The Effects of Fire on Two Vegetation Types at Matopos, Rhodesia

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INTRODUCTION

THE fact that the vegetation of Rhodesia has been influenced by fire from time immemorial is indisputable. West (1965) regards "all grassland in (Southern) Rhodesia as seral to bush or forest of various types, the grassland being maintained by some factor, or set of factors, which has prevented, or is retarding, its invasion by bush." He considers fire the most important retarding factor and quotes very extensively from the literature to substantiate the view that this is, in fact, the case throughout most of tropical and subtropical Africa. Rattray (1957) largely substantiates this view and considers that, ecologically, Rhodesia can be divided into three main vegetative regions only, viz:

1) Forest (of the closed evergreen type)
2) Woodland
3) Bushland or thicket

He goes on to say, however, that "although there are comparatively large areas in the country which are very nearly devoid of trees and can only be described as 'grassland,' there is, in the strict ecological sense, no true grassland in (Southern) Rhodesia."

Rattray goes on to describe three so-called grassland types. The open 'grassland' of the Eastern Districts which occurs at high altitudes and under conditions of high rainfall he describes as "small patches of evergreen forest surrounded by a sward of short grass and the general impression is one of extensive areas of grass devoid of trees." This type he believes to have evolved as a result of periodic fires and describes as a fire sub-climax.

Secondly, he describes "open 'grassland' areas that occur as islands in the woodland region of the main and subsidiary plateaux." These he believes to have developed as a result of poor drainage but qualifies this statement by pointing out that some suggest "that wholesale clearing by natives may have taken place many years ago and that the open condition has been maintained by fire and frost."

Thirdly there are the "vleis" (waterlogged areas in the drainage lines of the watershed country which occur between ridges of wooded topland). These Rattray believes to be devoid of trees as a result of waterlogging owing to the presence of an impermeable layer of clay or rock near the surface.

West (1969) does not agree that the "grassland" areas of the main and subsidiary plateaux and of the watershed "vleis" are the result of edaphic factors such as poor drainage and waterlogging. He believes that fire, assisted by cultivation, has eliminated forest and woodlands in these parts and is of the opinion that protection from these two factors could result in the re-establishment of woody species capable of thriving in the areas concerned. In support of this belief he quotes, as examples, numerous islands of forest or woodland, occurring within otherwise open areas, that have been protected for one reason or another, from felling and from fire.

The view that woody species are (or would be, if natural conditions prevailed) the dominant constituents of the vegetation throughout practically the whole of Rhodesia is further supported by West (1947a, 1958, 1963, 1964), Rattray (1961, 1963, 1964), Davies (1947), Kennan (1969), Kennan, et al. (1955).

Experimentation with veld (or range) in the Matabeleland Province of Rhodesia was initiated in 1945 by Dr. Oliver West. He laid down a comprehensive series of trials designed to study the effects of various forms of management on vegetation at Matopos (West, 1947b). In particular, he laid down two small-plot experiments designed to investigate the effects on the vegetation of burning at different times of the year and at different frequencies, of mowing at different times of the year and of complete protection. The object of this paper is to report the results of these two experiments.

THE ENVIRONMENT

Both experiments were laid down on the Central Veld and Pasture Station for Matabeleland (now known as Matopos Research Station), one being sited on what is known as Thornveld and the other on Sandveld. The soils and vegetation of these veld types are vastly different as is the reaction of the vegetation to treatment.

Soils

The soils at Matopos Research Station have been described by Thompson (1960) who carried out a detailed survey. There is no need, in this paper, for more than a brief description of the soils. Suffice to say that two major types are represented, namely:

a) Sandy soils derived from a relatively felspathic rich gneissic granite. These are shallow and relatively infertile and permeability is usually severely restricted by weathering granite and clayey, soil-like material below the subsoil horizon. This soil type together with its vegetation is known locally as Sandveld. Alkaline patches (isiQuaquas) varying in size from a few square yards to many acres occur irregularly within it.

b) Moderately fertile soils derived more or less in situ from epidiorite and related schists of the Bulawayan system. These are extremely variable and are known colloquially as red or black soils or, with their vegetation as Thornveld. They range in depth from very shallow to moderately deep and the colour varies from reddish brown through brown or dark brown to dark grey and black, the latter being heavy, self-ploughing clays. Permeability is usually severely restricted in the red and brown soils by weathering rock and in the grey and black soils by dense, hard, heavy clays.

CLIMATE

The climate at Matopos is characterised by a comparatively short summer rainfall season, a comparatively long dry winter period, relatively hot summers and cold winters. The period between the end of winter and the beginning of the summer rains is invariably very hot and dry. Rainfall is extremely erratic and annual totals have varied in the past 24 years from 54.17 inches to 10.12 inches. Details of temperature and rainfall are presented in Table 1.

TABLE 1. MEAN TEMPERATURES, AVERAGE AND ABSOLUTE MAXIMUM AND MINIMUM TEMPERATURES (DEGREES FAHRENHEIT) AND AVERAGE RAINFALL (INCHES) FOR MATOPOS RESEARCH STATION

	July	Aug.	Sept.	Oct.	Nov.	Dec.
Mean	53.6	58.3	65.9	71.1	71.1	70.5
Average Max.	70.6	75.5	82.2	85.8	83.2	81.0
Absolute Max.	83.0	91.0	98.0	101.0	99.0	95.0
Average Min.	36.5	41.0	49.5	56.3	59.0	59.9
Absolute Min.	15.0	16.0	26.0	33.0	40.0	46.0
Rainfall	0.02	0.03	0.11	0.85	3.43	5.30

	Jan.	Feb.	Mar.	Apr.	May	June	Year
Mean	69.6	69.7	68.0	64.9	58.1	53.4	64.5
Average Max.	80.4	80.9	80.2	79.1	74.8	70.2	78.7
Absolute Max.	98.0	94.0	93.0	91.0	86.0	82.0	101.0
Average Min.	58.8	58.4	55.8	50.7	41.4	36.5	50.3
Absolute Min.	44.0	41.0	39.0	31.0	23.0	15.0	15.0
Rainfall	4.94	4.06	2.96	0.94	0.28	0.14	23.06

VEGETATION

The vegetation of the two soil types differs a great deal. Rattray (1957 and 1967) describes it in detail and, according to him, the main characteristics are as follows:

Thornveld:—On the RED SOILS the vegetation is described as Acacia Tree–Bush Savanna of varying density with various *Acacia* spp. the dominant trees. Notable amongst these are *A. karroo*, *A. rehmanniana*, *A. gerrardi*, *A. nilotica* and *A. nigrescens* which occur with *Ziziphus mucronata*, *Combretum* spp., *Sclerocarya caffra*, *Peltophorum africanum*, *Rhus* spp., *Grewia* spp., *Euclea divinorum*, *Ormocarpum trichocarpum*, and others. The commonest grasses are *Themeda triandra*, *Heteropogon contortus*, *Cymbopogon plurinodis*, *Bothriochloa insculpta*, *Eragrostis* spp., *Hyparrhenia* spp., and *Digitaria* spp.

