The importance of browse in late dry season and early wet season diets of cattle and goats in a communal area of the eastern Transvaal lowveld

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Declaration

I declare that this dissertation is my own, unaided work. It is being submitted in partial fulfillment of the requirements for the degree of Master of Science in Quantitative Conservation Biology at the University of the Witwatersrand, Johannesburg, and has not been submitted before for any degree or examination at any other University.

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Covering introduction

Owners and herders involved in traditional livestock production systems supplement the fodder available to their small livestock herds during the dry season through the lopping of tree branches (Sahel region - Devendra 1989, Nigeria - Devendra 1989, Atta-Krah 1989, South-east Asia - Devendra 1987a) and the cutting of grass from protected areas (such as roadsides - Devendra 1987b). These practices are aimed at improving the survival rates, increasing milk and meat yields and draft power of livestock (Devendra 1987a). The provision of high-protein or molasses concentrates is common in other areas of Africa, but the commonest method, and the only one available to the poorest rural stock-owners, is the provision of crop residues or natural forages such as grass and tree foliage. A wide variety of herbaceous and woody species are used; grasses are cut and and woody plant foliage is lopped from trees, providing relatively nutritious fodder during the dry season. Leguminous species are particularly suitable for use as dry season fodders in semi-arid to arid regions, since they supply relatively high concentrations of protein at a place and time in which most vegetation is nutrient poor (Atta-Krah 1989).

Cut-and-carry browse supplementation had not been properly documented in southern Africa. Because much of southern Africa is semi-arid or arid, fodder quality is often low, particularly during the dry season. Woody foliage lopped by herders may benefit animal production by improving the quantity and quality of fodder available to livestock. Limitations on and methods of improving browse supply in rural areas could be identified only if the relative importance of various browse components in livestock diets had been established for southern African savanna rangelands.

Although the general importance of browse to livestock in savanna rangelands is well-documented (Rees 1974, Aucamp & Danckwerts 1986; Aucamp *et al.* 1986, Dicko & Sangare 1986, Schwartz *et al.* 1986, Devendra 1989) few studies have quantified the relative utilisation of browse components (such as standing browse, supplied browse, leaf litter, fruits, flowers, bark). Owen-Smith & Cooper (1985) had quantified some of these contributions for kudu, impala and goats in a northern Transvaal nature reserve, and du Toit (1972) and Teague (1987,

1988) had studied defoliation of *Acacia karroo* by goats in the Eastern Cape.

This report is submitted in the form of a manuscript entitled "The contribution of browse to the late dry season and early wet season diets of cattle and goats in a communal area of the eastern Transvaal lowveld", and prepared for submission to the Journal of the Grassland Society of southern Africa.

Manuscript

The contribution of browse to the late dry season and early wet season diets of cattle and goats in a communal area of the eastern Transvaal lowveld

Abstract

The contribution of browse and grass to the diets of cattle and goats was assessed in relation to the total biomass of woody foliage and grass available in the study area. Livestock made less use of browse during the dry season than was shown by studies conducted in the Sahel and Nylsvley, northern Transvaal.

Goats fed more selectively, utilised newly flushed foliage more and fed upon a greater variety of woody plant species than did cattle. Browse contributed more to goat diets than to cattle diets although goats were less often supplied with browse. For goats, feeding on standing browse, supplied browse and leaf litter occupied 34.7 % of observation time before the tree/shrub flush and 8.3 % post-flush; for cattle the contributions were 14.7 % and 5.8 %, respectively. Fruits, flowers and bark were utilised only during the pre-flush period and only by goats. Goats spent significantly more time grazing and more time browsing than did cattle during the post-flush period. *Agave sisalana* (sisal) contributed to cattle diets during the pre-flush and post-flush periods, and to goat diets during the pre-flush period.

Since relatively little standing woody foliage is accessible to the animals (16.6 % pre-flush and 30.7 % post-flush of the wet season maximum), lopping of woody foliage by herders substantially increases the amount of food accessible to livestock, and supplied browse was eaten wherever it was encountered. Aerial cover of grass averaged less than 20 %, grass biomass less than 120 kgDM.ha^{-1} and biomass concentration of grass less than 553.5 gDM.m^{-3} for catena toplands, catena bottomlands and drainage line thickets.

The low contribution of browse to livestock diets during this study was due to the scarcity of accessible, palatable forage, exacerbated by the late flush on woody plants. In addition, local people harvesting live wood for fuel may compete with foraging livestock. To

increase the supply of food for livestock further the following practices could be encouraged: storage of woody foliage litter until the late dry season, use of chemicals to increase the nutritional value of poor quality browse and establishment of woodlots of palatable, perhaps leguminous, evergreen woody species for use as livestock fodder.

Additional index words: rangeland, tree fodders.

Introduction

Since there is little new growth of grass during the dry season in semi-arid savannas, the quality and quantity of grass material available to herbivores decreases with the progression of the dry season. Consequently, the woody foliage resource of deciduous savannas is particularly valuable to livestock during the dry season (Wilson 1986), and the contribution of browse to livestock diets increases during the dry season (Owen-Smith 1992). Although woody plant foliage is often richer in protein than that of grass, it tends to contain chemical compounds which deter feeding by ruminants, epsecially where it grows in nutrient poor soils (Owen-Smith & Cooper 1987b). Owen-Smith & Cooper (1987a) have suggested that browsers and mixed-feeders are better able to make use of highly defended woody plant foliage than are grazers.

Mixed stocking with cattle and goats or sheep is common in communal areas of southern Africa. Mixed browser-grazer systems can make better use of forage resources in savanna areas (Aucamp & Danckwerts 1986; Aucamp *et al.* 1986). Cattle are traditionally regarded as grazers and goats as mixed-feeders, but in the study area cattle have been observed eating browse supplied to them by herders (C.M. Shackleton pers. comm. PO Box 7, Klaserie 1381). Because of their smaller size, goats require less food than do cattle (Foster & Coe 1968 cited in Bunderson 1986), although they require more food relative to their body mass. Goats feed more selectively with regard to the plant species and plant parts they choose than do larger ruminants (Hoffman 1973, cited in Tainton *et al.* 1989).

In semi-arid and arid savannas, dry season leaf fall increases the accessibility of tree and shrub foliage to ungulates, as standing foliage biomass decreases as leaf litter biomass increases. The contribution of browse to goat diets at Nylsvley, northern Transvaal, ranged from 75 % in the wet season to 95 % in the dry season, a major component of which was leaf litter (Owen-Smith & Cooper 1985). Dicko & Sangare (1986) found that Sahelian cattle and goats on rangelands in Mali browsed for about two-thirds of their total annual foraging time. According to Rees (1974), cattle in the miombo woodlands of Zambia obtained over one-third of their energy requirements from standing browse between August and October, and gained enough protein for a 0.20-0.75 $kg.day^{-1}$ increase in live weight.

