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Acacia tortilis subsp. *heteracantha* productivity in the Tugela Dry Valley Bushveld: preliminary results

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ABSTRACT

Acacia tortilis Hayne subsp. *heteracantha* (Burch.) Brenan dominates secondary succession in the Tugela Dry Valley Bushveld of the Natal midlands. The parts of KwaZulu in this veld type are impoverished, overpopulated and over-grazed. Preliminary results indicate that at a density of 2 700 ± 600 trees/ha there is a standing crop of c.2,87 t/ha (DM) of acacia twigs suitable for hand pruning and milling into fodder, but that this is a costly process. Herbage biomass peaked at 0,73 t/ha (DM). Veld condition assessments suggested a stocking rate of|0,1 AU/ha (grazers), but actual grazer stocking rates may be many times this density. It is recommended that the browser/grazer ratio be altered to make use of the c. 1,05 t/ha (DM) of shoot growth produced annually by *A. tortilis* subsp. *heteracantha*.

RÉSUMÉ

*LA PRODUCTIVITÉ DE L'*ACACIA TORTILIS *SUBSP.* HÉTÉRACANTHA *DANS LE BUSHVELD DE LA VALLÉE SÈCHE DE LA TUGELA: RESULTATS PRÉLIMINAIRES*

L'Acacia tortilis *Hayne subsp.* heteracantha *(Burch.) Brenan, domine dans la succession secondaire dans le bushveld de la valée sèche de la Tugela dans les Midlands au Natal. Les zones du KwaZulu dans ce type de veld sont appauvries par la surpopulation et le pâturage intensif. Des résultats préliminaires indiquent qu'à une densité de 2 700 ± 600 arbres/ha, il y a une récolte sur pied de c. 2,87 t/ha matière sèche de rameaux d'acacia susceptibles d'être taillés manuellement et broyés en fourrage, mais ceci est un procédé coûteux. La bio-masse d'herbage a son optimum à 0,73 t/ha. Des estimations du rendement du veld ont suggéré une densité de cheptel de 1 animal broutant par 10 ha, alors que les densités du cheptel paîssant actuellement peuvent être largement supérieures. Il est recommandé que le rapport broutage des rameaux/broutage de l'herbe soit modifié afin d'utiliser les c. 1,05 t/ha de jeunes rameaux produits annuellement par* A. tortilis *subsp.* heteracantha.

INTRODUCTION

This paper presents preliminary findings of a study of the productivity of *Acacia tortilis* Hayne subsp. *heteracantha* (Burch.) Brenan relative to that of the herbage at contrasting sites in secondary acacia veld in Bioclimatic Zone 10 of Natal (Phillips, 1967). The aim of the study is to assess the carrying capacity of the veld for browsers and grazers in order to maximize production and minimize environmental degradation.

Study species

Acacia tortilis (Forsk.) Hayne, a flat-topped thorn tree with indehiscent, coiled pods, is widely distributed in the drier parts of Africa — from the northern Cape and Natal to Arabia (Ross, 1975). Subspecies *heteracantha* (Burch.) Brenan, the subject of this study, occurs throughout the interior of Natal and indeed throughout most of southern Africa. Its basionym is *A. heteracantha* Burch., and synonyms are *A. litakunensis* Burch., *A. spirocarpoides* Engl. and *A. maras* Engl.

Study area

All data presented in this study were collected on a farm on the Weenen-Msinga border (Fig. 1), 26 km upstream from Tugela Ferry, but the study will be extended to other areas of *A. tortilis* subsp. *heteracantha* semi-deciduous bush, where this occurs as a secondary community in Tugela Dry Valley Bushveld (Edwards, 1967).

This type of vegetation falls within Bioclimatic Group 10 (Phillips, 1973), which Thorrington-Smith *et al.*, (1978) describe as having low agricultural potential, and as being overstocked, denuded and eroded, with spectacular bush encroachment. The topography is broken with many stoney hills. Temperatures are extreme with frost in winter and a mean daily summer maximum of 30°C. Rainfall is low (637 mm), unreliable, and generally accompanied by electric storms (Edwards, 1967; West, 1950).