The BLACK SOILS also carry an Acacia Tree–Bush Savanna but the vegetation is less diverse and *Acacia karroo* is usually the dominant tree. *Ziziphus mucronata*, *Rhus* spp., *Euclea* spp., *Diospyrus sericea*, *Combretum hereroense*, and, sometimes, *Colophospermum mopane* also occur. The grasses are characteristic and consist mainly of *Dichanthium papillosum*, *Setaria porphyrantha*, *Ischaemum brachyatherum*, *Bothriochloa insculpta*, *Panicum maximum*, *Sorghum versicolor* and *Brachiaria eruciformis*.

Sandveld:—This carries a Terminalia (ranging to Burkea) Tree–Bush Savanna with *Terminalia sericea* or *Burkea africana* dominant. Associated trees and bushes are *Combretum* spp., *Sclerocarya caffra*, *Rhus* spp., *Ziziphus mucronata*, *Strychnos* spp., *Euclea divinorum*, *Erythrina tomentosa*, *Carissa edulis*, *Diospyros sericea*, *Gardenia* spp., and many others. The grass cover is very varied and commonly contains *Hyparrhenia* spp., *Hyperthelia dissoluta*, *Eragrostis* spp., *Heteropogan contortus*, *Brachiaria* spp., *Aristida* spp., *Digitaria* spp., *Loudetia* spp., *Schizachyrium jeffreysii*, *Pogonarthria squarrosa*, *Andropogon* spp., and *Rhynchelytrum* spp.

On the isiQuaquas the grass cover is usually sparse and consists of species such as *Sporobolus marginatus*, *Chloris virgata*, *Eragrostis* spp., and *Tragus berteronianus*. *Colophospermum mopane*, *Acacia mellifera*, and *Combretum* spp., are the commonest trees and *Carissa edulis* and *Diospyros sericea* the commonest bushes.

EXPERIMENTAL PROCEDURE

Typical areas of Thornveld and Sandveld were selected for the two experiments—one experiment being sited on each soil–vegetation type. Apart from site differences and the facts that the Sandveld trial was started in 1947 and that the one on Thornveld started a year later, and that the plots in the former measured 100 feet x 90 feet, whereas those in the latter measured 90 feet x 75 feet, the two experiments were identical in every respect.

In each trial, 12 treatments were randomised and replicated three times, with each set (or block) of treatments arranged in line and parallel to the next set. Plots were surrounded by mown verges, five feet in width and cleared of all woody vegetation, and were separated from each other by 10 feet wide graded roadways.

Treatments applied were as follows:

1) Complete protection
2) Burnt annually in autumn
3) Burnt annually at the end of the dry season before the first rains
4) Burnt annually in spring before the rains set in
5) Burnt every second year in autumn
6) Burnt every second year at the end of the dry season before the first rains
7) Mown annually for hay; cut herbage removed
8)* Burnt every fourth year in mid-growing season
9) Burnt every third year at the end of the dry season before the first rains
10) Burnt every third year in spring before the rains set in
11) Burnt every fifth year at the end of the dry season before the first rains
12) Mown annually at the end of the dry season before the first rains; cut herbage removed

The various seasons at which treatments were applied were defined as follows:

Autumn:—As early as possible in the dry season, but after the first frosts when the grass is dry enough to burn well. (At this time of year many of the trees were leafless, or were dropping their leaves and the grasses were approaching dormancy.)

Before first rains:—As late as possible in the dry season but before any rain falls. (These burns usually took place before there was any flush of spring growth.)

Before rains set in:—Very late in the dry season, after the first showers, but before the main rains break. (These burns usually took place after most of the trees had burst into leaf but before the grasses had shown much, or any, sign of growth.)

Mown for hay:—Cut once per year at the height of summer when grasses yields are approaching maximum. (Mowing usually took place when most of the grasses were still in flower but had set some seed.)

Except in the two mowing treatments, where all woody vegetation

* Treatment 8. Burnt every fourth year in mid-growing season was found to be impracticable and was discontinued after the first year.

was completely removed by stumping at the start of the trials, with as little disturbance as possible to the grasses, the vegetation on the plots was undisturbed except by the various treatments applied.

No grazing by domestic animals was permitted while the experiments were in progress and attempts were made to exclude wild animals. However, some grazing or browsing was inevitably done by wild animals, and hares (*Lepus saxtilis micklemi*), steenbok (*Raphicerus campestris campestris*) and duiker (*Sylvicapra grimmia grimmia*) were occasionally encountered in both experiments.

In addition, springhares (*Pedestes cafer cafer*) were relatively common in the Sandveld trial, which was also occasionally invaded by sable antelope (*Ozanna grandicornis grandicornis*), notorious fence-breakers. Birds, too, occasionally damaged plots by scratching for insects and roots and, of these, the chief offenders were crowned guinea fowl (*Numida meleagris transvaalensis*) and francolins (*Francolinus natalensis* and *Pternistis swainsoni swainsoni*). Although incursions were not very frequent these animals and birds tended to concentrate, when they did enter the experimental area, in the plots burnt in autumn and on those burnt at the end of the dry season before the first rains. These plots invariably exhibited a certain amount of fresh growth before the break of the rainy season and were thus an attraction at a time when the grass in all the other plots, and in the surrounding areas, was still dormant and very dry. It is therefore possible that the behaviour of the vegetation in these plots was, to some extent, influenced by these factors.

Methods of Assessing Results

In each trial one permanent quadrat, 15 feet square, was pegged in each plot. These were located in vegetation typical of the plot as a whole and, as far as possible, centrally. However, because they were to be used for measuring the effects of the treatments on the grass component of the vegetation, some attempt was made to exclude trees. In these, point quadrat analyses to determine percentage basal cover were carried out in 1949, 1957 and 1963, using the method described by Levy and Madden (1933). In the Thornveld trial one additional analysis was done in 1961; 1000 points per quadrat were recorded each time, except in 1949 when only 500 were recorded.

At the same time as these analyses were carried out, counts were made of all woody species occurring within the quadrats. In general, the numbers of plants so recorded were small and, because the quadrats were sited in areas largely free of trees, most of the plants were seedlings or very small trees and bushes.

In order to obtain an estimate of total tree population per plot, all woody species occurring within the plots were counted in 1963. However, because tree density varied considerably throughout the experimental areas when the trials started and because no comparative figures are available for the plots before differential treatments were imposed, the data have little value apart from interest. A better, though qualitative, idea of changes in the tree cover is gained from fixed point photographs. Two photographs of each plot were taken annually, from soon after the commencement of the trial and from these it is possible to obtain some impression of the effects of fire on the woody species.

In addition, regular "walk through" observations were conducted. In these various specific factors (e.g. grass cover, relative contribution of perennial and annual grasses, degree of wash and erosion, increase or decrease in bush density, fire damage to trees and bushes, etc.) were noted and recorded. On occasions, too, rings were used to provide an estimate of the relative dominance and frequency of the various grass species.

Finally, because the grass cover in some quadrats was seen to have behaved differently to the plots as a whole the basal grass cover of more typical sites was charted in 1962. Here again, the data are only of academic interest because (a) no comparative data from the start of the experiment are available and (b) very small sampling units were charted (only two metre-square quadrats per plot). Because none of these fell within the quadrats in which point quadrat analyses were carried out close agreement between the point quadrat and charting data was not expected and, although agreement was remarkably good in the Thornveld trial the reverse was the case in the Sandveld.