Tree and shrub fodders may be offered to animals in foraging areas or used in enclosures at night (Devendra 1987a; Atta-Krah 1989). The cut-and-carry system often allows higher weight gains among livestock than does an extensive ranching system without supplementation (Devendra 1987a). The contribution of supplied browse to the dry season diets of cattle and goats in communal lands of semi-arid regions of southern Africa had not been documented. Moreover, most studies of browse utilisation have failed to distinguish the utilisation of standing foliage and twigs from that of leaf litter, fruits, flowers or bark.

The aim of this study was to assess the contribution of the browse resource, including supplied browse, leaf litter, fruits, flowers and bark, to the late dry season and early wet season diets of livestock in the communal lands, and to identify the browse species preferred by livestock during these periods. The pre-flush period was defined as that period before either the grass or woody plants began to flush. The post-flush period was defined as beginning when at least 50 % of woody plants had flushed.

Study area

Timbavati communal land in the Mhala district of Gazankulu is apprriximately 740 ha of communal land which has been zoned as such for at least 15 years. Since scattered homesteads existed before this, utilisation of plant species for fuelwood, construction, livestock fodder and other purposes has probably been taking place for a considerably longer period (Shackleton 1993). The most abundant livestock species in the study area are cattle, goats and chickens, with smaller numbers of pigs and donkeys. The stocking rate of cattle is 0.862 $LU.ha^{-1}$ (Parsons 1991) - substantially higher than the 0.125 $LU.ha^{-1}$ suggested for as an "economic optimum" for commercial ranching (van Hooven, cited in du P. Bothma 1989). Stocking densities of other livestock species in the study area are unknown.

The study area falls into Acocks' (1988) Arid Lowveld. According to Edwards' (1983) classification, the vegetation physiognomy is short sparse woodland. Soils are derived from archaean granite and gneiss, and undulating catenal sequences are formed on the granites (Young 1976; Witkowski 1983). The topography is a series of low, gently sloping hills interspersed with drainage lines. The catena toplands are characterised by a rather regular distribution of mature *Sclerocarya birrea* and *Pterocarpus angolensis* trees; soils are shallow, nutrient poor sand lithosols (Scholes 1987). Bottomlands are dominated by the shrubs *Maytenus senegalensis* and *Euclea divinorum* and some mature *Strychnos madagascariensis*; their soils are deeper, nutrient richer clays (Scholes 1987). There is some evidence of both sheet and gully erosion in bottomland areas. A perched water table may lie at mid-slope, resulting in a seepline characterised by a narrow band of hydromorphic grassland with a band of *Terminalia sericea* upslope. Drainage lines are thickly vegetated with shrubs and trees.

According to Parsons (unpublished data), the two dominant grass species in the study area, in terms of basal area, are: *Perotis patens* and *Digitaria eriantha*, and toplands support 90.3 % Increaser IIa grasses, whereas bottomlands support only 51.2 % Increaser I and IIa grasses. According to van Oudtshoorn (1992), *D. eriantha* is palatable, while *P. patens* is unpalatable.

Mean July-June rainfall for the years 1980/81-1991/92 was 547 mm (SD = 135 mm), 75 % of which (457 mm) was received during the summer months (October to March). During 1991/1992 347 mm fell in total, with 308 mm falling during the wet season months. Thus, 1991/1992 was a below average rainfall year. During the first four months of the 1992/1993 wet season (October to January), 548 mm fell. 484 mm fell in December and January alone, while the first two months of the wet season (October and November) had below average rainfall, most of which fell in the form of very light rains. During the study period grass began to flush early in October, while the woody flush only began about a month later.

Procedure

All sampling was stratified according to three landscape units: catena toplands, catena bottomlands and drainage line thickets. Toplands were defined as the area above the *T. sericea* band, and bottomlands as the area below and including, the *T. sericea* band. The sampling periods were based upon woody plant phenology, so that they fell into the pre-flush and early leaf flush periods. The pre-flush sample began in the second week of September, when neither grass nor woody plants had flushed. Plant phenology was assessed at regular intervals after the pre-flush sample, using a belt transect at a randomly determined position in each landscape unit. The transect was 10 m wide, and long enough to contain 100 woody plants. Each woody plant in the transect was designated as: (a) not flushed: no apical buds or young leaves noticeable, (b) budding: apical buds noticeable but no new leaves or (c) flushed: apical buds and/or new leaves present. The post-flush sampling period was to begin when more than 50 % of the woody plants in one or more landscape units had flushed. Sampling in fact began when 62 % of the woody plants in the toplands were flushed, 29 % in bottomlands, and 33 % in drainage line thickets.

The browse resource was defined as the total amount of foliage, edible small twigs (< 1 cm in diameter), fruits and flowers present on trees and shrubs, and on the ground. Food categories were defined as follows:

Grass: all leaf and stem material on graminoid plants.

Standing browse: foliage on woody plants.

Accessible standing browse: woody plant foliage less than 1.5 m above the ground.

Bark: bark of standing or dead wood.

Leaf litter: woody plant leaves, small twigs (< 1 cm in diameter) and flowers on the ground.

Attached fruits: fruits attached to woody plants.

Detached fruits: fruits on the ground.

Supplied browse: leaves, twigs and branches lying on the ground which had been deliberately cut by stock-owners or herders for the purpose of feeding livestock or deliberately left on the ground after fuelwood harvesting.

Distribution-free (non-parametric) methods for statistical analysis were used th[illegible]hout, since no data conformed to a normal distribution. The statistical package SYSTAT (version 5.0) was used.

Total grass biomass

Grass availability was sampled by 25 quadrats (50 cm x 50 cm) placed at 10 m intervals along 250 m line transects. A grid was laid over an aerial photograph of the study area, and sample blocks were generated randomly for each of the three landscape units (catena toplands, catena bottomlands and drainage line thickets) until five blocks per unit had been selected. This process was repeated for the post-flush period.

For each quadrat, the average grass height (in 5 mm classes) and aerial cover (in 5 % classes) were recorded. In every fifth quadrat, all grass material was clipped to ground or stubble level. Clippings were oven-dried for 3 days at 50°C and weighed (to the nearest 0.0001 g). Biomass concentration is a measure of the "physical architecture" of the grass sward, and influences its forage value (Shackleton 1990). Grass biomass concentration was determined for each landscape unit, using data from clipped quadrats; grass biomass per cubic metre (grass biomass concentration) was calculated by conversion of grass biomass and average grass height per quadrat to correspond to a cubic metre volume; these values were then averaged for each landscape unit during each study period.

Grass height, cover and biomass of clipped quadrats were compared between landscape units and between sampling periods using the Kruskal-Wallis test, and the *a posteriori* method for multiple comparison described by Zar (1984:199-201). This test was used because the multivariate ANOVA makes no provisions for *a posteriori* identification of significant differences in data sets. However, the Kruskal-Wallis test treats all variables as independent, and ignores dependence between different behavioural variables and between different seasonal variables, thus providing [illegible] which should be interpreted with caution.

