microhistological technique, principal components.

Resumen

El consumo selectivo por ovejas en pastoreo en la vegetación de Caatinga del semiárido noreste de Brasil ha sido muy poco documentado. En este estudio fue evaluada la composición botánica tanto del forraje potencial disponible como del consumido por ovejas Dorpers x Santa Ines en una Caatinga raleada y sobre-sembrada con las gramíneas *Cenchrus ciliaris* y *Urochloa mosambicensis*. En la vegetación se identificaron 63 especies de 23 familias, dominadas por arbustos y árboles pequeños de bajo valor forrajero. La composición botánica reveló, en promedio, alta presencia de especies de la familia Malvaceae (29.2%) y de *C. ciliaris* (13.0%). Utilizando la técnica microhistológica se encontró que a través del año las ovejas tuvieron, en promedio, una preferencia del 59.6% por las dicotiledóneas. Sin embargo, los índices de selectividad indicaron, en promedio, una mayor selección por las Poaceae durante la época de lluvias (1.5) y en la estación seca por las dicotiledóneas (1.8), y una aversión hacia las Malvaceae durante todo el año (0.3). Estos resultados indican que el manejo de la vegetación de la Caatinga debe incluir un control de las Malvaceae y una mayor incorporación de gramíneas y leguminosas herbáceas para mejorar la capacidad de carga de los pastizales en la zona.

Palabras clave: Brasil, componentes principales, pastoreo continuo, selección de dieta, técnica microhistológica.

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Introduction

Livestock production in semi-arid Brazil is based on Caatinga rangeland (Araújo Filho et al. 1998), which covers approximately 86% (83.5 Mha) of the region (3–16° S, 35–45° W) and 9.8% of Brazil's land area (IBGE 2012). Caatinga rainfall ranges from 200 to 800 mm/yr. The upper story of shrubs, small trees and prickly deciduous vegetation consists mostly of Leguminosae, Euphorbiaceae, Cactaceae and Bromeliaceae, while the herbaceous layer is comprised primarily of annual grasses and dicotyledons. The majority of this vegetation has low forage value and the upper story is partially inaccessible to sheep (Santos et al. 2010).

More efficient utilization of the natural vegetation for ruminant production requires greater knowledge of species preferred by grazing animals. To improve management of the Caatinga, studies of ecosystems should determine botanical composition, forage mass and nutritive value as well as soil characteristics (Heady 1975; Holechek et al. 2006; Albuquerque et al. 2008). Taken as a whole, this information will help land managers better understand soil-plant-animal-environment interrelationships and develop productive and sustainable management strategies.

Forage allowance and animal species have marked effects on native plant populations (Bhatta et al. 2001; Sankhyan et al. 2001). Albuquerque et al. (2008) observed that botanical composition of shrub/tree-pasture combinations under grazing tends to vary over time because palatable species suffer selective grazing pressure which can result in their decline, while those not consumed by animals tend to increase.

Due to differences in selectivity between browsers and grazers, intake of various forage species differs among animal species as does the concentration of dietary nutrients (Holechek et al. 2006). Dietary botanical composition can be estimated by collecting dietary samples via esophageal or rumen fistulae for examination using the point microscopic technique (Heady and Torrel 1959) or analyzing feces using the microhistological technique (Sparks and Malechek 1968). As the latter technique is less labor-intensive and is conducted with intact sheep grazing without interference and therefore not subject to possible inaccuracies in sampling, we chose to use this methodology.

Studies conducted in Northeast Brazil show that 70% of species from Caatinga rangeland contribute to the botanical composition of ruminant diets. Herbaceous species can contribute over 80% of diets in the rainy season, while woody perennials become more important in the dry season and can contribute up to 48.5% (Araújo Filho et al. 1998).

The objective of this study was to document the seasonal changes in botanical composition of available forage and the diets selected by sheep continuously grazing partially cleared Caatinga over-seeded with perennial grasses.

Materials and Methods

Rangeland study

The research was conducted from January 2011 to January 2012 in São Miguel (8°10'50'' S, 38°23'14'' W), which is located in Serra Talhada, Pernambuco, Brazil. The location is characterized by undulating relief, shallow, well-drained, medium to high fertility Luvisols, 439-m elevation, and a tropical semi-arid climate with a mean annual temperature of 25.7 °C. The vegetation is primarily composed of hyperxerophilic Caatinga, consisting of shrubland plus thorn and deciduous forest (CPRM 2005). Annual rainfall during the study, derived from a pluviometer, was 696 mm compared with a 10-year average of 674 mm (Figure 1).

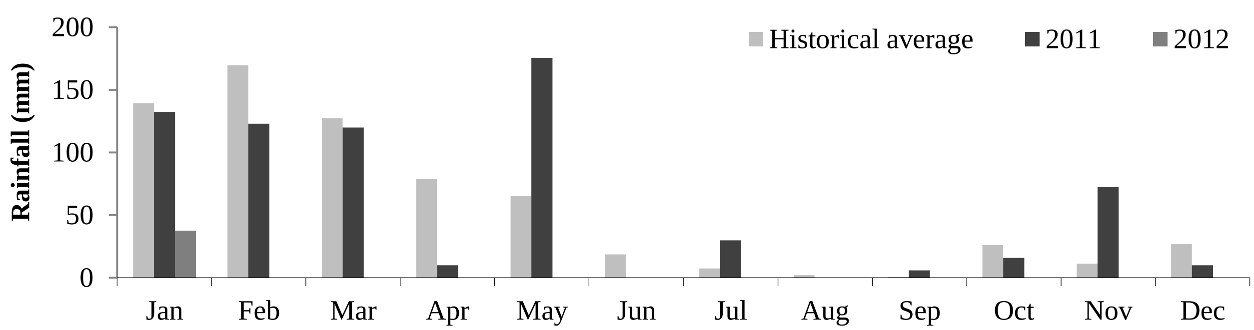

Figure 1. Rainfall during the experimental period and the medium-term (2001–2011) average. Source: São Miguel Farm, Serra Talhada, PE, Brazil.