RESULTS

Because the trials were sited on widely different soil and vegetation types it is necessary to discuss their results separately. However, because space precludes the possibility of presenting all relevant data, only that of the 1949, 1957, and 1963 analyses are presented in full and information derived from intermediate analyses and other observations is only presented where this is considered important.

THORNVELD

The experiment was sited on soil which is red, and very shallow at the highest point but which becomes progressively rather darker and somewhat deeper lower down the slope. In general, tree density was greatest and the grass cover poorest on the shallower soils. In the same way, the grass species composition varied to some extent from one end of the experiment to the other, the most notable effect being that although grasses such as *Themeda triandra*, *Heteropogon contortus* and *Cymbopogon plurinodis* occurred throughout the experiment, others such as *Setaria porphyrantha* and *Hyparrhenia filipendula* were usually only recorded on the deeper soils, where they were often common constituents of the sward. The vegetation on the red soils, in particular, is known to be extremely sensitive to use and, where damage is done to the grass cover, recovery is extremely slow.

Basal cover: —Data derived from the 1949, 1957, and 1963 point quadrat analyses are presented in Table 2.

The data in Table 2 reflect changes that had taken place by 1963 when the experiment was last botanically analyzed. During the past seven years Matopos has experienced a series of droughts, or years in which rainfall distribution has been extremely unfavorable to grass growth, and further marked changes have taken place. In the discussion which follows conclusions are drawn from the botanical analysis data reflected in the table but note is also made of the condition of the plots some eight years later after "walk through" observations in March 1971. Different teams of workers undertook the analyses in 1949, 1957, and 1963 and operator differences can therefore be expected. In 1957, in particular, the workers concerned adopted an extremely strict interpretation of what constituted a "strike" and their figures for basal cover were very low. However, when the figures for each species were converted to percentages of total cover, agreement with the 1949 and 1963 data, and the general trend indicated by these data, was in most cases remarkably close.

Table 2 shows complete protection resulted in a slight decrease in

TABLE 2. PERCENTAGE BASAL COVER AND PERCENTAGE SPECIES CONTRIBUTION—1949, 1957 AND 1963—THORNVELD. (AVERAGE OF 3 PLOTS)

		% Basal Cover			% Species Contribution		
Treatment	Species	1949	1957	1963	1949	1957	1963
Complete protection	*Andropogon schirensis*	—	0.03	0.07	—	2.38	2.36
	Bothriochloa insculpta	0.40	—	—	10.92	—	—
	Cymbopogon plurinodis	0.93	0.23	0.20	25.41	18.25	6.73
	Digitaria ternata	—	—	0.03	—	—	1.01
	Heteropogon contortus	0.13	0.27	0.10	3.55	21.43	3.37
	Hyparrhenia filipendula	0.33	—	—	9.02	—	—
	Rhynchelytrum repens	—	—	0.10	—	—	3.37
	Setaria porphyrantha	0.07	0.13	0.80	1.91	10.32	26.94
	Themeda triandra	1.80	0.60	1.67	49.18	47.62	56.23
	Total	3.66	1.26	2.97			
Burnt annually in autumn	*Aristida congesta*	—	N.R.	0.13	—	N.R.	6.34
	Bothriochloa insculpta	0.40	,,	—	12.74	,,	—
	Brachiaria eruciformis	—	,,	0.03	—	,,	1.46
	Cymbopogon plurinodis	0.33	,,	0.40	10.51	,,	19.51
	Digitaria ternata	—	,,	0.03	—	,,	1.46
	Eragrostis atherstonei	0.13	,,	0.03	4.14	,,	1.46
	Eragrostis jeffreysii	0.07	,,	0.03	2.23	,,	1.46
	Eragrostis superba	0.07	,,	—	2.23	,,	—
	Heteropogon contortus	1.07	,,	—	34.08	,,	—
	Setaria porphyrantha	—	,,	0.10	—	,,	4.88
	Sporobolus stapfianus	—	,,	0.03	—	,,	1.46
	Themeda triandra	1.07	,,	0.07	34.08	,,	3.41
	Unidentified	—	,,	1.20	—	,,	58.54
	Total	3.14	,,	2.05			
Burnt annually at the end of the dry season before first rains	*Aristida scabrivalvis*	—	—	0.03	—	—	1.41
	Bothriochloa insculpta	—	0.13	—	—	10.92	—
	Brachiaria eruciformis	—	—	0.20	—	—	9.39
	Cymbopogon excavatus	—	0.03	0.03	—	2.52	1.41
	Cymbopogon plurinodis	1.33	0.27	0.90	48.91	22.69	42.25
	Digitaria ternata	0.07	—	0.17	2.62	—	7.98
	Diheteropogon amplectens	—	—	0.03	—	—	1.41
	Eragrostis atherstonei	—	—	0.07	—	—	3.29
	Eragrostis jeffreysii	0.07	0.03	—	2.62	2.52	—
	Heteropogon contortus	0.20	0.30	0.30	7.49	25.21	14.08
	Panicum sp.	—	0.03	—	—	2.52	—
	Setaria porphyrantha	—	—	0.03	—	—	1.41
	Sporobolus stapfianus	—	0.03	0.10	—	2.52	4.69
	Sporobolus sp.	—	—	0.10	—	—	4.69
	Themeda triandra	1.00	0.37	0.17	37.45	31.09	7.98
	Total	2.67	1.19	2.13			

percentage cover but there was a considerable change in the composition of the sward. *Themeda triandra* and *Cymbopogon plurinodis* were the main components in 1949, with *Bothriochloa insculpta* and *Hyparrhenia filipendula*, but fourteen years later both

Table 2 (Continued)

Treatment	Species	% Basal Cover			% Species Contribution		
		1949	1957	1963	1949	1957	1963
Burnt annually in spring before rains set in	*Aristida congesta*	0.07	—	—	1.43	—	—
	Bothriochloa insculpta	0.73	0.03	0.07	14.96	1.58	2.26
	Brachiaria eruciformis	—	—	0.20	—	—	6.45
	Cymbopogon plurinodis	1.07	0.57	1.10	21.93	30.00	35.48
	Digitaria ternata	0.53	—	0.03	10.86	—	0.97
	Eragrostis atherstonei	0.07	—	0.03	1.43	—	0.97
	Eragrostis superba	0.07	0.03	—	1.43	1.58	—
	Eragrostis spp.	0.07	—	—	1.43	—	—
	Heteropogon contortus	1.00	0.70	0.90	20.49	36.84	29.03
	Hyparrhenia filipendula	—	0.07	—	—	3.68	—
	Setaria porphyrantha	0.07	—	—	1.43	—	—
	Sporobolus stapfianus	—	—	0.07	—	—	2.26
	Themeda triandra	1.20	0.50	0.70	24.59	26.32	22.58
	Total	4.88	1.90	3.10			
Burnt every second year in autumn	*Bothriochloa insculpta*	—	0.03	—	—	2.05	—
	Brachiaria eruciformis	—	0.07	—	—	4.79	—
	Chloris virgata	—	0.07	—	—	4.79	—
	Cymbopogon plurinodis	0.60	0.20	0.27	18.35	13.70	6.85
	Digitaria ternata	0.70	0.30	—	2.14	2.05	—
	Eragrostis atherstonei	—	—	0.03	—	—	0.76
	Eragrostis spp.	—	0.03	0.10	—	2.05	2.54
	Heteropogon contortus	0.67	0.23	0.77	20.49	15.75	19.54
	Hyparrhenia filipendula	0.13	0.10	0.27	3.97	6.85	6.85
	Rhynchelytrum repens	—	—	0.03	—	—	0.76
	Sporobolus stapfianus	—	—	0.07	—	—	1.78
	Themeda triandra	1.80	0.70	2.40	55.05	47.95	60.91
	Total	3.27	1.46	3.94			
Burnt every second year at the end of the dry season before first rains	*Bothriochloa insculpta*	0.27	—	0.03	8.28	—	0.89
	Brachiaria eruciformis	—	—	0.10	—	—	2.98
	Cymbopogon plurinodis	0.93	0.33	0.57	28.53	16.84	16.96
	Cynodon dactylon	0.20	0.10	—	6.13	5.10	—
	Digitaria ternata	0.20	0.10	0.10	6.13	5.10	2.98
	Diheteropogon amplectens	—	—	0.03	—	—	0.89
	Eragrostis atherstonei	—	—	0.07	—	—	2.08
	Eragrostis jeffreysii	0.13	—	—	3.99	—	—
	Eragrostis superba	0.07	—	—	2.15	—	—
	Heteropogon contortus	—	0.20	0.50	—	10.21	14.88
	Setaria porphyrantha	0.53	0.53	1.20	16.26	27.04	35.71
	Sporobolus stapfianus	—	0.10	0.23	—	5.10	6.85
	Themeda triandra	0.93	0.60	0.53	28.53	30.61	15.77
	Total	3.26	1.96	3.36			