To predict grass biomass from the more easily measured parameters of percentage aerial cover and average grass height, linear regressions of the product of percentage aerial cover and average grass height (height:cover index) on dry mass of grass were performed for clipped quadrats. If the regression relationships were strong, then these equations would be used to calculate biomass values for unclipped quadrats. A generalised regression equation was obtained using data for all landscape units and both sampling periods together. Regression equations were also derived for toplands, bottomlands and drainage line thickets for each sampling period, and for both sampling periods together. All other regression equations were tested against the generalised equation using the method of Zar (1984:292) to determine whether different equations should be used for different landscape units or for different seasons.

Total and accessible standing leaf biomass

To calculate the maximum standing leaf biomass during the wet season in the study area, woody stem circumference and density data were obtained from Shackleton (1993). Stem circumference was used to derive total leaf biomass (as dry mass) per plant, using the regression equation formulated by Barnes *et al.* (1976) for *Colophospermum mopane*. Available standing biomass was all leaf material ~~present~~ remained on the plant during a study period. Accessible standing leaf biomass was all available material within reach of livestock. Thus, the total standing leaf biomass was divided into available and unavailable (foliage already shed) and accessible and inaccessible portions for each sampling period.

The proportion of foliage present on the plant (available fraction) at the time of sampling was estimated visually in relation to the wet season maximum. The proportion of this foliage mass which was accessible to livestock (accessible fraction) was also visually estimated in relation to the vertical extent of the woody plant canopy for plants of each species and size class. From preliminary observations of the feeding behaviour, it appeared that the average maximum height to which goats and cattle could reach was 1.5 m; therefore all leaf material above this level was considered inaccessible to livestock.

These analyses were carried out for all woody plant species which contributed 1 % or more to the total number of stems in the study area, plus all those species eaten by the livestock during sampling, plus those woody species identified by herders as most often cut for livestock. Data on stem density were not available for uncommon species such as *Acacia gerrardii*, *A. swazica*, *Carissa bispinosa*, *Maerua angolensis*, *Ficus thonningii*, *Trichilia emetica* and *Xanthocercis zambesiaca*.

Abundance of leaf litter

Leaf litter abundance was sampled by four quadrats (50 cm x 50 cm) placed under the canopy of each of trees of various species. Four quadrats were sampled per tree, and eight to ten trees of various sizes were sampled per species. Leaf litter biomass per unit area under canopies of each species was calculated.

The set of six species which made up 86 % of the total stems in the study area (Shackleton 1993), plus other species which were judged to produce large amounts of leaf litter in the areas where livestock feeding was concentrated, or whose litter appeared to be preferred by livestock, were sampled. The set of species sampled was: *Cassia petersiana*, *Dichrostachys cinerea*, *Diospyros mespiliformis*, *Lantana camara*, *M. senegalensis*, *Peltophorum africanum*, *S. birrea*, *S. madagascariensis*, *T. sericea* and *Xanthocercis zambesiaca*. Linear regressions of leaf litter biomass on stem circumference showed no significant relationships between these two variables for all the woody species sampled. Leaf litter biomass under canopies was tested for significant differences between the sampling periods using the Mann-Whitney U test. To ensure that stem circumference of the particular plants sampled did not bias the leaf litter measurements, stem circumference data sets were also tested for significant differences between the sampling periods; none were found.

Livestock foraging behaviour

Observations were carried out between the time livestock were let out to forage and the time that they were herded home (approximately 07h30 to 16h30). Five observation days were devoted to cattle and to goats during each sampling period. Every 45 minutes, a fifteen minute period was sampled (a sampling bout). A feeding bout was defined as the time period spent feeding on an individual plant(s) of a certain species. The following data were recorded for each feeding bout during each sample: length of feeding bout, number of bites taken per bout, food category and species eaten if a woody species or *Agave sisalana* (sisal).

A rough visual estimate of bite size (in terms of the number of leaves per bite) was made for all woody food species and for sisal. The average bite size for animals feeding on grass was estimated as mass per bite, in order to calculate the dietary contribution, by time and by mass, of each food plant (see Appendix). It should be noted that bite size of grazing animals is very difficult to estimate in the field, and therefore should be treated as a rough approximation and interpreted with caution. A sample of 20 leaves of each of five woody plant species was collected, dried as for grass samples, and weighed. Food species were then placed into leaf mass categories according to these data and leaf mass data from Cooper (1985). The mass ingested per bite, the total amount eaten per livestock species per sampling period and the dietary contribution by mass of each species was calculated. Data were analysed using the Kruskal-Wallis test, and *a posteriori* tests for significance followed the method of Zar (1984:199-201). This method presents the same problems as were described for analysis of the grass cover and biomass data sets.

Woody species preference ratios

Preferred woody plant species were identified by means of preference ratios (Petrides 1975) Plant species with a preference index of greater than one were actively selected by foraging livestock, while those with ratios of less than one were consumed in proportion to their abundance in the landscape, or less. For these calculations, values for accessible standing leaf mass as described (under "Total and accessible standing leaf mass") and estimates of dietary contribution by mass (under "Livestock foraging behaviour") were used. For woody plant species, only litter and standing foliage which was at or below the maximum reach of the livestock was considered accessible and included in the calculation of preference ratios. All grass material above stubble height was considered accessible to livestock. One of the limitations of this method of identifying preferred food species are that for uncommon species, preference ratios are artificially high, and for common species, artificially low.

Results

Total grass biomass

Toplands were generally better covered, and supported greater grass biomass than either bottomlands or drainage lines, although these differences were not all significant (Table 1). In toplands and bottomlands, both grass cover and biomass tended to be higher (not significantly), during the pre-flush period than during the post-flush period. In drainage line thickets, cover and biomass tended to be lower during the pre-flush period than during the post-flush period.

Grass biomass in toplands was greater ($p < 0.05$) during the pre-flush period than during the post-flush period. Since some light rain fell during September, grass regrowth began earlier than woody foliage regrowth, between the two sampling periods. Since only the toplands had significantly different grass biomass values for the pre-flush and post-flush periods, less regrowth of grass or more grass consumption by livestock must have occurred in toplands than in either of the other landscape units. Biomass concentration of grass in topland areas was substantially higher than that in either bottomlands or drainage line thickets, and was also higher during the pre-flush period than during the post-flush period. Results obtained from the use of the Kruskal-Wallis test should be interpreted with caution, since interactions between non-independent variables are ignored, namely that between the seasonal variables, "pre-flush" and "post-flush".