The population density of Bioclimatic Zone 10 of KwaZulu is given as 50 people/km² (Thorrington-Smith *et al.*, 1978), but hut counts suggest that it may be higher (Schulze, 1969). Topographic factors and resettlement schemes have resulted in areas of locally high population density, and the environmental degradation in the vicinity of these is severe and is characterized by vegetation destruction, dongas and drying up of springs. As Thorrington-Smith *et al.* (1978) point out, cultivation without irrigation is hazardous, so much of the money and food required is brought in from the cities or irrigated white farms, thereby artificially boosting the carrying capacity. Livestock, particularly cattle, are cherished as insurance to be sold in times of dire need or to be sacrificed on special occasions. Tribal land is common land exploited by all to provide fuel, grazing and building materials, but where carrying capacity has been exceeded the "system of the commons is absolutely intolerable" and the environment is degraded, further reducing carrying capacity (Hardin, 1977).

Secondary acacia communities are the product of ploughing, over grazing or other forms of disturbance (Edwards, 1967; West, 1950). Under heavy

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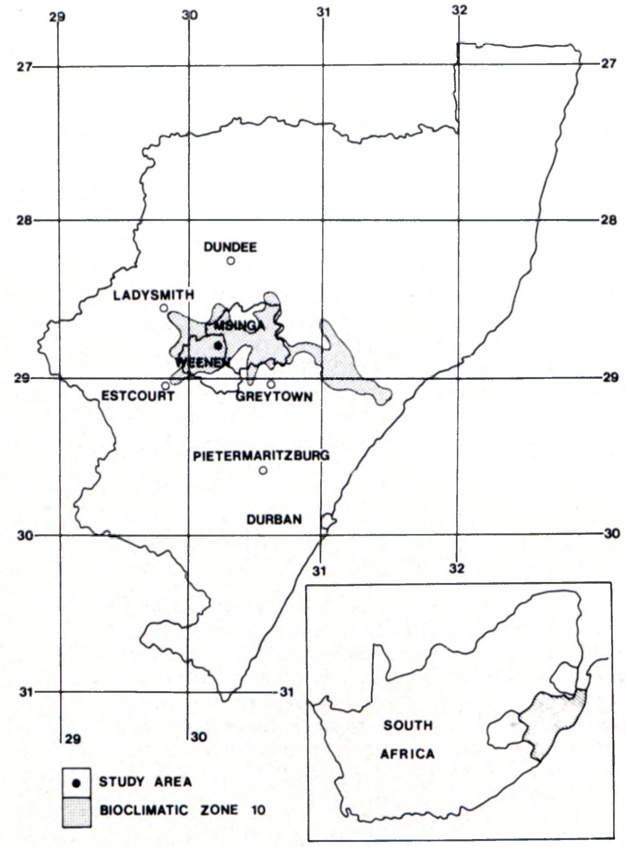

FIG. 1.—Study area in relation to the Weenen and Msinga Districts, and the distribution of Bioclimatic Zone 10 in the Tugela Valley. Inset: South Africa, Natal Province shaded.

grazing such bush lands deteriorate rapidly and become more woody or eroded (Kelly & Walker, 1976; Whyte, 1947). Removal of thorn trees would be not only costly and difficult to implement, but would deprive local people of 'free' fuel and fencing. As browse appears to be under-utilized and herbage over-utilized in semi-arid rangelands (Whyte, 1947; Trollope, 1975; Kelly, 1977) it may be cheaper, more acceptable and more productive to alter the grazer-browser ratio.