B. insculpta and *H. filipendula* had disappeared and *C. plurinodis* had become a minor constitutent of the sward. These had been replaced by *Setaria porphyrantha*, a shade-tolerant grass, and *T. triandra*, which had become somewhat more strongly dominant although

Table 2 (Continued)

Treatment	Species	% Basal Cover 1949	% Basal Cover 1957	% Basal Cover 1963	% Species Contribution 1949	% Species Contribution 1957	% Species Contribution 1963
Mown annually for hay	*Aristida* spp.	0.07	—	—	1.51	—	—
	Bothriochloa insculpta	1.07	—	0.10	23.11	—	1.66
	Brachiaria nigropedata	—	0.03	0.07	—	1.42	1.16
	Cymbopogon excavatus	—	0.10	0.07	—	4.72	1.16
	Cymbopogon plurinodis	—	0.10	0.63	—	4.72	10.43
	Digitaria ternata	0.07	—	0.03	1.51	—	0.50
	Eragrostis atherstonei	—	—	0.07	—	—	1.16
	Eragrostis jeffreysii	—	—	0.07	—	—	1.16
	Eragrostis superba	—	0.03	—	—	1.42	—
	Eragrostis spp.	0.07	0.03	—	1.51	1.42	—
	Heteropogon contortus	1.67	0.23	0.07	36.07	10.85	1.16
	Hyparrhenia filipendula	0.07	0.37	0.50	1.51	17.45	8.28
	Rhynchelytrum repens	0.07	0.03	0.20	1.51	1.42	3.31
	Setaria porphyrantha	0.27	0.10	0.87	5.83	4.72	14.40
	Sporobolus stapfianus	—	0.13	0.13	—	6.13	2.15
	Themeda triandra	1.27	0.97	3.20	27.43	45.75	52.98
	Urochloa trichopus	—	—	0.03	—	—	0.50
	Total	4.63	2.12	6.04			
Burnt every third year at the end of the dry season before first rains	*Aristida congesta*	0.07	—	—	2.06	—	—
	Bothriochloa insculpta	0.40	0.03	0.03	11.80	2.05	0.66
	Cymbopogon plurinodis	1.13	0.23	0.70	33.33	15.75	15.49
	Digitaria ternata	0.13	0.03	—	3.83	2.05	—
	Eragrostis atherstonei	0.13	—	0.50	3.83	—	11.06
	Eragrostis jeffreysii	—	0.27	—	—	18.49	—
	Eragrostis rigidior	—	—	0.07	—	—	1.55
	Heteropogon contortus	0.33	0.13	0.33	9.73	8.90	7.30
	Hyparrhenia filipendula	0.13	0.27	0.43	3.83	18.49	9.51
	Rhynchelytrum repens	—	—	0.03	—	—	0.66
	Setaria porphyrantha	—	—	—	—	—	—
	Sporobolus stapfianus	—	—	0.03	—	—	0.66
	Themeda triandra	1.07	0.50	2.40	31.56	34.25	53.10
	Total	3.39	1.46	4.52			
Burnt every third year in spring before rains set in	*Bothriochloa insculpta*	1.47	0.17	0.10	27.89	9.66	2.05
	Cymbopogon plurinodis	2.20	0.60	1.07	41.75	34.09	21.88
	Digitaria ternata	0.07	0.03	—	1.33	1.70	—
	Heteropogon contortus	0.13	0.23	0.33	2.47	13.07	6.75
	Rhynchelytrum repens	—	—	0.03	—	—	0.61
	Setaria porphyrantha	—	0.03	0.13	—	1.70	2.66
	Sporobolus stapfianus	—	0.03	0.10	—	1.70	2.05
	Themeda triandra	1.40	0.67	3.13	26.57	38.07	64.01
	Total	5.27	1.76	4.89			

its basal cover was slightly reduced. *Rhynchelytrum repens*, which was not recorded in 1949 and 1957 contributed a small extent to the sward in 1963. *Heteropogon contortus* increased very considerably in the early years of the trial but the plants became gradually

Table 2 (Continued)

		% Basal Cover			% Species Contribution		
Treatment	Species	1949	1957	1963	1949	1957	1963
Burnt every fifth year at the end of the dry season before first rains	*Bothriochloa insculpta*	0.20	0.03	0.07	5.26	1.92	1.71
	Cymbopogon plurinodis	1.27	0.47	1.13	33.42	30.13	27.63
	Digitaria ternata	0.13	—	0.03	3.42	—	0.73
	Diheteropogon amplectens	—	0.03	0.03	—	1.92	0.73
	Heteropogon contortus	0.13	0.07	0.13	3.42	4.49	3.18
	Setaria porphyrantha	0.20	0.13	0.37	5.26	8.33	9.05
	Sporobolus stapfianus	—	0.03	0.03	—	1.92	0.73
	Themeda triandra	1.87	0.80	2.30	49.21	51.28	56.23
	Total	3.80	1.56	4.09			
Mown annually at the end of the dry season before first rains	*Bothriochloa insculpta*	0.33	—	0.07	5.44	—	1.05
	Brachiaria eruciformis	0.07	—	—	1.15	—	—
	Cymbopogon plurinodis	1.80	0.60	0.77	29.65	30.61	11.54
	Digitaria ternata	0.07	0.03	0.07	1.15	1.53	1.05
	Eragrostis atherstonei	0.33	—	0.13	5.44	—	1.95
	Eragrostis jeffreysii	—	0.10	—	—	5.10	—
	Heteropogon contortus	0.87	0.03	0.23	14.33	1.53	3.45
	Hyparrhenia filipendula	0.07	0.23	0.10	1.15	11.73	1.50
	Rhynchelytrum repens	—	—	0.03	—	—	0.45
	Setaria porphyrantha	0.20	0.10	0.40	3.29	5.10	6.00
	Sporobolus stapfianus	—	0.10	0.07	—	5.10	1.05
	Themeda triandra	2.33	0.77	4.80	38.39	39.29	71.96
	Total	6.07	1.96	6.67			

choked by an over-accumulation of dead top-hamper and most had died by the time the last analysis was done.