Insert Table 1

Although the grass cover and biomass data were non-normally distributed, neither square root nor reciprocal transformations improved the shape of the residual plot. Thus, the regression equations derived from untransformed data were considered to be the most accurate. The generalised height:cover - biomass regression equation was significantly different from the regression equations for each landscape unit seperately, using data from both sampling periods; the equations derived from data for one sampling period only were not significantly different from the generalised equation. Regression equations for each landscape unit are as follows:

Bottomlands: Grass biomass $_{(gDM.0.25m\text{-}2)}$ = 0.003(average height $_{(mm)}$ × aerial cover $_{(\%)}$) + 0.650 ($n = 50$, $p < 0.0005$, $R^2 = 0.488$, R^2 adj. = 0.477).

Drainage line thickets: Grass biomass $_{(gDM.0.25m\text{-}2)}$ = 0.007(average height $_{(mm)}$ × aerial cover $_{(\%)}$) + 0.218 ($n = 50$, $p < 0.0005$, $R^2 = 0.691$, R^2 adj. = 0.684).

Toplands: Grass biomass $_{(gDM.0.25m\text{-}2)}$ = 0.004(average height $_{(mm)}$ × aerial cover $_{(\%)}$) + 0.922 ($n = 50$, $p < 0.0005$, $R^2 = 0.392$, R^2 adj. = 0.379).

In these equations, R^2 adj. represents the coefficient of determination adjusted for sample size and the number of predictor variables used in the regression. These coefficients of determination were judged to be too low to allow the equations to be used for predictive purposes (see Boecklen and Gotelli 1984), so biomass data for clipped quadrats only was used in subsequent analyses.

Total and accessible standing leaf biomass

The accessible woody foliage fraction was 16.6 % (pre-flush) and 30.7 % (post-flush) of the maximum standing leaf biomass. However, the majority of the accessible standing foliage biomass present in the study area during the study period was of low nutritional value: together, *Lantana camara*, which is toxic (van Wyk & Malan 1988) and *M. senegalensis*, which is not highly palatable (see Owen-Smith & Cooper 1987b) made up approximately 90 % (pre-flush) and 50 % (post-flush) of the accessible standing leaf biomass. The remaining species made up 28 $kgDM.ha^{-1}$ (pre-flush) and 207 $kgDM.ha^{-1}$ (post-flush). *T. sericea*, a dominant woody species, accounted for 61.6 % of the total stems in the study area, and standing foliage was abundant post-flush. However, standing foliage of *T. sericea* was completely unavailable during the pre-flush period, due to leaf fall, and its litter was scarce, probably due to consumption by livestock prior to the study.

Many specimens of *D. mespiliformis*, *P. angolensis*, *S. birrea* and *S. madagascariensis* in the study area had minimum canopy heights greater than 1.5 m, so that little of the estimated wet season maximum standing foliage was ever accessible to the livestock. Statistical comparison of standing leaf biomass in different landscape units was not possible because Shackleton's (1993) sampling was not stratified into landscape units.

Insert Table 2

Abundance of leaf litter

The abundance of leaf litter under canopies of common trees and shrubs is shown in Table 3. *Cassia petersiana*, *D. cinerea*, *L. camara* and *P. africanum*, which are common species, had no litter remaining beneath their canopies during the sampling periods. *Xanthocercis zambesiaca*, which is relatively rare, but is eaten by livestock whenever it is accessible, had no litter during the study, almost certainly because of consumption by livestock.

Insert Table 3

The stem circumferences of the sets of trees under which leaf litter was sampled was not significantly different between sampling periods, indicating that leaf litter biomass comparisons are not confounded by the stem circumferences of the plants sampled. All the species investigated, except *D. mespiliformis*, provided more litter during the pre-flush period than during the post-flush period. This difference was significant for *S. birrea* and *T. sericea*, which had more litter under canopies during the pre-flush period than during the post-flush period. In total, almost twice as much litter was available during the pre-flush period than during the post-flush period, suggesting that litter had been dispersed by wind or trampling or consumed by livestock between the two sampling periods. *Diospyros mespiliformis* was the only woody species which provided more litter during the post-flush period than during the pre-flush period, probably because this species loses its leaves very late in the dry season.

Livestock foraging behaviour

Goats spent significantly more time grazing than they did browsing during both sampling periods (see Table 4). Goats spent significantly more time grazing than did cattle during the post-flush period. The results obtained from the use of the Kruskal-Wallis test should be interpreted with caution, since interactions between non-independent variables, such as "pre-flush" and "post-flush" and between the four behaviours, "grazing", "browsing", "feeding on sisal" and "inactivity" are ignored. These interactions may have produced significant results.

During observations, cattle and goats together spent 82 % of their time in toplands, 15 % in bottomlands and 3 % in drainage line thickets. These values are roughly proportional to the extent of these landscape units in the study area (approximately 65 % toplands, 25 % bottomlands and 10 % drainage line thickets).

There were no significant differences between the utilisation of different landscape units for either cattle or goats, but this is likely to be a function of sample size - bottomlands and drainage line thickets were relatively little utilised, particularly during the post-flush period.

Insert Table 4

Dietary contributions (Tables 5a and 5b) are expressed as percentages of the total diet mass (% mass) of the total observation time (% time). Both cattle and goats fed from a greater number of woody species during the pre-flush period than during the post-flush period. The inaccessible portion of standing woody foliage was large relative to the accessible portion during both sampling periods, indicating that there is potential for increased lopping of foliage by herders. No fruits, flowers or bark were eaten by cattle, but goats ate *M. angolensis* flowers and detached fruits of *S. madagascariensis*. Bark of an unidentified species (fuelwood lying in the lands) was also eaten by a goat.

Insert Tables 5a and 5b

Woody species preference ratios

Preference ratios were not calculated for those woody species for which stem density data were not available; in addition, species which were supplied to livestock by herders were excluded from the preference analysis because their abundance in the study area was not representative of their actual availability to livestock. However, it should be borne in mind that the supply of foliage by herders could have affected food selection by livestock and therefore the preference rankings of other food species.

Insert Table 6

During the pre-flush period, the preferred food plants for cattle were *P. curatellifolia*, followed by grass (Table 6). For goats, *C. aethiopica*, grass and *E. divinorum* were preferred above all other species. For both cattle and goats, combined grass species was the preferred food during the post-flush period. *Parinari curatellifolia* ranked second in preference for goats during this period (Table 6). With the exception of *E. divinorum*, all of the food plants mentioned above had very high preference ratios, indicating that they were relatively rare but palatable to livestock. *E. divinorum* may have been highly preferred by goats during the pre-flush period, but this is not reflected in a high preference ratio for this species, due to its abundance. Similarly, *C. aethiopica* and *P. curatellifolia* appeared to be highly preferred above all other species, but this may be a function of local rarity (< 1 % of accessible standing biomass in the study area) rather than of the high quality of their foliage.