The experimental area consisted of 38 ha of thinned Caatinga, with one-third of the area oversown with buffel grass (*Cenchrus ciliaris*) and sabi grass (*Urochloa mosambicensis*). During the study the paddock was continuously grazed by 70 crossbred sheep (Dorper x Santa Inês), free of parasites, with initial average body weight of 30.9 ± 4.4 kg and 10 months old. Water and salt were available at all times.

Soil analysis

Soil samples collected at depths from 0 to 20 cm and 20 to 40 cm were analyzed for particle size by the pipette method (EMBRAPA 1997) and for soil fertility at the Universidade Federal Rural of Pernambuco laboratories. The soil was sandy-loam, eutrophic, with: pH (H_2O) = 6.4; P (Mehlich-1) = 11.8 mg/dm^3; Na^+ = 0.17 cmol$_c$/dm^3; K^+ = 0.2 cmol$_c$/dm^3; Ca^{2+} = 3.5 cmol$_c$/dm^3; Mg^{2+} = 1.5 cmol$_c$/dm^3; Al^{3+} = 0.08 cmol$_c$/dm^3; $H^+ + Al^{3+}$ = 3.1 cmol$_c$/dm^3; organic carbon = 7.3 g/kg; and OM = 12.6 g/kg (Cavalcanti 1998).

Botanical composition of rangeland

We initiated sample collection when inflorescences appeared and sent them to the Dárdano Andrade Lima Herbarium (MOSS), Agronomic Institute of Pernambuco, Brazil for identification. Botanical composition was estimated by the dry-weight-rank method adapted from Jones and Hargreaves (1978) using 1-m^2 quadrats. Evaluation took place every 56 d from January 2011 to January 2012. In order to take into account vegetation heterogeneity, data points were located on nine 100-m transects, each with 20 sampling points at least 10 m apart.

Botanical composition of the diet

Commencing in March 2011, 2 fecal samples were collected from the rectums of 7 sheep at the same time as pasture assessments were conducted. Samples were stored in plastic bags at -15 °C. Dietary botanical composition was determined subsequently using microhistological techniques modified from Scott and Dahl (1980) by removing the abaxial and adaxial epidermis of the leaf blades (paradermal cuts). A set of microscopic slides was used as references by collecting fresh plant material from species considered abundant and possessing forage potential. The species chosen were divided into 3 distinct groups: Poaceae (*U. mosambicensis*, *Melinis repens*, *C. ciliaris* and *Brachiaria plantaginea*); Malvaceae (*Herissantia crispa*, *Sida galheirensis*, *Melochia tomentosa* and *Waltheria macropoda*); and other dicotyledons (*Cnidoscolus quercifolius*, *Aspidosperma pyrifolium*, *Croton sonderianus*, *Bauhinia cheilantha*, *Caesalpinia pyramidalis*, *Mimosa tenuiflora* and *Macroptilium martii*).

Epidermal structures were used for identification using photomicrographs from light microscopes equipped with cameras. These included shape and arrangement of epidermal cells, shape and presence of siliceous cells, types of glandular trichomes, types of stomata and shape of stomata subsidiary cells (Sparks and Malechek 1968). Fecal material was filtered with distilled water in ABNT No. 140 sieves with 0.105-mm pores. The residue was then subjected to the same procedure used for mounting reference slides. Five slides per cycle per animal were made where 20 field readings were photomicrographed by a light microscope set at 10x objective. The fragments obtained were recorded and then the relative frequency of each component was determined, according to a formula developed by Holechek and Gross (1982):

$$\% = \frac{\text{component frequency}}{\sum \text{of identified component frequencies}} \times 100$$

Selectivity index

Indexes were used to compare botanical composition of the pasture and diet. Pasture composition was used as the reference for dietary composition. If the index was <1, there was avoidance of the component, while if the index was >1, that component was selected at a greater level than its presence in the paddock (Heady 1975).

The selectivity indexes were calculated by Kulczynski formula (Hansen and Reid 1975; Alipayo et al. 1992; Bauer et al. 2008):

$$SI_{jk} = \frac{2\sum_{i=1}^{I} \min\ (P_{ij}, P_{ik})}{\sum_{i=1}^{I} (P_{ij} + P_{ik})} \times 100$$

where SI_{jk} is the Selectivity Index (%), P_{ij} and P_{ik} are percentages of the component i in the diet j and pasture k.

Statistical analysis

Data were subjected to descriptive statistics (mean and confidence interval at 5% probability) and multivariate analysis using Statistica, Version 7 (StatSoft Inc., Tulsa, OK, USA). Principal components analysis was used to simplify the data set, summarizing the information in a few components that retained maximum variation. Cluster analyses between the botanical composition of pasture and diet as a factor of similarity were undertaken by the Tocher Method, where the Euclidean average distance intragroup must be smaller than the average distance intergroup.