These results confirm previous findings in an experiment designed to study the effects of prolonged heavy grazing and/or prolonged protection on Thornveld vegetation where it was found that *T. triandra* and *R. repens* were favored by protection but that *C. plurinodis* and *H. contortus* decreased. (Kennan, 1969). *H. filipendula,* however, reacted differently in the two trials as it increased to some extent with protection in the earlier one but, as it was a comparatively minor contributor in both cases, the difference may be due to sampling errors.

When the plots were examined in 1971 it was found that the cover had further deteriorated very considerably, that there was much dead grass and that in two of the plots *C. plurinodis*, although very sparse, was the most prominent perennial. In the third plot, which was the most heavily bushed, *C. plurinodis*, *T. triandra*, *H. contortus* and *Eragrostis atherstonei* occurred in approximately equal proportions in what can only be termed an extremely poor cover. The sensitivity of *T. triandra* to drought has been recorded previously, at the Nyamandhlovu Experiment Station, (Kennan, 1969), and there is little doubt that its disappearance in those plots and, in fact, in plots throughout the experiment, was due largely to drought.

Annual autumn burning caused severe deterioration of basal cover but the data in Table 2 are of little assistance in determining the effect of this treatment on species composition. No attempt was made to analyse the plots in 1957 as the work was done shortly after these plots were burnt. Again, in 1963, botanical analysis was done in September, some three months after burning, but as no rain had fallen during the intervening period little or no regrowth had taken place and 58 percent of the plants struck could not be identified with certainty. These were thus listed as "unidentified". However, frequency counts done in 1961 (20 two foot diameter rings recorded per plot) showed that the cover at that time was extremely poor, this being rated as "poor or very poor" in 81.6 percent of rings cast, as "fair" in 13.3 percent of the rings and as "good" in 5 percent. This analysis also showed that *Brachiaria eruciformis* was dominent in 43.3 percent of the rings cast. Dominant in the remaining rings were *Heteropogon contortus* or *Panicum atrosanguineum* (both 10 percent), *Eragrostis jeffreysii* (8.3 percent), *Sporobolus stapfianus* or *Themeda triandra* (both 6.6 percent), *Bothriochloa insculpta* (5 percent) and *Cymbopogon plurinodis*, *Aristida barbicollis* or *Eragrotis patenti-pilosa* (each 3.3 percent). The genera *Brachiaria*, *Panicum*, *Aristida* and *Eragrostis patenti-pilosa* are all undesirable pioneering annuals and, having very small basal attachments, are rarely struck in point quadrat analyses.

By 1971 the basal cover was probably not much different than it was in 1963, when it was already very poor. In two of the plots, however, *Eragrostis atherstonei* was by far the commonest perennial and this had colonised evenly throughout. In these plots annual grasses and weeds were not very apparent and it would seem that this species acts similarly to the commonly cultivated *E. curvula* which has the ability to prevent invasions by weeds and other grasses.

Where burning took place every second year in autumn deterioration of the grass cover was visually apparent by 1963 although this was far less marked than it was with annual burning. The deterioration is not, however, reflected by the data in Table 2 where the figures indicate that there was a slight improvement in total basal cover, with *Themeda triandra* increasing at the expense of *Cymbopogon plurinodis*. Certain pioneering species, too (such as species of *Eragrostis*, *Rhynchelytrum* and *Sporobolus*) were recorded for the first time in 1963. Nevertheless, there was no doubt that the grass cover had become more open and although individual tufts (especially of *T. triandra* and *H. contortus*, remained large or may, in some cases have increased in size, the spaces between these surviving tufts had enlarged as other grasses died out.

Observations in March 1971 indicated that cover had deteriorated a great deal during the past eight years. This was rated as "poor" in one plot and "very poor" in the other two and in one of the latter plots an even, but sparse stand of *Eragrostis atherstonei* had replaced most of the grasses that occurred at the beginning of the trial, the only other perennials of note being *C. plurinodis* and *T. triandra*, both of which occurred very sparingly. As was the case in the annually burnt plots where *Eragrostis atherstonei* had become dominant, annual grasses were rare. In the other plot with a "very poor" cover rating *E. atherstonei* and *C. plurinodis* occurred sparsely in approximately even quantities and annual grasses such as *Brachiaria eruciformis*, *Panicum atrosanguineum* and *Chloris virgata* were common. It seems logical to assume that in time, the plot will be dominated by *E. atherstonei* to the exclusion of most other species. The third plot, which happens to be on reasonably deep soil, still carries a cover consisting largely of *Heteropogon contortus* and *T. triandra*. The cover is, however, patchy and where the stand of perennials is weak, annuals such as those mentioned above are dominant. This plot is remarkable for the fact that a dense and vigorous stand of *Hyparrhenia filipendula* and *Setaria porphyrantha* survived for many years under the shade of one large tree (*Sclerocarya caffra*). These grasses were found, in 1971, to have disappeared completely and to have been replaced by weeds (especially *Commelina* sp.) and annual grasses. Their demise is assumed to be mainly the result of drought which would have been accentuated by the autumn burning in alternate years.

Although burning was obviously the prime cause of sward deterioration in these two autumn–burnt treatments, other factors which resulted from the treatments applied must be regarded as having contributory effects. No significant rainfall was ever recorded in less than four months after burning and drying out of the soil and surface–crusting was very marked. As a result run–off, when rain did fall, was excessive and infiltration was poor. The effect of this reduced infiltration rate was often very marked during temporary dry spells in the rainy season, when the grasses in the autumn–burnt plots would wilt whilst those in plots receiving more lenient treatments would remain lush. Also, because there was invariably some small degree of regrowth during the dry season, after burning, rodents and other small wild animals were attracted to these plots and their grazing undoubtedly had deleterious effects. West (1969) confirms these conclusions.

The effects of burning each year at the end of the dry season befor the first rains are, again, not nearly so apparent from the figures in Table 2 as they were to the eye. Although the data reflect a slight reduction in basal cover the most marked effect was on species composition. *Cymbopogon plurinodis*, although reduced in quantity, maintained its dominance but *Themeda triandra* was almost eliminated by 1963 by which time over 28 percent of the cover consisted of annuals or pioneering species such as *Aristida scabrivalvis*, *Brachiaria cruciformis*, *Digitaria ternata* and *Sporobolus* sp., most of which were not recorded at all in 1949. Here again, baked and crusted soil, excessive run–off and reduced infiltration of rainwater was very apparent and drought effects during short dry spells in the rainy season were often marked.

A feature of this treatment was that no gradual deterioration of the sward was noted. For some eight years after the start of the trial the cover of all plots remained vigorous and reasonably dense. In 1955–56 however, when a poorly distributed total rainfall of 17.95 inches was recorded, a large proportion of the perennial grasses succumbed and were replaced by annuals. Since that time progressive deterioration of cover has been observed and, in March 1971, all plots were rated as very poor and dominated by annual. *C. plurinodis*, although very sparse, was the main surviving perennial in two of the plots (in one it occurred with lesser quantities of *T. triandra* and *R. repens*) and *Eragrostis atherstonei* was the commonest perennial in the third.