Leaf litter and supplied browse

Leaf litter contributed more to goat diets during the pre-flush period than during the post-flush period, and more to goat diets than to cattle diets during both sampling periods (Table 7). Litter made very little contribution to livestock diets during the post-flush period. The much-utilised litter species are *S. madagascariensis* and *X. zambesiaca*. The low litter biomasses of *S. madagascariensis*, *T. sericea* and *X. zambesiaca* present under canopies during the study indicate that leaf litter of these species may be preferred by livestock when it is available during leaf-fall.

The contribution of supplied browse to livestock diets was highest for cattle during the pre-flush period. In general, supplied browse contributed more to cattle diets than to goat diets, and more during the pre-flush period than during the post-flush period. A greater variety of species were supplied to goats (5 species) than to cattle (3 species), although there were more occurrences of foliage being lopped for cattle than for goats. *Ficus* spp. were frequently supplied to cattle during both sampling periods.

Insert Table 7

Discussion

The contribution of browse to goat and cattle diets during this study is small compared to that found by Rees (1974), Owen-Smith & Cooper (1985, 1987a), Dicko & Sangare (1986), Atta-Krah (1989). The contribution of leaf litter and fruits to livestock diets in this study is low relative to that found by Owen-Smith & Cooper (1985). The reasons for this finding may lie with (a) conditions during the study year, particularly the magnitude and timing of rainfall, the timing of the tree/shrub flush in relation to the grass flush, and the timing of the study after leaf fall and the disappearance of a large proportion of leaf litter; (b) the abundance and quality of the woody plant resource relative to those of the grass resource during the pre-flush and post-flush periods.

Availability and accessibility of browse components

Because the canopies of many woody species were completely out of reach of livestock, a large part of the standing woody foliage resource was inaccessible to livestock. This is, at least in part, due to the active selection of intermediate size classes of trees and shrubs by people harvesting fuelwood (Shackleton 1993), resulting in a high proportion of specimens of these species being concentrated in the very small (recruits) and very large (mature) size classes (personal observations). In addition, a similar minimum canopy height or "browse line" appears among most mature individuals of several woody species in the study area, indicating that livestock feeding has impacted the woody plant resource, reducing the accessible foliage in the study area.

The low biomass of leaf litter present under canopies of most woody plant species during the study indicates that either consumption by livestock since leaf-fall earlier in the dry season or fragmentation by trampling and dispersal by wind had reduced the available litter. Leaf litter appeared to accumulate in depressions in the ground or under low shrub canopies, so the biomass of litter present under woody canopies is probably not representative of the litter biomass available to livestock throughout the study area.

The low contribution of fruits to livestock diets is probably linked to the inaccessibility of attached fruits on mature trees, harvesting by local people and narrowly seasonal fruit yields. Although harvesting of fruit by local people was not observed during the study, fruits harvested in other communal areas of the arid lowveld are *D. mespiliformis*, *E. divinorum*, *F. stuhlmannii*, *P. curatellifolia*, *S. birrea*, *S. madagascariensis* and *S. spinosa* (Liengme 1981). Flowers are similarly seasonal, and can only contribute to livestock diets during brief annual periods.

Browse supplementation in the study area

Herders made an effort to increase the food supply of livestock during both sampling periods. However, it appears that more browse was supplied to cattle than to goats, and that more was supplied during the pre-flush period than during the post-flush period. Woody species most often supplied to livestock were those of which the majority of foliage was out of reach of livestock (eg. *Ficus* spp., *T. emetica* and *X. zambesiaca*). *C. imberbe*, a good fuelwood (Liengme 1981), was probably supplied only in tandem with harvesting for fuelwood or timber.

The impact of browse supplementation by herders on the woody foliage resource is unknown, and is difficult to distinguish from the impact of fuelwood harvesting. The woody species most often cut by herders are concentrated in toplands; species occurring mainly in bottomlands were never cut. Some of these species are unpalatable (e.g. *Euclea* spp. and *M. senegalensis*), and therefore less suitable as fodder supplements for livestock.

The major impact of browse supplementation is presently concentrated in toplands, although the extent of harvesting by herders is low (relative to standing leaf biomass). Although an increase in the extent of woody foliage harvesting by herders may exacerbate this impact, harvesting of preferred species, in addition to the species already being harvested, may provide a short-term solution to the problem of livestock survival through the dry season.

Quality of the woody plant resource

Several evergreen woody species in the study area (*L. camara* - van Wyk & Malan 1988, some *Euclea* spp. and *some Maytenus* spp. - Owen-Smith & Cooper 1987b) are unpalatable or toxic. *E. divinorum* and *M. senegalensis* were eaten mainly during the pre-flush period, and only a very small proportion of the available standing foliage was consumed.

Foliage of woody species of the family Caesalpiniaceae, which is important to browsing ungulates in other parts of Africa, such as Zambia (Rees 1974), Nigeria and the Sudan (Atta-Krah 1989), was not a major part of livestock diets in this study. In Zambia, the mainly leguminous woody species of miombo woodland begin to flush in July, towards the middle of the dry season (Rees 1974), and thus provide protein-rich young leaves throughout the late dry season and early wet season period. In contrast, many leguminous species in the study area are deciduous and thus are unavailable during the dry season (*Acacia* spp., *D. cinerea*) except *P. angolensis*, of which small specimens tended to flush early (personal observations). Also, *Acacia* spp., *D. cinerea* and other thorny tree and shrub species in the study area seem to be heavily harvested for the construction of barriers around kraals and cultivated lands, so their contribution to livestock diets may be limited, even during the wet season, by the number of stems available.

The concentration of livestock feeding in toplands is probably due to the greater abundance of grass there. However, since the grass in the study area is of low quality, the high contribution of grass to livestock diets during the periods covered by this study is probably due to the low quality and abundance (due to inaccessibility) of woody foliage, rather than to the quality and abundance of the grass. The higher contribution of grass to livestock diets during the post-flush period than the pre-flush period indicates that the newly-flushed grass was nutritionally valuable to the livestock. From the preference ratios, it appears that, during the post-flush period, grass was preferred above foliage of all woody plant species and that the pre-flush (i.e. dormant) grass was not preferred. However, this interpretation requires that the estimates of accessible fractions for woody species are accurate, and that all grass material above stubble height is accessible to grazing livestock. *E. divinorum* was third in preference for goats during the pre-flush period, suggesting that this woody species may act as a dry season reserve food species for goats as it does for kudu (Owen-Smith & Cooper 1987b).

Timing of the grass flush and the woody flush

The year in which the study took place had been preceded by the worst drought at least since 1968 (Shackleton pers. comm.). The late tree/shrub flush in relation to the grass flush, may be due to low soil moisture carried over from the previous drought year. According to Shackleton (pers. comm.), woody plants usually flush before the grass in the study area. In other years, the woody plant flush may begin in response to increased temperatures during the early summer months, if the soil moisture remaining from the previous wet season is sufficient to sustain the early flush (Tinley 1982, Chidumayo 1992). Thus, during the wet season following a drought, early, light rains may be sufficient to stimulate the grass flush, while the woody flush is delayed until the onset of heavy rains.