Results

Available forage

The floristic diversity of the vegetation included 23 families and 63 species from different strata: 10 trees, 29 shrubs and 24 herbs. There was a predominance of woody species, with a diverse, dispersed herbaceous layer of mostly annuals (Table 1).

Plant families with the largest numbers of species were: Leguminosae with its 3 subfamilies, Caesalpinoideae, Mimosoideae and Papilionoideae; Malvaceae, Poaceae, Euphorbiaceae and Cactaceae. Fifty-two percent of the families found in this study had only 1 species (Figure 2). Of the total number of genera, 51 (90%) were represented by only 1 species (Table 1).

Table 1. Plant species present in thinned Caatinga browsed by sheep at Serra Talhada, PE, Brazil. Species and family names are according to The Plant List taxonomic database (www.theplantlist.org).

Family	Scientific Name	Common Name
Herbaceous Stratum		
Amaranthaceae	*Froelichia humboldtiana* (Schult.) Seub.	Froelichia
Compositae	*Centratherum punctatum* Cass.	Perpétua-roxa
Boraginaceae	*Heliotropium tiaridioides* Cham.	Crista-de-galo
Cactaceae	*Melocactus bahiensis* (Britton & Rose) Luetzelb.	Coroa-de-frade
Cactaceae	*Tacinga inamoena* (K.Schum.) N.P.Taylor & Stuppy	Quipá
Cleomaceae	*Cleome spinosa* Jacq.	Mussambê
Cyperaceae	*Cyperus uncinulatus* Schrad. ex Nees	Barba-de bode
Convolvulaceae	*Ipomoea asarifolia* (Desr.) Roem. & Schult.	Salsa
Leg. Mimosoideae	*Mimosa sensitiva* L.	Malícia / Dormideira
Leg. Papilionoideae	*Macroptilium martii* (Benth.) Marechal & Baudet	Orelha-de-onça
Nyctaginaceae	*Boerhavia diffusa* L.	Pega-pinto
Poaceae	*Andropogon gayanus* Kunth	Capim-andropogon
Poaceae	*Aristida setifolia* Kunth	Capim-panasco
Poaceae	*Brachiaria plantaginea* (Link) Hitchc.	Capim-milhã
Poaceae	*Cenchrus ciliaris* L.	Capim-buffel
Poaceae	*Melinis repens* (Willd.) Zizka	Capim-favorito
Poaceae	*Urochloa mosambicensis* (Hack.) Dandy	Capim-corrente
Pontederiaceae	*Eichhornia paniculata* (Spreng.) Solms	Rainha-dos-lagos / Aguapé
Portulacaceae	*Portulaca halimoides* L.	Beldroega
Rhamnaceae	*Crumenaria decumbens* Mart.	-
Rubiaceae	*Spermacoce verticillata* L.	Vassourinha-de-botão
Rubiaceae	*Diodella teres* (Walter) Small	Engana-bobo
Rubiaceae	*Staelia virgata* (Link ex Roem. & Schult.) K.Schum.	Poaia
Plantaginaceae	*Angelonia cornigera* Hook.	-
Shrub Stratum		
Amaranthaceae	*Alternanthera brasiliana* (L.) Kuntze	Quebra-panela
Apocynaceae	*Allamanda blanchetii* A.DC.	Alamanda-roxa
Apocynaceae	*Calotropis procera* (Aiton) Dryand.	Algodão-de-seda
Boraginaceae	*Cordia leucocephala* Moric.	Moleque-duro
Bromeliaceae	*Bromelia balansae* Mez	Macambira-de-cachorro
Bromeliaceae	*Bromelia laciniosa* Mart. ex Schult. & Schult.f.	Macambira
Cactaceae	*Arrojadoa rhodantha* (Gürke) Britton & Rose	Rabo-de-raposa
Cactaceae	*Cereus jamacaru* DC.	Mandacaru
Cactaceae	*Pilosocereus gounellei* (F.A.C.Weber ex K.Schum.) Byles & G.D.Rowley	Xique-xique
Euphorbiaceae	*Cnidoscolus quercifolius* Pohl	Faveleira
Euphorbiaceae	*Cnidoscolus urens* (L.) Arthur	Cansanção
Euphorbiaceae	*Croton heliotropiifolius* Kunth	Quebra-faca
Euphorbiaceae	*Croton sonderianus* Müll.Arg.	Marmeleiro
Euphorbiaceae	*Jatropha mollissima* (Pohl) Baill.	Pinhão bravo
Euphorbiaceae	*Manihot carthaginensis* subsp. *glaziovii* (Müll.Arg.) Allem	Maniçoba