Burning every second year at the end of the dry season before the first rains also brought about changes. In the case of *Bothriochloa insculpta*, *Cymbopogon plurinodis* and *Themeda triandra* there was a reduction in basal cover as well as in their contribution to total cover (which showed little change), but there was a corresponding increase of *Heteropogon contortus*, *Setaria porphyrantha* and *Sporobolus stapfianus*. The annual *Brachiaria* and *Eragrostis atherstonei* invaded at the expense of *E. jeffreysii* and *E. superba*, neither of which were recorded in 1963. Although these changes reflect a change for the worse, with stable species that are high in the succession being replaced mainly by lower successional species, the vegetation stood up comparatively well to the somewhat harsh treatment applied for 15 years and the cover remained reasonably vigorous. In the following eight years, however, marked deterioration took place and in 1971 there was very close similarity between these plots and those burnt annually at the same time of the year.

Burning every third year at the end of the dry season before the first rain resulted in a considerable improvement in cover, mainly because of a large increase in the amount of *Themeda triandra*. The contribution of *Eragrostis atherstonei* and *Hyparrhenia filipendula* was also increased to some considerable extent but *Cymbopogon plurinodis* and *Bothriochloa insculpta* decreased in face of competition from the other species. No annuals were recorded in 1963 and the plots had a vigorous and healthy appearance. In 1971, however, all plots showed marked effects of drought and most of the *T. triandra* and *H. filipendula* had died out leaving *C. plurinodis* or *Eragrostis atherstonei* as the dominant perennials. Annuals were common in all plots.

The changes, by 1963, in the plots burnt at the same time of year, but every *fifth year*, were almost identical to those in the triennially burnt plots. After a further eight years, however, deterioration was markedly less than in the case of the triennial burns and all plots contained a predominance of *C. plurinodis* and *T. triandra* although it was evident that some *T. triandra* plants had succumbed to drought.

Burning in spring just before the rains set in was only done annually and triennially. In the case of the annual burning the major difference between the effects of burning at the end of the dry season before the first rains and burning in spring before the rains set in was that *T. triandra* showed very much greater tolerance to the latter treatment and, although it decreased to some extent was still one of the dominant species (22.58 percent) by 1963. Neither *C. plurinodis* nor *H. contortus*, the only two other species that occurred to any great extent, showed much change. A further difference was that annuals and pioneers contributed less than 10 percent to total basal cover in 1963 in the case of the spring burn compared with over 28 percent in the case of the somewhat earlier burn.

By March 1971, however, the plots had deteriorated to such an extent that there was little difference between the two treatments. As was the case with the earlier burning. *C. plurinodis* was the dominant surviving perennial in all plots, although it was very sparse, and occurred mainly with *T. triandra* in one plot and with *Eragrostis atherstonei* in another. In the third it was the only perennial of note. In all three plots the cover was very poor and annual species were very common. There was much evidence of recently-dead *T. triandra* and some of *C. plurinodis*.

The effects of burning every third year in spring before rains set in were similar to those of burning triennially before the first rains. Here, though, total cover was slightly reduced because the large decrease in the contribution of *Bothriochloa insculpta* and *C. plurinodis* were not completely balanced by the great increase of *T. triandra* and a smaller increase of *H. contortus* and other grasses. The reason for this deterioration in cover is not clear but operator error could have some bearing on the matter. Whatever the reason, the plots remained vigorous and appeared to be in good health, in 1963, when *T. triandra* was very strongly dominant and annuals were conspicuous by their absence.

The two mowing treatments were, quite obviously, the most beneficial to the sward. The cover in both cases, in 1949, was considerably better than that in nearly all the other plots. This is understandable because all woody vegetation was removed from the plots set aside for mowing two full seasons before the first botanical analysis was done, and the grasses clearly responded to the reduced competition for light, water and plant nutrients. Further improvement in cover was recorded at the time of the last analysis in 1963.

Defoliation every summer (mown annually for hay) brought about a change from heteropogon-themeda-bothriochloa dominance to cover dominated very strongly by *T. triandra* which occurred with much lesser amounts of *Setaria porphyrantha* and *Cymbopogon plurinodis*. During 14 years between the first and last analyses both *Bothriochloa insculpta* and *H. contortus* virtually disappeared whilst species of *Cymbopogon*, *Setaria* and *Hyparrhenia* increased to some extent and *T. triandra* increased enormously.

In the plots mown annually at the end of the dry season *T. triandra* more than doubled its basal cover and increased its contribution from 38 percent to nearly 72 percent. As in the previous treatment, *Setaria porphyrantha* increased to some extent and *H. contortus* and *B. insculpta* decreased but, in contrast, *C. plurinodis* decreased. The only explanation that can be given to this anomaly is that *C. plurinodis* invariably starts growing before the onset of the rains and defoliation in the late dry season, when this species had already started growing and had drawn upon its root reserves, whilst the other species were still dormant, could have had damaging effects.

Subsequent to 1963 both treatments, in common with all others, suffered severely from drought. Their condition in 1971, though poor, was still better, however, than any of those in which burning was practised, the plots mown in the late dry season being somewhat better than those mown in summer. Annual grasses, which until 1963 were very minor constituents of the sward, were common in all mown plots but perennials such as species of the genera *Themeda*, *Cymbopogon*, and *Heteropogon* still persisted in reasonable amounts.

Effect on trees and bushes:—The effects of the various treatments on the trees and bushes cannot be determined with any real degree of accuracy because only those occurring within the fixed quadrats, which were purposely sited to avoid most of the trees, were counted at the start of the trial. Numbers involved, therefore, are very small. Nevertheless some conclusions can be drawn when these are considered in conjunction with photographic evidence, "walk through" observations and whole plot tree counts (only done in 1963).

When the experiment was started the size and density of the trees and bushes varied considerably between plots. A study of the species involved, and of the change in number and size of those encountered within the quadrats, revealed little of value in establishing a pattern that could be ascribed to treatment. The changes in the quadrats varied haphazardly from plot to plot within treatments and in only three treatments (complete protection, burnt triennially in spring before rains set in and mown annually at the end of the dry season) were they the same for each quadrat. In these treatments all quadrats contained more trees and bushes in 1964 than in 1949, the increase under complete protection being very considerable and that in the other two treatments being relatively small. In all other treatments the numbers of trees or bushes increased in some quadrats but decreased in others. For this reason the data are not presented in detail and, more for the sake of interest than for scientific value, treatment totals of trees and bushes occurring within quadrats (in 1949 and 1964) and within whole plots (in 1963 only) are presented by height class, in Table 3.

Although a greater variety of species (41) were recorded in the protected plots, compared with 16 to 28 in the burnt or mown treatments no consistent trend could be detected to establish species-reaction to treatment. Only two species occurred in the protected plots only, but as both are known from other studies to be fire-tolerant and as only two specimens of the one, and one of the other, were recorded, little can be deduced from their presence. In general, the distribution of species was dictated more by distribution of plant communities existing before the trial started than by treatment.