METHODS

Density, biomass and production of A. tortilis *subsp.* heteracantha

Density was estimated from stem and tree (stems joined on or below ground level) counts on 80 10 × 10 m plots distributed over five sites. Stem diameter, referred to as basal diameter in this paper, was measured approximately 20 cm above soil level. To estimate the standing crop of biomass available for milling into fodder, trees were pruned with long handled shears, and the shorn shoots (approximately 1 cm diam.) of individual trees at sites 2, 4, 5, 6 and whole plots at sites 1 & 3 were weighed in the field using a spring balance. Two methods were used to estimate annual production. Firstly, all the new season's twigs were measured, counted and clipped from 9 trees of known diameter, then weighed. Secondly, 10 new season's twigs from each of 10 trees were measured. The number of twigs per branch approximately 2,2 cm diam. was recorded, as was the number of such branches per tree of known diameter. Total twig mass was estimated from total length. This method was also used when comparing the growth of pruned and unpruned trees, and of trees of different ages.

The pod crops of 64 measured trees were weighed in the field, and podbearing trees counted in two quarter hectare quadrats. To obtain diameter-mass regressions, 68 trees were felled at site 6. Diameters were measured and prunable twigs and wood weighed separately in the field. The leaf dry mass/pruned branch fresh mass ratio from site 1 was used to provide a rough estimate of dry leaf yield per unit area. Leaf production and retention data are based on counts of leaves on the terminal 10 cm of new seasons shoots.

Herbage composition, utilization, cover and biomass

Species composition at two sites was assessed using the step-point method (Mentis, in press) and data obtained were used to estimate veld condition (Tainton *et al.*, 1980) and utilization ratios for each species:

utilization ratio = % use / % occurrence

where use is evidence of grazing. Cover at these sites was measured at two monthly intervals using a 100 point grid half a metre square. Ten 1/4 m^2 plots per 1/4 ha quadrat were then clipped, oven dried and weighed to obtain a grid number/mass relationship. The grid was also used when comparing herbage cover beneath acacia canopies with that in the open. At site 6 where shrubby forbs prevented the use of the grid, a perforated horizontal bar was used to assess cover.

RESULTS AND DISCUSSION

Acacia density, prunable biomass and production

Tree densities are similar to those of *A. karroo* Hayne in the Valley Bushveld of the Eastern Cape (Aucamp, 1976) and semi-arid mopane in Zimbabwe (Kelly & Walker, 1976). 4,56–6,84 t/ha (FM) of branches suitable for milling into bush 'hay', are available for hand pruning (Table 1. At site 6, where canopies would have been out of reach, 16,6 t/ha of such branches were harvested when the trees were felled. The relationship between basal diameter and harvestable shoot fresh mass was as follows:- log

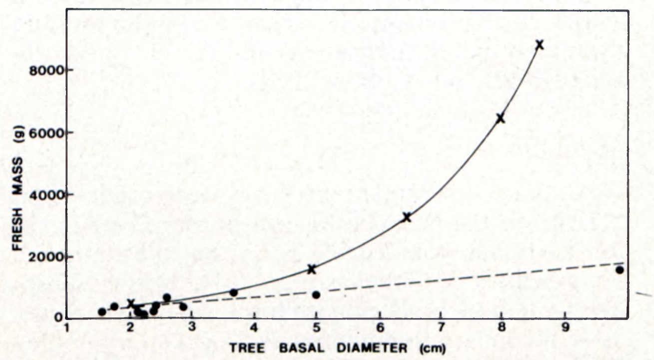

FIG. 2.—Tree diameters related to pruning biomass and annual shoot production: —×—, pruning yield at Site 6 (g FM) relative to diameter (cm) log mass −2,24 + 0,17 diameter; r − 0,845; n−68; - -●- -, annual shoot production of individual trees (g FM), curve fitted by eye.

TABLE 1.—Harvestable *Acacia* biomass and shoot production

Site description no & appearance	Stem diam. cm	Tree density no/ha	Prune biomass kg/ha(FM)	Production * kg/ha/yr(FM)
1 dense, 1 m regen.	2,0(0,1)	4428(703)	4896(672)	2670 −1328
2 dense, 1,5 m	2,9(0,1)	2533(149)	6844(609)	2507
3 open, 1−2,5 m	4,0(0,4)	1460(300)	4560(930)	1368−876
4 thicket, 2 m	5,1(0,3)	2416(217)	6547 −	1933
5 as above	5,4(1,8)	"	5798 −	2114
6 closed, 3 m	6,6(0,3)	1667(312)	16576(3251)	3889

* Rough estimate based on mass derived from eye fitted curve (Fig 2) and stem density (not shown).

mass (g) = 2,42 + 0,17 basal diam. (cm); r = 0,848; n = 55 (Fig. 2).