Continued

Family	Scientific Name	Common Name
Shrub Stratum		
Leg. Caesalpinioideae	*Bauhinia cheilantha* (Bong.) Steud.	Mororó
Leg. Mimosoideae	*Mimosa tenuiflora* (Willd.) Poir.	Jurema-preta
Leg. Papilionoideae	*Aeschynomene filosa* Benth.	Angiquinho
Leg. Papilionoideae	*Dioclea grandiflora* Benth.	Mucunã
Leg. Papilionoideae	*Indigofera suffruticosa* Mill.	Anileira
Malvaceae	*Herissantia crispa* (L.) Brizicky	Malva
Malvaceae	*Herissantia tiubae* (K.Schum.) Brizicky	Malva / Mela-bode
Malvaceae	*Sida galheirensis* Ulbr.	Relógio / Malva-branca
Malvaceae	*Wissadula periplocifolia* (L.) Thwaites	Veludo-branco
Malvaceae	*Melochia tomentosa* L.	Capa-bode
Malvaceae	*Waltheria macropoda* Turcz.	Malva-branca
Malvaceae	*Waltheria rotundifolia* Schrank	Malva-amarela
Passifloraceae	*Piriqueta guianensis* subsp. *elongata* (Urb. & Rolfe) Arbo	-
Verbenaceae	*Lantana camara* L.	Chumbinho
Arboreal Stratum		
Apocynaceae	*Aspidosperma pyrifolium* Mart.	Pereiro
Leg. Caesalpinioideae	*Caesalpinia pyramidalis* Tul.	Catingueira
Leg. Caesalpinioideae	*Chamaecrista hispidula* (Vahl) H.S.Irwin & Barneby	Visgo
Leg. Mimosoideae	*Anadenanthera colubrina* var. *cebil* (Griseb.) Altschul	Angico
Leg. Mimosoideae	*Prosopis juliflora* (Sw.) DC.	Algaroba
Leg. Papilionoideae	*Amburana cearensis* (Allemao) A.C.Sm.	Imburana-de-cheiro
Rhamnaceae	*Ziziphus joazeiro* Mart.	Juazeiro
Rubiaceae	*Mitracarpus longicalyx* E.B.Souza & M.F.Sales	-
Sapindaceae	*Talisia esculenta* (A. St.-Hil.) Radlk.	Pitombeira
Sapotaceae	*Sideroxylon obtusifolium* (Roem. & Schult.) T.D.Penn.	Quixabeira / Rompe-gibão

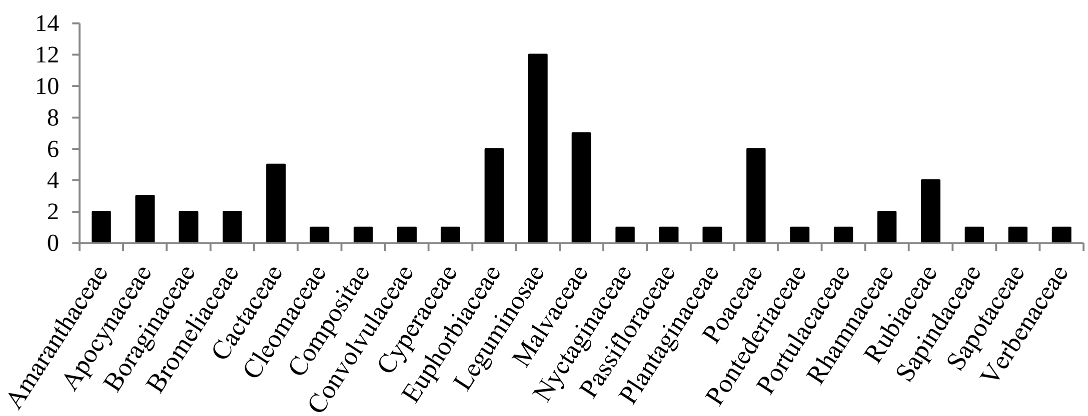

Figure 2. Number of species in different families in thinned Caatinga grazed by sheep at Serra Talhada, PE, Brazil.

Despite the floristic diversity (Table 1), botanical composition was dominated by "other Malvaceae" of low palatability to sheep (Santos et al. 2008) and the component "other species" (Table 2). During the dry season (Figure 1), prevalence of "other Malvaceae" increased, probably due to tolerance of the xerophytic environment (Prado 2003), which made it more competitive than less drought-tolerant species (Table 2).

Buffel grass (*C. ciliaris*) and the "other Poaceae" component were less prevalent but persisted throughout the year (Table 2), possibly because they are evergreen in the presence of minimal soil moisture (Hanselka et al. 2004). As the dry season progressed, the contribution of sabi grass (*U. mosambicensis*) and the "other species" component to available forage declined, the former due to drought dormancy (Skerman and Riveros 1990) and

Table 2. Botanical composition (% ± s.e.) of Caatinga with thinned over-story and an under-story grazed by sheep at Serra Talhada, PE, Brazil.