The most notable effect of treatment on tree or bush density and size was that of burning as compared to protection. The data in Table 3 show that a far greater number of woody plants were recorded, in 1963, in the protected plots than in any of the burnt ones. In addition, a greater proportion of the plants in these plots, than in any of the others, were taller than three feet. These findings

TABLE 3. TREATMENT TOTALS OF TREES AND BUSHES IN QUADRATS (1949 AND 1964) AND WHOLE PLOTS (1963 ONLY) BY HEIGHT CLASSES—THORNVELD. (TOTALS FOR THREE QUADRATS OR PLOTS)

Treatment		Height Class					Total
		0″–6″	6″–1′	1′–3′	3′–10′	Over 10′	
Complete protection	Quadrat—1949	22	1	—	—	—	23
	Quadrat—1964	4	29	33	7	—	73
	Plot —1963	173	722	920	343	22	2180
Burnt annually in autumn	Quadrat—1949	23	22	—	—	—	45
	Quadrat—1964	8	16	5	1	—	30
	Plot —1963	184	556	271	28	14	1053
Burnt annually at the end of the dry season before first rains	Quadrat—1949	10	15	2	—	—	27
	Quadrat—1964	6	10	17	1	—	34
	Plot —1963	75	321	386	53	17	852
Burnt annually in spring before rains set in	Quadrat—1949	16	3	—	—	—	19
	Quadrat—1964	8	7	6	—	—	21
	Plot —1963	73	301	329	45	11	759
Burnt every second year in autumn	Quadrat—1949	4	1	—	—	—	5
	Quadrat—1964	2	2	6	—	—	10
	Plot —1963	61	278	195	22	9	565
Burnt every second year at the end of the dry season before first rains	Quadrat—1949	—	1	1	—	—	2
	Quadrat—1964	3	4	4	—	—	11
	Plot —1963	74	308	347	13	6	748
Mown annually for hay	Quadrat—1949	38	4	—	—	—	42
	Plot —1964	21	33	3	—	—	57
	Plot —1963	230	891	383	—	1	1505
Burnt every third year at the end of the dry season before first rains	Quadrat—1949	22	2	—	—	—	24
	Quadrat—1964	4	8	12	—	—	24
	Plot —1963	47	306	843	92	11	1299
Burnt every third year in spring before rains set in	Quadrat—1949	14	—	—	—	—	14
	Quadrat—1964	10	10	3	—	—	23
	Plot —1963	53	328	373	85	5	844
Burnt every fifth year at the end of the dry season before first rains	Quadrat—1949	18	2	—	—	—	20
	Quadrat—1964	14	10	1	—	—	25
	Plot —1963	76	430	653	105	15	1279
Mown annually at the end of the dry season before first rains	Quadrat—1949	15	2	1	—	—	18
	Quadrat—1964	3	18	8	—	—	29
	Plot —1963	69	494	741	13	—	1317

Note. When the whole-plot counts were done in 1963 it was found that 46 different species, from 37 genera, were represented in the 33 plots of the experiment. A total of 12401 plants were recorded and, of these, more than half (6740) were *Acacia* spp. These were made up of *A. karroo* (2934), *A. gerrardi* (2663), *A. nilotica* (836), *A. rehmanniana* (283), *A. nigrescens* (13), *A. robusta* (10) and *A. galpinii* (i).

Other common species were *Ormocarpum trichocarpum* (2934), *Maytenus senegalensis* (683), *Combretum hereroense* (330), *C. apiculatum* (210), *Diospyros sericea* (283), *Turraea nilotica* (176), *Grewia* spp. (138), *Ziziphus mucronata* (127), *Dichrostachys cinerea* (109), *Albizzia harveyi* (107), and *Commiphora* spp. (106).

clearly illustrate that fire had no inconsiderable effect in retarding the invasion by trees and bushes and support the contention of West (1947a, 1954, 1955, 1958, 1963, 1964, 1965) who believes that fire is the greatest single factor in maintaining grasslands in Rhodesia in an open condition.

A study of the quadrat counts done in 1949 and 1964 (Table 3) further confirm that tree numbers and size greatly increased (more than threefold) in the protected plots. These figures also show that there was no very clear trend in the remaining treatments. In all except 2 of these (annual autumn burning, where quadrat counts reflect a 33 percent reduction between 1949 and 1964, and triennual burning at the end of the dry season, where there was no change) some increase in both numbers and size of tree was noted. In most cases, these increases were small in comparison with the protected plots.

Observations during the course of the trial indicated that, provided grass growth was sufficient to provide a good fire, burning at all times of the year and at all frequencies exercised control of the smaller trees and bushes which were usually killed to, or near, ground level, and that the more frequently fire was used the more effective was the control. Complete killing, however, was extremely rare and nearly all affected plants regrew vigorously from their undamaged bases after the fire. In the case of the larger trees, burning invariably caused complete defoliation (if they were in leaf when burning took place) but seldom did more than to kill branches occurring up to a height of about six feet.

Initially, control of woody species was best in the annually burnt plots but, as the trial progressed and this too-frequent burning caused a deterioration in the grass cover, fires became less intense and damage to trees was less marked. Degradation of the grass cover usually started with patches of perennial grasses succumbing, or being so weakened, that annual grasses invaded. These degraded patches then enlarged and joined up until much of the plot was covered with annuals and, because these grasses die at the end of the rainy season and usually disintegrate long before the end of the dry season, annual burning (except in autumn) became ineffective and sometimes impossible. Despite the fact that the plots burnt annually in autumn were the first to show signs of cover deterioration there was usually sufficient cover at that time of year to carry a fire hot enough to damage young trees and it is for this reason, it is thought, that woody species were reduced in this treatment whereas they increased with annual burning later in the year.

In plots burnt less frequently the grass cover remained vigorous for a longer period and, because more than one year's growth of grass accumulated between fires, the resultant fires were hotter and more damaging to the aerial parts of trees. Regrowth, however, was rapid and, when the next burning took place, young trees had usually regrown to a height in excess of that attained when killed to the roots by the previous fire.

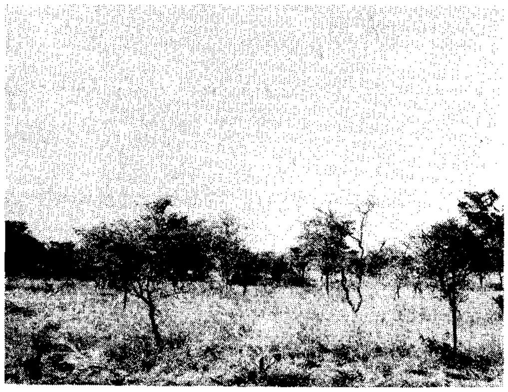
The very large number of trees that persisted in the mowing treatments are of interest. These plots were clean-stumped when the trial started but some seedlings and newly established plants were not removed. Many seeds germinated and became established immediately after the stumping, probably as a result of soil disturbance and the removal of the tree canopy, and these persisted throughout the period despite very severe competition from the vigorous grass cover and annual decapitation by mowing. In the plots mown annually at the end of the dry season, in fact, a few trees have now reached a size such that they can no longer be cut with a mower.