The lag period between the grass flush and the tree/shrub flush during the study period raises an important question: Was the timing of the flushes during the study year usual for the study area? If so, then an earlier tree/shrub flush and, consequently, higher browse contributions could be expected in years when the rains begin early or following high rainfall years.

Limited browse use by livestock would result in a reliance upon food supplementation with concentrates or with foliage harvested from roadsides and other protected areas. These solutions are likely to be more expensive and therefore less accessible to the rural farmers in the study area.

Solutions to limitations on browse supply in the study area

Livestock in the study area, particularly cattle, appeared to undergo severe nutrient deficiency during both study periods (personal observations), and some herders reported that the mortality of cattle during the current dry season had been as high as 75 %. This mortality rate was probably a combined result of the preceding severe drought year and the very late onset of rains during the study year. In the context of the low quality and abundance of woody foliage in the study area, a number of solutions to limitations on woody foliage supply can be identified.

(a) Increasing browse supplementation through lopping by herders. Since several woody plant species were preferred to grass during the pre-flush period, it is clear that the grass is either of such low abundance or of so little nutritional value to livestock during this period, that browsing, even on relatively unpalatable plants (such as *E. divinorum*) is preferred. Increased supplementation of livestock diets through lopping of palatable or preferred woody species by herders would thus have a beneficial effect during this period. The impact of this solution on the woody foliage supply in the study area would have to be carefully monitored in relation to the impacts of other practices such as the harvesting of fuelwood, construction timber and carving materials. Browse supplementation could be used in conjunction with fuelwood harvesting, so that foliage lopped at the same time as livewood could be stripped and left in the lands as fodder for livestock. Most branches seen being lopped by herders were later removed and presumably used as fuelwood.

The potential for lopping to contribute to the diets of livestock during the post-flush period is certainly lower than it is during the pre-flush period, due to the greater palatability of the newly-flushed grass. More than 80% of foliage in the study area is woody foliage, and much of it is inaccessible to livestock, so, in the absence of severe depletion of the woody foliage resource, increased lopping should be encouraged throughout the dry season and early wet season.

(b) Collection and storage of leaf litter from leaf-fall until it is required by livestock later in the dry season. This is a potentially valuable way of improving livestock productivity (in terms of gain in live mass - Devendra 1989) during the dry season. Leaf litter could be collected in litter baskets placed under tree canopies at the commencement of leaf fall and stored until the late dry season, to be fed to livestock in night enclosures. The much-utilised litter species appear to be *S. madagascariensis*, *T. sericea* and *X. zambesiaca*. For *D. mespiliformis*, an abundant litter species, leaf-fall occurs late in the dry season; this litter could be left on the ground for consumption, collected and fed to livestock in night enclosures or stored until the following dry season.

(c) Minimising impact on the woody plant resource from other local uses (harvesting fuelwood, construction materials) may increase both the maximum standing leaf biomass during the wet season and the available woody foliage fraction during the dry season. This fraction is important for browse supplementation. However, this may not be a sustainable practice in view of the needs of local people.

(d) The establishment of woodlots of leguminous trees. Livestock productivity and survival during the dry season could be increased through browse supplementation using evergreen woody trees and shrubs which have been cultivated for this purpose. Fast-growing exotic species such as *Leucaena leucocephala* could be introduced, in a controlled programme, for this purpose.

(e) Use of chemical browse supplements which improve the palatability of woody foliage. Such a measure may result in higher stocking densities in the study area, as well as higher impact levels on both the grass and browse resources of the area, and would have to be carefully researched and planned prior to its implementation.

Conclusion

While browse makes an important contribution to livestock diets during the late dry season, grass forms the bulk of the diet and feeding is concentrated in toplands where most grass is available. With the onset of the grass flush, both livestock species turn almost entirely to grazing, indicating that the grass is sufficiently nutritious to make browsing almost unnecessary.

During this study goats fed more selectively, utilised newly flushed foliage more and fed upon a greater variety of woody plant species than did cattle. The goats observed during this study appeared to be in better condition than the cattle observed, and, although they were less often supplied with tree leaves, browse contributed more to their diets than to cattle diets. The relatively low contribution of browse to livestock diets during this study is explained by the scarcity of accessible, palatable forage, exacerbated by the late flush on woody plants, in conjunction with the modified size class distributions of some important food species.

Browse supplementation by herders has the potential to increase the fraction of the available leaf biomass which is accessible to livestock. Other mechanisms of improving browse supply include storage of woody foliage litter until the late dry season, use of chemicals to increase the nutritional value to livestock of poor quality browse and the establishment of woodlots of palatable, perhaps leguminous, evergreen woody species for use as livestock fodder.

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Table 1. Mean cover, grass biomass and biomass concentration in each landscape unit. (Entries with the same superscript are significantly different from one another.)

Landscape unit	Mean aerial cover (% ± SE; n = 125)	Mean biomass ($kgDM.ha^{-1}$ ± SE; n = 25)	Mean biomass concentration ($gDM.m^{-3}$ ± SE; n = 25)
		Pre-flush	
Bottomlands	15 ± 1^{a}	63.8 ± 13^{c}	290 ± 60
Drainage line thickets	$10 \pm 1^{a,b}$	74.0 ± 15^{d}	250 ± 50
Toplands	20 ± 2^{b}	$118.9 \pm 24^{c,d,f}$	555 ± 100
		Post-flush	
Bottomlands	5 ± 0.4^{e}	41.9 ± 8	210 ± 40
Drainage line thickets	10 ± 1	103.4 ± 21	305 ± 60
Toplands	15 ± 1^{e}	64.2 ± 13^{f}	310 ± 60

Table 2. Maximum standing leaf biomass (wet season) and accessible standing leaf biomass during the pre-flush and post-flush periods, for woody species. (Stem densities from Shackleton (1993); maximum standing leaf biomass is derived from the regression relation for stem circumference on standing leaf biomass in Barnes *et al.* (1976).)