Component	Jan 11	Mar 11	Apr 11	Jun 11	Aug 11	Oct 11	Jan 12
Melochia tomentosa (Malv.)	3.3 ± 12.7	2.0 ± 10.8	3.1 ± 14.5	2.3 ± 12.1	0.8 ± 7.6	2.0 ± 10.4	1.2 ± 8.5
Cenchrus ciliaris (Poaceae)	10.7 ± 26.5	10.0 ± 26.1	8.7 ± 22.8	14.7 ± 30.5	17.5 ± 33.6	14.1 ± 28.7	15.0 ± 31.8
Urochloa mosambicensis (Poaceae)	2.9 ± 15.7	1.4 ± 9.7	2.6 ± 13.4	8.2 ± 24.7	9.6 ± 17.6	3.5 ± 15.0	4.0 ± 17.4
Caesalpinia pyramidalis (Leg.-Caesalp.)	1.5 ± 12.3	3.6 ± 14.3	0.2 ± 0.9	0.5 ± 3.9	2.7 ± 13.3	1.6 ± 10.0	11.4 ± 30.1
Diodella teres (Rubiaceae)	1.2 ± 5.7	8.8 ± 24.5	11.3 ± 27.3	11.0 ± 26.3	2.6 ± 14.7	4.8 ± 16.1	0.1 ± 0.7
Mimosa tenuiflora (Leg.-Mimos.)	1.0 ± 5.3	0.4 ± 4.2	0.6 ± 6.8	0.2 ± 2.3	1.1 ± 8.8	0.7 ± 5.8	2.7 ± 15.5
Croton sonderianus (Euphorb.)	14.2 ± 29.9	4.5 ± 19.3	3.2 ± 15.4	1.4 ± 7.7	3.9 ± 15.1	5.1 ± 20.0	8.6 ± 25.6
Macroptilium martii (Leg.-Papil.)	0.3 ± 1.3	5.0 ± 17.4	7.2 ± 23.1	3.4 ± 16.4	2.8 ± 16.5	0.7 ± 5.8	0.0 ± 0.0
Aspidosperma pyrifolium (Apocyn.)	3.1 ± 12.6	3.6 ± 15.4	1.0 ± 7.6	1.1 ± 8.5	1.7 ± 8.9	1.5 ± 10.6	5.5 ± 20.5
Ipomoea asarifolia (Convolv.)	0.4 ± 2.2	0.0 ± 0.0	0.8 ± 7.3	1.1 ± 7.8	1.2 ± 10.0	0.5 ± 4.6	1.5 ± 10.0
Cactaceae	1.3 ± 5.1	0.7 ± 7.2	1.5 ± 11.0	0.8 ± 9.1	1.2 ± 10.5	5.1 ± 20.0	1.2 ± 8.9
Other Malvaceae	21.6 ± 36.0	25.6 ± 36.0	18.3 ± 30.9	27.1 ± 36.7	30.4 ± 40.8	42.7 ± 40.7	38.6 ± 43.6
Other Poaceae	10.8 ± 25.5	6.6 ± 19.6	5.0 ± 17.0	5.2 ± 18.2	8.3 ± 25.6	9.5 ± 23.7	2.2 ± 13.3
Other Leguminosae	0.5 ± 2.3	0.1 ± 1.0	0.2 ± 1.2	2.8 ± 14.6	0.5 ± 6.0	1.5 ± 10.8	0.5 ± 3.1
Other species[1]	27.2 ± 35.2	27.6 ± 36.3	36.3 ± 35.9	20.2 ± 31.9	15.6 ± 33.0	6.7 ± 20.8	7.5 ± 26.7

[1]Species not mentioned in this table nor belonging to any of the families mentioned in this table.

the latter largely because these were rainy season ephemerals that senesced during the dry season (Table 2). During the rainy season, contribution of Poaceae to the Caatinga herbaceous layer was greater than during the drier months (Figure 1).

The annual native legume *M. martii* is highly palatable to ruminants (Ydoyaga-Santana et al. 2011) and had its greatest contribution to the rangeland during the rainy season, persisting only until the early dry season (Table 2). “Other Leguminosae” also occurred infrequently throughout the survey periods. Among these, *B. cheilantha*, despite not fixing atmospheric N, is a valuable forage and is palatable to ruminants (Moreira et al. 2006; Martinele et al. 2010; Ydoyaga-Santana et al. 2011). In January 2011, *C. sonderianus* (Euphorbiaceae) was frequent (Table 2).

Buffel grass, “other Malvaceae” and the “other species” components were the most plentiful throughout the year. Using multivariate analysis of the first principal components, these formed isolated groups apart from the other components, explaining 91% of total variation (Figure 3).

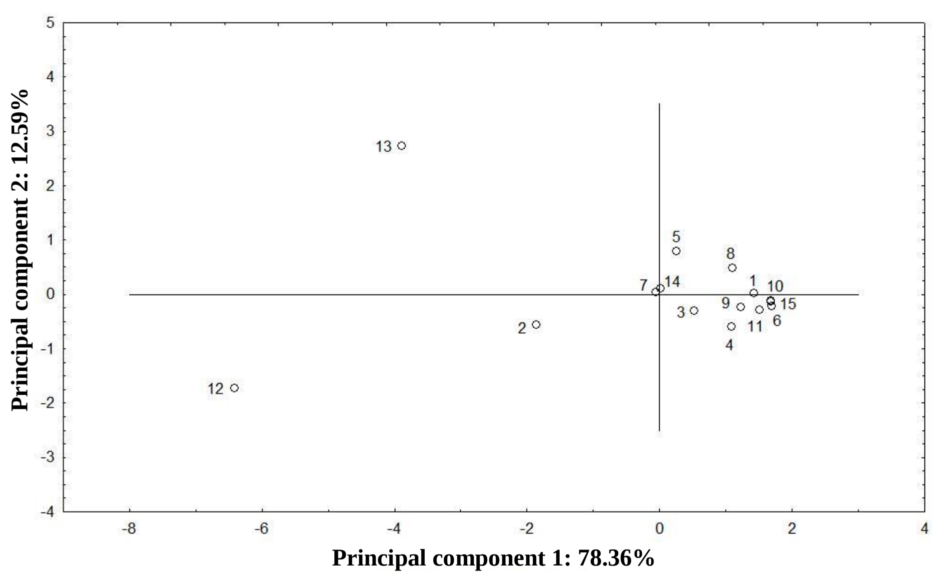

Figure 3. Projection of dissimilarity between 15 components as a percent of total botanical composition of a Caatinga pasture at Serra Talhada, PE, Brazil, with the components 13, 2 and 12 explaining 91% of total variation. Legend: (1) *M. tomentosa*, (2) *C. ciliaris*, (3) *U. mosambicensis*, (4) *C. pyramidalis*, (5) *D. teres*, (6) *M. tenuiflora*, (7) *C. sonderianus*, (8) *M. martii*, (9) *A. pyrifolium*, (10) *I. asarifolia*, (11) Cactaceae, (12) other Malvaceae, (13) other species, (14) other Poaceae, (15) other Leguminosae.