Assuming a 50% moisture content, the rough estimate of annual shoot production (Table 1) is comparable with that of semi-arid Mopane-veld: 594−2 121 kg/ha/yr DM (Kelly & Walker, 1976) and central African savanna: 1 500 kg/ha/yr DM (Trollope, 1981)., however, it is low when compared to the 5 000 kg/ha/yr available to giraffe in the mixed *Acacia* veld of Serengetti (Felker, 1981).

The effects of pruning, size-class and species on shoot growth

Pruned trees tended to produce longer and more branched shoots with greater diameters than unpruned trees, and this trend was more marked under heavy pruning than under light pruning (Table 2). The most dramatic differences were in mean shoot length at Site 1 ($F_{1,46}$ = 8, 6; P = 0,01), and in stem diameter at Site 3 ($F_{1,23}$ = 9,2; p = 0,01). As fewer shoots were produced by pruned trees, the total shoot length per branch c. 2,2 cm diam. was only marginally greater in pruned than in unpruned trees ($F_{1,22}$ = 2,9; P= 0,2).

Young trees (2,1−2,9 cm diam.) at Site 1 produced longer, plumper and more highly branched shoots than did the older trees (4,9−5,3 cm diam.) at Site 3. The difference in lateral shoot number was most significant: ($F_{1,64}$ = 9,9: P = 0,01). *A. karroo* reacted to pruning in the same way as *A. tortilis* subsp. *heteracantha* but produced shorter, less branched shoots than the latter (Table 2). The difference in lateral shoot number between the two species was greater under heavy pruning ($F_{1,55}$ = 12,4: P = 0,01).

Site 1 yielded 62,8 (19,4)% of the initial prune mass when repruned 10 months later. Heavily pruned plots at Site 3 yielded 20,5 (0,5)%, and lightly pruned plots 11,8 (0,2)% of the original harvest mass at the second prune. These data suggest that the smaller diameter classes have a more rapid recovery rate.

Leaf production and loss

During the summer the density of leaves on new seasons twigs is 1,84 (0,1) leaves/cm. Production of leaves is not significantly affected by pruning, but leaf retention during winter is influenced by site

TABLE 2.—Pruning, size-class and species effects on shoot growth

Acacia tortilis subsp. *heteracantha*	Treatments; mean (SEM)*				
Plot	3	3	3	1	1
Pruning intensity	control	light	heavy	light	heavy
Tree diameter (cm)	*5,0(0,4)*	*4,9(0,3)*	*5,3(0,4)*	*2,9(0,2)*	*2,1(0,1)*
mean shoot length (cm)	24(3)	48(6)	71(4)	88(19)	130(20)
no. laterals/shoot	0,6(0,2)	1,9(0,3)	2,6(0,8)	5,4(0,9)	10,1(0,6)
shoot diameter (cm)	0,4(0,01)	*0,5(0,02)*	*0,5(0,03)*	*0,6(0,01)*	*0,7(0,05)*
no. shoots/branch	*33(7)*	*30(1)*	24(4)	--	--
shoot length/branch (cm)	860(30)	*1480(24)*	*1730(250)*	--	--
Acacia karroo					
mean shoot length (cm)	--	--	--	*61(11)*	*73(9)*
no. laterals/shoot	--	--	--	2,2(0,6)	3,6(0,3)

*Pairs of results which do not differ significantly are italicized.