Woody species	Standing foliage biomass (wet season max, kgDM.ha^{-1})	Density (stems.ha^{-1})	Accessible standing leaf biomass (kgDM.ha^{-1})	
			Pre-flush	Post-flush
Terminalia sericea	664.6	2980.7	0	132.9
Maytenus senegalensis	117.0	566.9	117.0	117.0
Sclerocarya birrea	100.6	41.9	0	0
Lantana camara	85.5	380.7	64.1	64.1
Dichrostachys cinerea	49.4	246.3	0	0
Pterocarpus angolensis	43.0	4.4	0	4.3
Cassia petersiana	29.5	156.3	0	29.5
Lonchocarpus capassa	23.5	43.2	0	11.8
Peltophorum africanum	22.4	105.6	0	0
Diospyros mespiliformis	21.5	39.4	10.8	0
Ehretia amoena	13.6	64.4	0	6.8
Euclea divinorum	12.2	53.8	6.1	6.1
Combretum collinum	12.2	33.2	0	1.2
Euclea natalensis	12.0	57.5	9.0	9.0
Combretum imberbe	11.8	26.9	0	1.2
Ficus stuhlmannii	11.0	3.8	0	0
Acacia nilotica	10.3	45.0	0	0
Strychnos spinosa	9.6	15.0	0	0
Strychnos madagascariensis	6.5	35.7	0	0.7
Combretum hereroense	2.2	10.0	0	1.2
Parinari curatellifolia	1.9	8.8	0.2	0.2
Cassine transvaalensis	0.9	5.0	0.9	0.9
Cassine aethiopica	0.7	3.1	0.7	0.7
Gardenia volkensii	0.3	1.3	0	0.2
Carissa edulus	0.2	1.3	0	0.2
Total	1262.4	4839.7	208.8	388.0

Table 3. Biomass of leaf litter of various tree and shrub species under canopies of the same species in the study area. (Entries with the same superscript are significantly different from one another.)

Woody species	Litter biomass under canopies (kgDM.ha^{-1} ± SE)	
	Pre-flush	Post-flush
Maytenus senegalensis	355 ± 112 (n = 10)	82 ± 26 (n = 10)
Sclerocarya birrea	238 ± 84^a (n = 8)	83 ± 26^a (n = 10)
Diospyros mespiliformes	205 ± 72 (n = 8)	256 ± 81 (n = 10)
Terminalia sericea	148 ± 52^b (n = 8)	50 ± 16^b (n = 10)
Strychnos madagascariensis	120 ± 38 (n = 10)	92 ± 29 (n = 10)
Total	1066 ± 31 (n = 44)	563 ± 16 (n = 50)

Table 4. Proportion of observation time spent in each of four activity categories by cattle and goats, expressed as a percentage of observation time. "n" refers to the number of sampling bouts taken. (Entries with the same superscript are significantly different from one another.)

Activity	Percentage of observation time			
	Pre-flush		Post-flush	
	Cattle (n=60)	Goats (n=50)	Cattle (n=61)	Goats (n=50)
Grazing	71.4 ± 9.2	62.0 ± 8.8[a]	83.8 ± 10.7[b]	86.4 ± 12.2[b,c]
Browsing	14.7 ± 1.9	34.7 ± 7.1[a]	5.8 ± 0.7	8.3 ± 1.2[c]
Feeding on sisal	9.4 ± 1.2	0.3 ± 0	5.9 ± 0.8	0
Inactivity	4.5 ± 0.6	3.0 ± 0.4	4.5 ± 0.6	5.3 ± 0.7

Table 5a. Contributions of grass, sisal and woody species to cattle diets.

Species eaten	Pre-flush		Post-flush	
	Time (%)	Mass (%)	Time (%)	Mass (%)
	Dietary contribution			
Grass	74.8	65.6	87.8	94.2
Sisal	9.8	13.3	6.2	2.0
C. aethiopica	<0.1	<0.1	0	0
D. mespiliformis	0.3	0.6	<0.1	<0.1
F. stuhlmannii	8.6	13.1	<0.1	0.2
F. thonningii	3.5	2.4	0	0
M. senegalensis	0.6	0.9	0.9	0.8
P. curatellifolia	1.0	1.3	0	0
S. birrea	1.6	0.3	0	0
S. madagascariensis	0.1	0.3	0	0
S. spinosa	0.3	0.1	0	0
T. emetica	1.5	0.1	0	0
T. sericea	0.1	0.2	0	0
X. zambesiaca	2.0	4.4	0	0
Forbs	0.8	-	0	0

Table 5b. Contributions of grass, sisal and woody species to goat diets.

Species eaten	Pre-flush		Post-flush	
	Time (%)	Mass (%)	Time (%)	Mass (%)
	Dietary contribution			
Grass	63.9	74.9	91.2	90.4
Sisal	0.3	0.6	0	0
A. gerrardii	0	0	0.2	<0.1
A. swazica	0	0	<0.01	<0.1
C. aethiopica	0.8	0.9	0	0
C. bispinosa	0.9	0.2	0	0
C. collinum	0	0	<0.1	0.1
C. hereroense	0.7	1.0	0	0
C. imberbe	2.3	2.0	0	0
D. cinerea	0.2	0.1	0	0
D. mespiliformis	2.6	2.1	0.1	0.1
E. divinorum	1.7	1.3	0	0
E. natalensis	<0.1	0.1	0	0
F. stuhlmannii	<0.1	0.2	1.5	2.8
F. thonningii	0.1	0.2	1.6	2.5
M. angolensis	5.2	0	0	0
M. senegalensis	1.0	1.0	0.2	0.1
P. angolensis	4.2	3.0	0	0
P. africanum	0.1	0.2	0	0
P. curatellifolia	<0.1	<0.1	0.1	0.2
S. birrea	0.2	0.1	0	0
S. madagascariensis	4.1	3.1	0.1	0.1
S spinosa	0.6	0.3	0	0
T. sericea	0.1	0.1	4.0	3.8
X. zambesiaca	9.3	8.6	0.2	0.1
Forbs	<0.1	-	0	0
Unidentified	1.4	-	0.8	-

Table 6. Preference ratios of grass and woody food species for cattle and goats during the pre-flush and post-flush periods.

Species eaten	Pre-flush			Post-flush		
	Foliage biomass (%)	Dietary contribution (% mass)	Preference ratio	Foliage biomass (%)	Dietary contribution (% mass)	Preference ratio
Cattle						
All grasses	6.3	95.3	13.1	4.6	96.8	20.6
T. sericea	10.9	0.2	<0.05	18.4	2.1	0.1
M. senegalensis	34.7	1.0	<0.05	31.0	0.8	<0.1
P. curatellifolia	0.0	1.5	88.4	0.0	0	0
S. birrea	17.5	0	0	15.6	0.3	<0.1
D. mespiliformis	15.9	0.7	<0.05	13.4	0	0
S. madagascariensis	8.8	0.3	<0.05	7.9	0	0
Goats						
Grass	6.3	83.0	11.9	4.6	95.4	19.7
T. sericea	10.9	0.1	<0.05	18.4	4.0	0.2
M. senegalensis	34.7	1.1	<0.05	31.0	0.1	<0.1
S. birrea	17.5	0.1	<0.05	15.6	0	0
D. mespiliformis	15.9	2.3	0.5	13.4	0.1	<0.1
E. divinorum	0.4	1.4	2.9	0.4	0	0
C. collinum	0.0	0	ERR	0.1	0.1	1.3
E. natalensis	0.7	0.1	0.2	0.6	0	0
S. madagascariensis	8.8	3.4	0.4	7.9	0.1	<0.1
P. curatellifolia	0.0	0	0	0.0	0.2	15.2
C. aethiopica	0.1	1.0	17.5	0.0	0	0

Table 7. Dietary contributions of litter and supplied browse as percentages of observation time and total diet mass for cattle and goats.