Diets of sheep

In the botanical composition of sheep diets, "other dicotyledons" predominated comprising 59.6% of the total dry matter in feces, on average, while Poaceae represented 30.5%. The Malvaceae, also dicotyledons, comprised 9.9% of dietary composition (Figure 4).

The similarity between some anatomical patterns of grasses and dicotyledons often makes species identification difficult in fecal samples. Some species, however, could be definitively identified, namely: *C. ciliaris*, *U. mosambicensis* and *M. repens* with stomata in parallel and hooks; *C. pyramidalis*, *A. pyrifolium*, *M. martii* and *B. cheilantha* with non-parallel stomata and long-hair trichomes; and *C. phyllacanthus* with glandular trichomes (Figure 5). It is noteworthy that the methodology used is simpler and less costly than the use of fistulated animals.

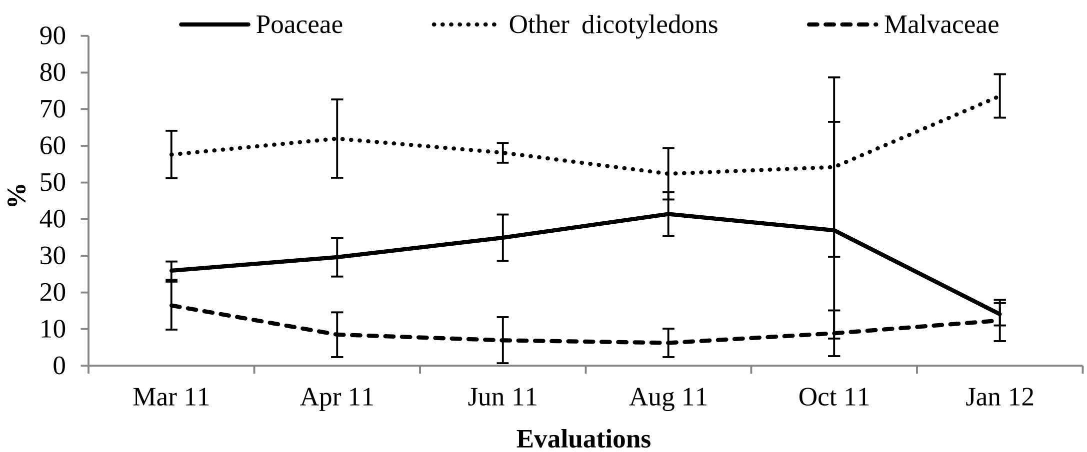

Figure 4. Seasonal dietary botanical composition, based on fecal samples, of sheep grazing thinned Caatinga at Serra Talhada, PE, Brazil.

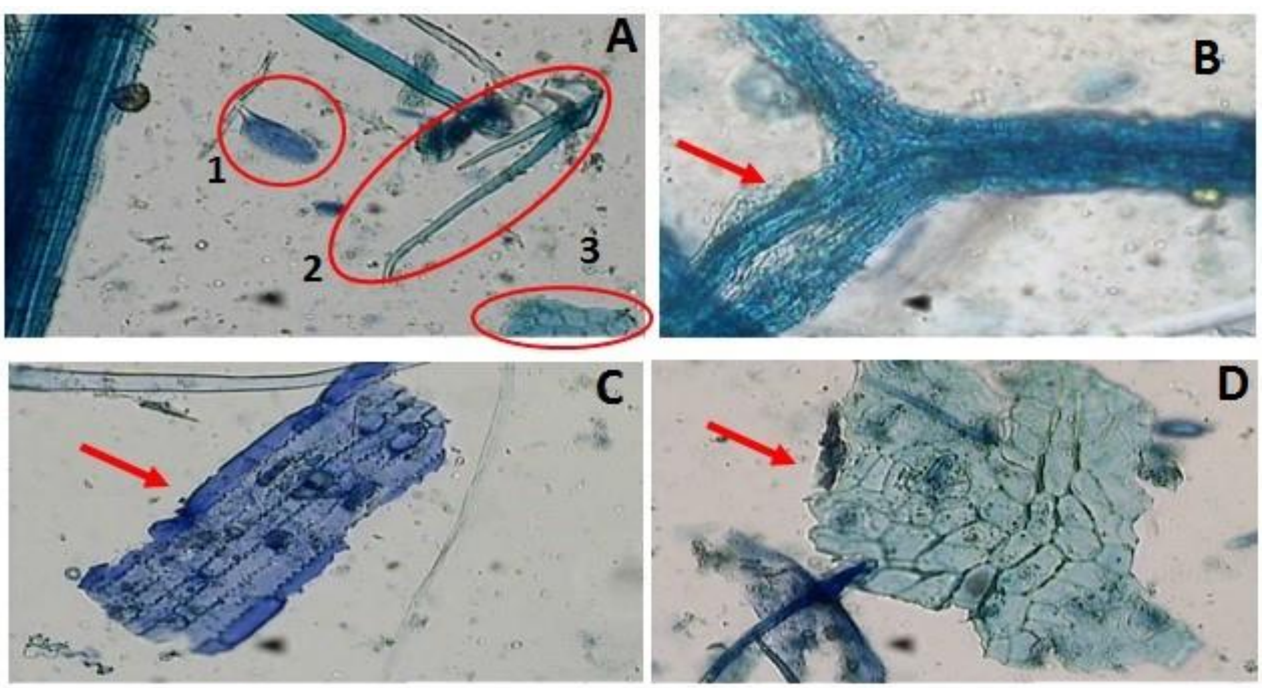

Figure 5. Slides of plant epidermal fragments from Brazilian Caatinga, obtained from sheep feces, at 10x objective: (A1) hooked *C. ciliaris*; (A2) Malvaceae star-shaped hair; (A3) dicotyledonous cuticle; (B) non-parallel dicotyledonous leaf rib network (arrow); (C) epidermal fragment of *C. ciliaris* (arrow); (D) epidermal fragment of *B. cheilantha* (arrow).