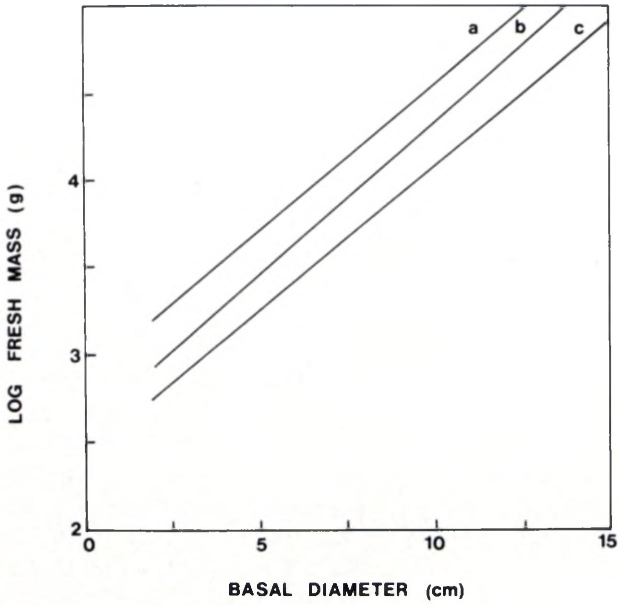

FIG. 3.—Basal diameter (cm)-fresh mass (g) relationships (Site 6): a, total biomass — n = 54, r = 0,891, log y = 2,85 + 0,17 x; b, wood mass — n = 57, r = 0,899, log y = 2,56 + 0,18 x; c, pruned shoots — n = 55, r = 0,845, log y = 2,42 + 0,17 x.

($F_{3,347}$ = 11,7; P = 0,001), pruning ($F_{1,238}$ = 6,8; P = 0,01), and among pruned trees, by tree diameter class ($F_{2,117}$ = 4,4: P = 0,05).

Soil moisture during the dry season appears to be the major site factor affecting leaf retention. In July, leaf retention of trees growing on the banks of the Tugela was c. 71% of the summer density at this site, 20 m above the Tugela 57% of the leaves were retained, 200 m above the Tugela on old fields, 30% and on very shallow soils at this altitude, 10% *A. tortilis* subsp. *heteracantha* trees are often leafless on higher, drier ground during the winter, and it is possible that frost also affects leaf attention.

The ratio of pruned branch fresh mass to air-dry leaf mass was 1: 0,052. Sites 1–5 would therefore yield 237–355 kg/ha air dry leaves.

Basal diameter/mass relationships and size-class distribution

An old *A. tortilis* subsp. *heteracantha* stand with a closed canopy had a wood crop of 23,2 (5,9) t/ha (FM) as compared with the 58–76 t/ha (FM) wood crop of 12 year old *A. tortilis* subsp. *heteracantha* trees of a north African subspecies growing in plantations in India (Muthana & Arora, 1980).

Weed, pruneable branch and total tree fresh mass increase logarithmically on basal diameter (Fig. 3). The wood yield of a self-established acacia stand should be estimated from the sum of the products of mass and frequency for each size class, and not from mean tree diameter as neither frequency nor mass are normally distributed in the size classes (Fig. 4). This also applies to branch and total biomass, as it is not uncommon for c. 25% of the trees to constitute c. 75% of the biomass.

During the period August 1980–August 1981 there was no significant change in the circumferences of a sample of 92 old stems marked at Site 6. The

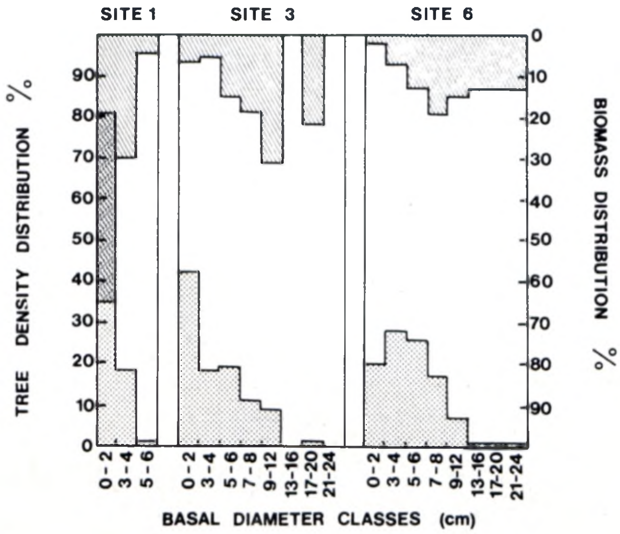

FIG. 4.—Tree density and biomass distribution in basal diameter classes.

young trees at Site 1, however, showed a mean diameter increment of 0,58 (0,17) cm, a change significant at the 1% level.