Species eaten	Food category	Pre-flush		Post-flush	
		Time (%)	Mass (%)	Time (%)	Mass (%)
	Dietary contribution for cattle				
X. zambesiaca	litter	1.9	4.4	0	0
D. mespiliformis	litter	0.2	0.6	0	0
S. madagascariensis	litter	0.2	0.3	0	0
T. sericea	litter	0.1	0.2	0	0
Total	litter	2.4	5.5	0	0
F. stuhlmannii	supplied	8.6	13.1	0	0
T. emetica	supplied	1.5	0.1	0	0
F. thonningii	supplied	0	0	3.5	2.4
Total	supplied	10.2	13.2	3.5	2.4
	Dietary contribution for goats				
X. zambesiaca	litter	7.0	7.3	0.2	0.1
S. madagascariensis	litter	3.2	2.8	0	0
P. angolensis	litter	1.9	1.3	0	0
C. imberbe	litter	0.8	0.4	0	0
E. divinorum	litter	0.6	0.8	0	0
S. spinosa	litter	0.5	0.3	0	0
S. birrea	litter	0.2	0.1	0	0
F. thonningii	litter	0.1	0.2	1.0	1.8
D. mespiliformis	litter	0	0	0	0
Total	litter	14.3	13.2	1.2	1.9
X. zambesiaca	supplied	2.6	1.4	0	0
C. imberbe	supplied	1.0	1.2	0	0
F. stuhlmannii	supplied	0	0.2	0.9	0.9
F. thonningii	supplied	0	0	0.6	0.6
P. curatellifolia	supplied	0	0	0.1	0.2
Total	supplied	3.6	2.7	1.6	1.7

Appendix

Table A: Derivation of dietary contribution by mass from observations on cattle and goats during the sampling periods. (Bite mass is the product of the estimated number of leaves per bite and leaf mass as determined during this study and from Cooper (1985). "Unidentified" refers to woody plants which were unidentified. * Denotes mean leaf mass values from Cooper 1985.)

Species eaten	Feeding time (s)	Dietary contribution (% time)	No. bites taken	No. leaves per bite	Mean leaf mass (g)	Mean bite size (g)	Mass eaten (g)	Dietary contribution (% mass)
				Cattle				
				Pre-flush				
All grasses	34153	74.8	13971	>1	-	0.1	1397	66
Sisal	4474	9.8	142	<1	-	2	284	13
C. aethiopica	14	0	5	3	0.06*	0.18	1	<1
D. mespiliformis	139	0.3	55	2	0.12	0.24	13	1
F. stuhlmannii	3913	8.6	386	6	0.12	0.72	278	13
M. senegalensis	278	0.6	67	3	0.09	0.28	19	1
P. curatellifolia	462	1.0	57	4	0.12	0.48	27	1
S. madagascariensis	68	0.1	30	3	0.07	0.22	7	<1
S. spinosa	132	0.3	8	3	0.07	0.22	2	<1
T. emetica	684	1.5	6	3	0.12	0.36	2	<1
T. sericea	40	0.1	20	3	0.08	0.24	5	<1
X. zambesiaca	925	2.0	396	3	0.08	0.24	94	4
Forbs	367	0.8	1	-	-	-	-	-
				Post-flush				
Grass	44371	87.8	27804	>1	-	0.1	2780	94
Sisal	3119	6.2	30	<1	-	2	60	2
D. mespiliformis	21	0	5	2	0.12	0.24	1	<1
F. stuhlmannii	25	0	9	6	0.12	0.72	6	<1
F. thonningii	1787	3.5	99	6	0.12	0.72	71	2
M. senegalensis	430	0.9	84	3	0.09	0.28	24	1
S. birrea	809	1.6	50	2	0.08	0.16	8	<1
Forbs	0	0	0	-	-	-	-	-
Unidentified	0	0	0	-	-	-	-	-

				Goats				
				Pre-flush				
Grass	21669	62.0	8902	>1	-	0.1	890	75
Sisal	109	0.3	7	<1	-	1	7	1
C. aethiopica	273	0.8	113	1.5	0.06*	0.09	10	1
C. bispinosa	295	0.8	73	1	0.03*	0.03	2	<1
C. hereroense	229	0.7	104	4	0.03*	0.12	12	1
C. imberbe	796	2.3	202	4	0.03*	0.12	24	2
D. cinerea	80	0.2	15	0.5	0.12*	0.06	1	<1
D. mespiliformis	895	2.6	203	1	0.12	0.12	24	2
E. divinorum	570	1.6	86	1	0.18*	0.18	15	1
E. natalensis	14	0	4	1	0.18*	0.18	1	<1
F. stuhlmannii	5	0	5	3	0.12	0.36	2	<1
F. thonningii	37	0.1	12	2	0.12	0.24	3	<1
M. angolensis	1765	5.0	583	-	-	flowers	-	-
M. senegalensis	336	1.0	130	1	0.09	0.09	12	1
P. angolensis	1421	4.0	225	2	0.08	0.16	36	3
P. africanum	48	0.1	4	1	0.51*	0.51	2	<1
P. curatellifolia	9	0	2	2	0.12	0.24	0	<1
S. birrea	57	0.2	16	1	0.08	0.08	1	<1
S. madagascariensis	1395	4.0	495	1	0.07	0.07	37	3
S. spinosa	213	0.6	45	1	0.07	0.07	3	<1
T. sericea	21	0	9	2	0.08	0.16	1	<1
X. zambesiaca	3167	9.0	1297	1	0.08	0.08	103	9
Forbs	11	0	3	-	-	-	-	-
Unidentified	491	1.4	7	-	-	-	-	-
				Post-flush				
Grass	34744	86.3	21963	>1	-	0.1	2196	90
A. gerrardii	65	0.2	23	1	0.04*	0.04	1	<1
A. swazica	9	0	6	1	0.04*	0.04	0	<1
C. collinum	4	0	4	3	0.12	0.36	1	<1
D. mespiliformis	30	0	17	1	0.12	0.12	2	<1
F. stuhlmannii	585	1.5	187	3	0.12	0.36	67	3
F. thonningii	597	1.5	251	2	0.12	0.24	60	2
M. senegalensis	80	0.2	22	1	0.09	0.09	2	<1
P. curatellifolia	45	0.1	20	2	0.12	0.24	5	<1
S. madagascariensis	42	0.1	24	1	0.07	0.07	2	<1
T. sericea	1524	3.8	570	2	0.08	0.16	91	4
X. zambesiaca	70	0.2	24	1	0.08	0.08	2	<1
Unidentified	304	0.8	111	-	-	-	-	-