Selectivity indexes indicated that Poaceae and "other dicotyledons" were preferred by the sheep over other plants, with "other dicotyledons" replacing grasses in the diet from the beginning of the dry season (June 2011) (Figure 6). The phenological state of Poaceae (mature standing hay) and availability of tree (up to 273-cm height) and shrub (up to 175-cm height) foliage (comprised mainly of unreached leaves) fallen to the ground ("litter"), contributed to this result. Malvaceae were not preferred by animals (SI<1.0) (Figure 6) throughout the experiment; in other words, their contribution to the pasture was greater (Table 2) than their contribution to the sheep diets.

According to multivariate analysis of relationships between pasture botanical composition and sheep diets, the only component with dissimilarity between botanical composition of pasture and diet was the Malvaceae, whereas "other dicotyledons" and Poaceae formed distinct groups according to Tocher grouping, indicating intergroup dissimilarity (selectivity) (Figure 7).

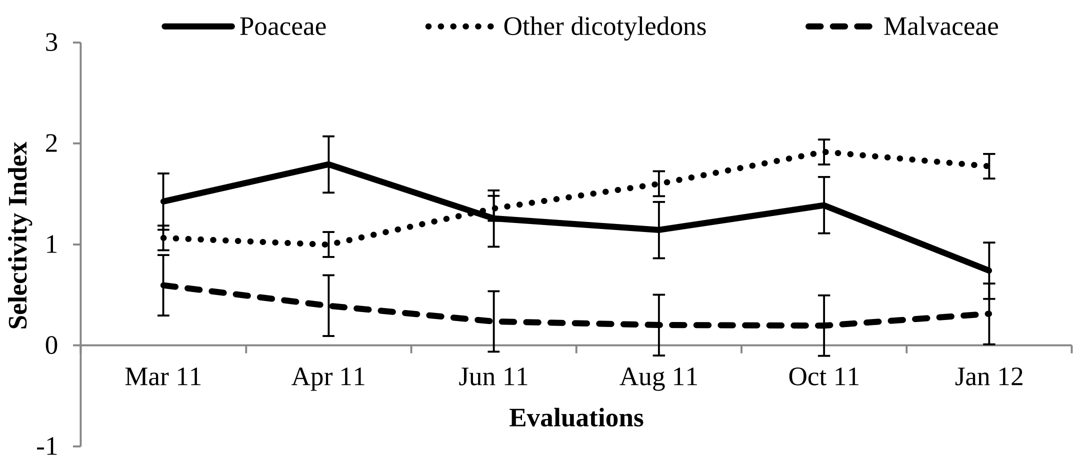

Figure 6. Selectivity indexes of sheep grazing Caatinga rangeland during different times of the year at Serra Talhada, PE, Brazil.

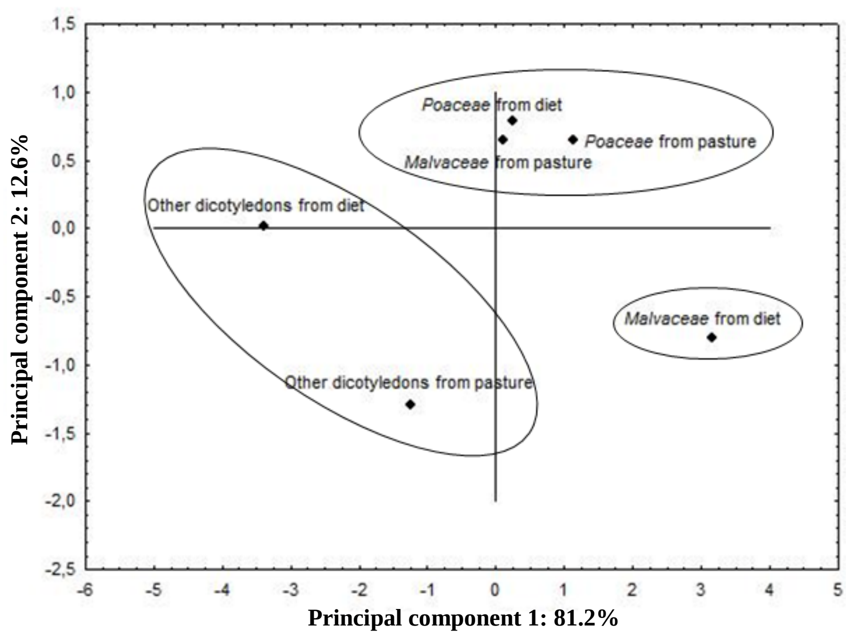

Figure 7. Projection of sheep diet dissimilarity and cluster among botanical components in Caatinga rangeland in which the first components explained 93.8% of the dissimilarity.