A. tortilis subsp. *heteracantha* at Site 3 starts to bear pods when in the 6–8 cm diameter class. Pod yield then increases exponentially on diameter (Fig. 5), but possibly falls off steeply in very old trees. c. 30 cm diam. Stunted trees on very shallow shaley soils started to bear in the 2–4 cm diam. class, and yield increased linearly on basal diameter. At site 3

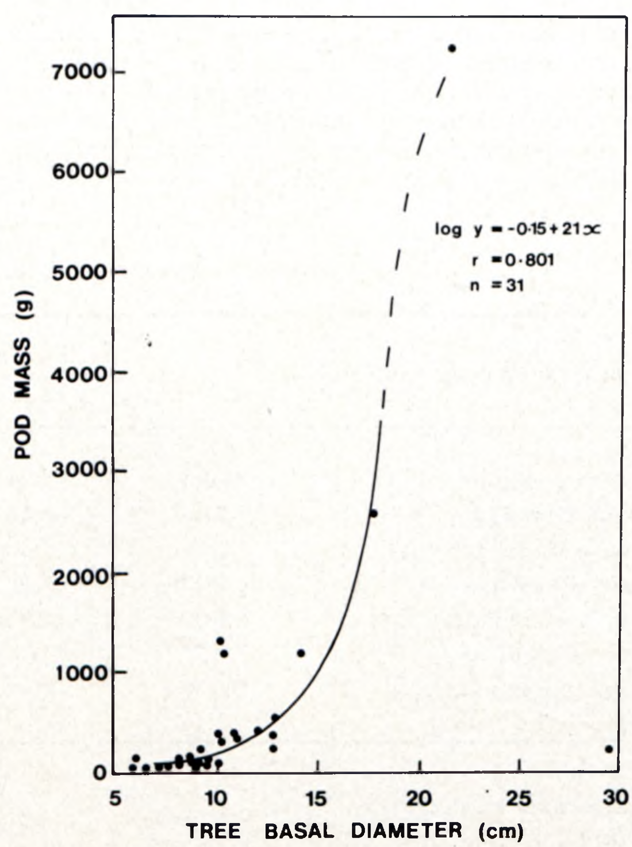

FIG. 5.—Relationship between pod yield (g) and basal diameter (cm) at Site 3. Note: the largest tree is excluded from the regression calculation.

TABLE 3.—Nutritional value and cost of acacia fodder

Product *Acacia tortilis* subsp. *heteracantha*	% Protein	% Fibre	% Fat	Cost c/kg	Cattle preference
Milled shoots average	*6,9(0,6)*	*47,0(1,2)*	*1,43(0,26)*	7–10	2
Milled leafy shoots	8,2	43,8	2,15		
Milled bare shoots	4,9	49,9	1,01		
Milled pods	15,2(1,1)	24,3(1,7)	1,81(0,10)	22–27	1
Dry green leaves	14,4(0,1)	19,6(0,9)	5,70(0,79)	30–70	3
Other feeds					
Eragrostis hay	6,0	44,5	2,0	8	
Lucerne hay	17,1	35,1	2,0		
Dairy meal					

where fruiting trees had a mean basal diameter of 11,2 (0,8) cm, the mean yield was 0,73 (0,25) kg/tree, and the maximum yield was 7,2 kg/tree. Pod yields recorded in the study area range from 1–139 kg/ha: very low compared with the 10–12 kg/tree in *A. tortilis* plantations in India (Muthana & Arora, 1980) or the 250–500 kg/ha yield of pods in natural stands in Zimbabwe (West, 1950).

Nutritional value, processing costs, and sundry uses of acacia products

The nutritional value of acacia fodders is acceptable, however, they are not cheap (Table 3). Costs shown include labour, fuel and maintenance of the machinery, but not the capital costs. Dry green leaves were obtained by stacking branches until they were dry, then beating off the leaves. A similar method is used for harvesting *Leucaena* leaves in Australia (Wildin, 1980) and would have been ideal for poor rural areas had not the thorns been shed with the leaves making the product unacceptable to cattle. Cattle, goats and horses accept milled branches and pods, and cattle have been maintained for up to two years on these products at the C.A.O. co-op farm at Weenen. Goats will eat 300–500 g pod meal per day in addition to browsing, and the meal may also be used as a poultry feed.

In the Msinga District, *Acacia tortilis* subsp. *heteracantha*, although not a preferred fuel wood, is much used for cooking and heating; the bark is used to tie bundles and roof laths, and the branches to construct thorn fences around kraals and gardens. These fences, which are renewed every year or two, comprise large branches packed together at a density of about 6,7 branches/m to form a breast high barrier. Three gardens sampled in Nomoya were enclosed by 65 (5) m of thorn fence comprising some 400 branches c. 4 cm diam. or the equivalent of 0,2 ha of bushes- an area ten times as great as that of a garden.

Herbage biomass, condition and response to acacia cover

Biomass on heavily grazed oldlands (Sites 3 & 7) peaked in January at 830 (139) and 630 (76) kg/ha DM. Although ⅔ of the grass at site 7 died between mid January and mid March, protein content dropped only slightly from 10,5% in February to 9,9% in April. The April protein content of *Bothriochloa*-dominated Site 3 was 5,1%. Fibre content of the herbage at both sites was low (25,9%) probably because the grasses, being continually grazed produced few inflorescences.

A veld condition assessment (Table 4) showed that all three study plots were overgrazed relative to the Bioclimatic Zone 10 benchmark. They also contained shade tolerant and old land species not found in the benchmark. Although the protein content and the species composition score of Site 3 is lower than that of Site 7, the former site is dominated by selected or neutral species, and the latter by avoided species.

Under a closed acacia canopy perennial forbs dominate, but the summer foliage cover (43%) is similar to that of open sites (37–40%). Where acacias are scattered, grass cover is higher under their canopies (18,7%) than between the canopies (8,8%) during winter ($F_{1,24}$ = 12,9; P–0,01). Grass under thorn trees is probably less accessible to grazers.

CONCLUSION

A standing crop of 5,7 t/ha FM (c. 2,9 t/ha DM) of acacia branches was available for hay making in secondary *A. tortilis* subsp. *heteracantha* veld, however, milling woody plants is an expensive way of maintaining an artificially high grazer population. The annual production of acacia shoots, 2,1 t/ha FM (c. 1,1 t/ha DM) was greater than the herbage biomass peak of 0,7 t/ha. The veld should therefore be stocked with as many or more browsers than grazers (within the limits of carrying capacity). Whereas it may be difficult to convince some people of the merits of increasing the browser/grazer ratio, because of social and cultural attitudes to cattle (ARDRI, 1981), this should be less disruptive and costly than an attempt to remove the trees and establish pasture for beef production — the solution implied by Thorrington-Smith *et al.*, (1980). It may

TABLE 4.—Veld condition

	Benchmark Zone 10*	Site 3	Site 7	Site 6
Acacia density (trees/ha)	121	1460	1300	1972
Canopy cover	open	open	open	closed
Taxa	*Themeda triandra*	*Bothriochloa insculpta*	*Urochloa mosambicensis*	Perennial forbs
% & utilization †	60 --	43 1,2	24 0,8	35 --
	Sehima galpinii	*Urochloa mosambicensis*	*Tragus berteron.*	*Panicum* sp.
	14 --	27 0,9	21 0,7	28 --
	Panicum spp.	*Aristida* spp.	Annual forbs	*Sporobolus smutsii*
	7 --	8 1,0	14 0,7	21 --
Composition score	100	8	14	30
% decreasers	89	4	13	30
% increaser II	7	66	30	21
% spp not in benchmark	--	30	57	49
Current grazing capacity AU/ha	0,2	0,11	0,10	0,14

* Data provided in Tainton *et al.* (1980).