Discussion

This study confirms that the Caatinga ecosystem is complex, containing numerous species with multiple uses in managed systems, mainly agroforestry (Giulietti et al. 2004; Araújo Filho 2006; Gariglio et al. 2010). Some species are toxic to mammals, e.g. *I. suffruticosa,* containing the alkaloid indospicine (Tokarnia et al. 2000); *M. tenuiflora,* which may cause embryo mortality and poor bone formation; and *F. humboldtiana* that promotes photosensitization (Riet-Correa and Méndez 2007).

The Caatinga diversity (Table 1) under sheep grazing was similar to that reported by Moreira et al. (2006) in the same region, who identified 67 species in samples collected during the rainy season. In another study by Ydoyaga-Santana et al. (2011) in rangeland grazed by cattle in Serra Talhada, 41 plant species and 24 families were recorded during the rainy season, with Leguminosae, Euphorbiaceae and Poaceae predominating. Factors such as the irregularity of rainfall and reduced forage mass can promote change in the botanical composition of the pasture and increase bare soil, which may contribute to the persistence of species with low forage value and less selected by animals (Tothill 1987). Bailey and Brown (2011) reported that in semi-arid rangelands, forage growth is delayed by moisture deficit rather than defoliation.

Poaceae are of great importance to people in the Caatinga because they are largely preferred by grazing ruminants (Moreira et al. 2006; Santos et al. 2008; Martinele et al. 2010; Ydoyaga-Santana et al. 2011). According to Sousa et al. (2007) one could speculate that the Poaceae would be more resilient in this rangeland if soil phosphorus and soil organic matter were greater than the concentrations found in this study (11.8 mg/dm^3 and 30 g/kg, respectively). For *M. martii*, Moreira et al. (2006) reported values of 1.6% (March) to 2.2% (June) of the Caatinga botanical composition in Serra Talhada, Pernambuco and Ydoyaga-Santana et al. (2011) found values of 3.5% (February) to 3.9% (July) in similar rangeland. According to Freitas et al. (2007), in degraded Caatinga, *C. sonderianus* and *M. tenuiflora* are often locally abundant.

Botanical composition of sheep diets in rangeland will vary according to species available, forage mass or density and sheep thirst (Newman et al. 1994; Parsons et al. 1994; Sankhyan et al. 2001; Albuquerque et al. 2008), all factors heavily influenced by seasonal climatic conditions. However, it is noteworthy that, in our study, the botanical composition of the diet showed limited variation when comparing dry and rainy seasons.

The percentage of herbaceous dicotyledons in the diet reached as high as 70%, confirming the findings of Kirmse (1984) in studies on diets of sheep and goats in Caatinga at Ceará, Brazil. The preference for other dicots in this study is reflected in the crude protein concentrations in the diet, which varied from 8.9 to 12.9% of dry matter (Oliveira et al. 2015).

Poaceae constituted 20–45% of the diet in this study. In contrast, Santos et al. (2008) observed that the contribution of grasses to sheep diets, as determined by esophageal fistula sampling, was low and ranged from 2.5 to 19.7% from September 2004 to July 2005 in Caatinga, located in Sertânia, Pernambuco. Other species ranged from 75.4 to 94% during the same period. The authors concluded that the high contribution by dicotyledons was due to senescence and high nutritional value with up to 17.2% crude protein and 64.6% potential degradability of dry matter (Santos et al. 2009). Small ruminants may also spend more time browsing in the more elevated strata of the pasture depending on the structural characteristics of the rangeland (Pfister et al. 1988). Araújo Filho et al. (1998) summarized several studies conducted in the Caatinga and observed that the contributions of woody species to sheep diets averaged 32.3 and 48.5% in the rainy and dry seasons, respectively.

Araújo Filho et al. (1996), studying the botanical composition of sheep diets in Ceará Caatinga, reported that grasses contributed from 23.5 to 25.0%, while dicotyledons contributed from 75.7 to 76.5%, resulting in similar selectivity indexes ranging from 82.8 to 93.4% for grasses and from 80.5 to 83.2% for dicotyledons. Santos et al. (2008) observed that the selectivity index for sheep in Caatinga indicated preference for dicotyledons from September 2004 to July 2005, as compared with our results which show a preference for broad leaf plants from July to January.

Conclusions

This study has demonstrated that this thinned Caatinga rangeland vegetation was floristically diverse with some species of known forage value. Despite the presence of numerous plant families, 52% of these were represented by only a single species, i.e. this Caatinga has low flora diversity.

Botanical composition of sheep diets varied throughout the year and consisted mainly of forbs and woody browse. While grasses were preferred by sheep during the rainy season, “other dicotyledons” were preferred from the beginning of the dry season.

The Malvaceae, despite their strong presence in the pasture, were generally largely avoided by the animals, possibly due to low palatability caused by, among other factors, hirsute leaves. Systematic removal of Malvaceae and incorporation of high-quality grasses and legumes by farmers into this Caatinga rangeland seem advisable to increase carrying capacity. The trend for sheep to selectively graze on herbaceous species could result in a steady disappearance of the best forage species in that stratum unless grazing of pastures is properly managed.

The microhistological technique used to determine botanical composition of the sheep diets under grazing in the Caatinga seemed a robust and reliable assessment methodology, which avoided significant modification to animal behavior as can result with other methodologies, such as fistulae. However, this technique does not allow the identification of a considerable portion of the diet to the species level; e.g. “other dicotyledons” always comprised more than 50% of the diet. Unfortunately, we are unaware of any techniques which can identify individual species in the diet without using fistulae. Further studies, however, with different techniques, e.g. F-NIRS and n-alkanes, are needed to validate our findings.

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(Received for publication 24 April 2015; accepted 20 February 2016)