† Utilization: see methods.

be feasible to camp and rest common land, but this is also likely to be complicated and costly.

'No specific studies have been undertaken on the growth of key browse species' (Trollope, 1981), and the value of leguminous trees for soil improvement, fuel and fodder has only recently been acknowledged (Folker, 1981). Although, as Janzen (1973) points out, they are not the solution to land management problems, we cannot afford to get rid of them before we have investigated their potential.

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REFERENCES

ARDRI, 1981. *KwaZulu beef industry: first report to the steering committee.* Agricultural and Rural Research Inst. Univ. Fort Hare.

AUCAMP, A. J., 1976. The role of the browser in the bushveld of the eastern Cape. *Proc. Grassld Soc. sth. Afr.* 11: 135–138.

EDWARDS, D., 1967. *A plant ecological survey of the Tugela River Basin.* Natal Town and Regional Planning Report No. 10.

FELKER, P.,1981. Uses of legumes in semi-arid regions. *Econ. Bot.* 35,2: 174–186.

HARDIN, G., 1977. *The limits of altruism: an ecologist's view of survival.* Bloomington: Indiana University Press

JANZEN, D. H., 1973. Tropical agro-ecosystems — these habitats are misunderstood by the temperate zones and mismanaged by the tropics. *Science* 182: 1212–1219.

KELLY, R. D., 1977. The significance of the woody component of semi-arid savanna vegetation in relation to meat production. *Proc. Grassld Soc. sth. Afr.* 12: 105–108.

KELLY, R. D. & WALKER, B. H., 1976. The effects of different forms of land use on the ecology of a semi-arid region in south-eastern Rhodesia. *J. Ecol.* 64: 553–576.

MENTIS, M. T., (in press). Evaluation of the wheel-point and step-point methods of veld condition assessment.

MUTHANA, K. D. & ARORA, G. D., 1980. Acacia tortilis *Forsk.: a promising fast growing tree for Indian arid zones.* Central Arid Zone Res. Inst., Jodhpur. Tech. Bull. No. 5.

PHILLIPS, J. F. V., 1973. *The agricultural and related development of the Tugela Basin and its influent surroundings.* Natal Town and Regional Planning Commission Report No. 19.

ROSS, J. H., 1975. *Acacia.* In O. A. Leistner, *Flora of southern Africa* 16,1: 24–114.

SCHULZE, R. E., 1969. A comparison between official population data and an aerial photographic population survey in the Tugela location. *S. Afr. geogr. J.* 51: 126–132.

TAINTON, N. H., EDWARDS, P. J. & MENTIS, M. T., 1980. A revised method for assessing veld condition. *Proc. Grassld Soc. sth. Afr.* 15: 37–42.

THORRINGTON-SMITH, E., ROSENBURG, M. J. & MCCRYSTAL, L. P., 1978. *Towards a plan for KwaZulu.* Official summary. KwaZulu Govt., Ulundi.

TROLLOPE, W. S. W., 1975. Veld rehabilitation in the Ciskei. *Fort Hare Papers* 7,3: 209–218.

WEST, O., 1950. Indigenous tree crops for Southern Rhodesia. *Rhodesia Agric J.* 47: 204–217.

WEST, O., 1951. The vegetation of Weenen County, Natal. *Mem. bot. Surv. S. Afr.* 23.

WHYTE, R. O., 1947. Africa (other than the Union). In *The use and misuse of shrubs and trees as fodder.* I.A.B. Joint Publ. no. 10.

WILDIN, J. H., 1980. A management system for *Leucaena. Qd. agric. J.* 106: 194–198.