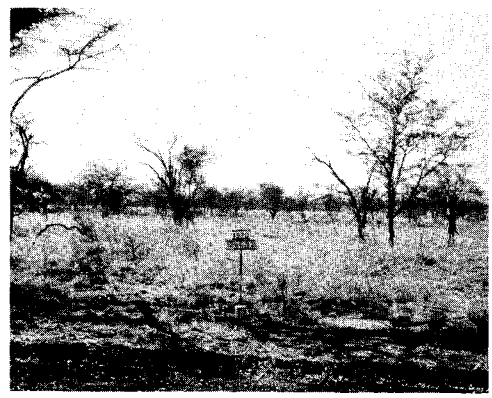
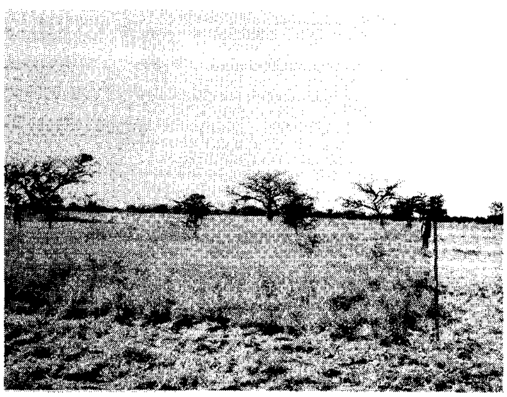
The series of droughts and years of poorly distributed rainfall experienced since the last analyses were done have helped to degrade the grass cover in all treatments and, as a result, fires have become progressively less effective and tree growth has accelerated.

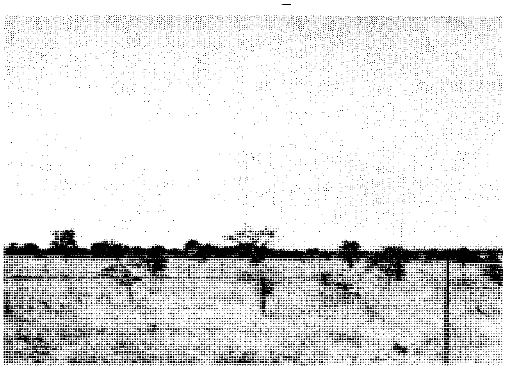
The condition of selected plots, photographed from the same place in 1948 and, again, some 19 to 22 years later, is illustrated in Figs. 1–12.

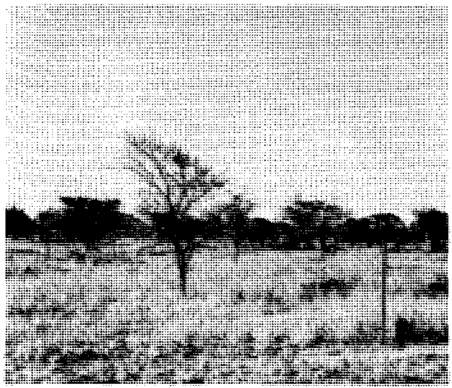
Sandveld

The Sandveld experiment is situated in vegetation typical of the sandy soils occurring on the fringe of the Matopos Hills. Soils in the experiment are, for the most part, well drained and carry a fairly well developed woodland but a few plots fall in a poorly drained area, which is relatively treeless. Sandveld vegetation is well known for its resistance to use (in contrast to that of the Thornveld, which is extremely sensitive) and the changes brought about by the treatments imposed in the experiment were much less marked than in the





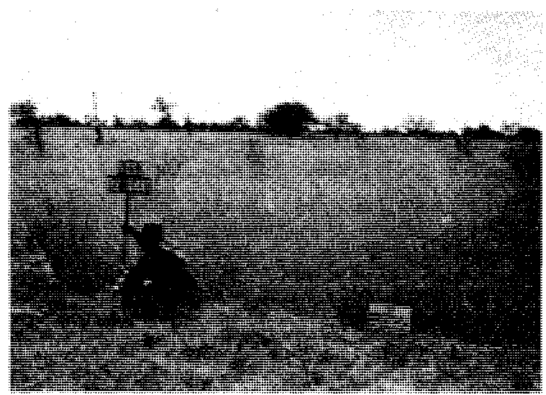


FIG. 1. Thornveld. Complete protection—October 1948. This plot is shallow-soiled and *Themeda triandra* is the dominant grass. (Photo by O. West).

FIG. 2. The same view—September 1969. Many young trees, obscured by the grass in the previous photograph, have attained a height of eight feet or more. Many others have established themselves. Most of the grasses are perennials but the cover has deteriorated and annuals are common. (Photo by A. Stead).

FIG. 3. Thornveld. Burnt annually in autumn—October 1948. Scattered acacias present a park-like effect. *Themeda triandra* and *Heteropogon contortus* are the dominant grasses. (Photo by O. West).

FIG. 4. The same view—May 1970. The grass cover is severly degraded and consists predominantly of scattered tufts of *Eragrostis atherstonei* with a little *Cymbopogon plurimodis*. There is much bare ground and small acacias are re-establishing themselves. (Photo by A. Stead).

FIG. 5. Thornveld. Burnt annually at the end of the dry season before first rains. October 1948. *Themeda triandra* and *Cymbopogon plurinodis* are the dominant grasses. (Photo by O. West).

FIG. 6. The same view—August 1969. The only perennial grass of note is *Cymbopogon plurinodis*. Burning is now ineffective and many young acacias are becoming established. Harvester termites have removed much of the top hamper. (Photo by A. Stead).

FIG. 7. Thornveld. Burnt biennially in autumn—October 1948. The soil on this plot is shallow and although the cover is fair the grasses lack vigour. *Themeda triandra is dominant* but species of *Cymbopogon* and *Heteropogon* are common. (Photo by O. West).

FIG. 8. The same view—May 1970. Cover has deteriorated and *Eragrostis atherstonei* is now dominant. Fire is no longer effective in controlling the trees. (Photo by A. Stead).

trial previously discussed. Likewise, drought effects since 1964 have been far less severe.

Basal Cover:—Data derived from the point quadrat analyses in 1949, 1957, and 1963 are presented in Table 4. Because many more species were recorded in this trial, as compared to the one on Thornveld and the inclusion of all species in the table would make it unnecessarily cumbersome, minor constituents have been grouped together as "other grasses" (see note under Table 4).

The data in Table 4 reflect changes which have taken place since 1963, when the experiment was last botanically analysed but, in discussing the results use is also made of visual observations made on the trial up to, and including, March 1971. As in the Thornveld trial, different teams of workers did each set of analyses and, again, those concerned with the 1957 operation adopted a very strict interpretation of what constituted a strike and their figures for basal cover are probably rather low. However, when converted to percentages of total cover, their data agree well with those for 1949 and 1963 and with the general trend.

Complete protection (Table 4) effected little change in basal cover between 1949 and 1963 but species composition altered to some extent. *Digitaria pentzii*, the dominant grass in 1949, decreased very considerably and gave way to *Hyperthelia dissoluta*, which more than doubled its cover and its contribution to total cover. *Pogonarthria squarrosa* also decreased to some extent but *Rhynchelytrum repens*, which was not recorded in 1949, invaded and made up 13 percent of the cover in 1963. *Heteropogon contortus*, the only other grass of any importance in either

FIG. 9. Thornveld. Burnt every third year in spring before rains set in. October 1948. Another shallow-soiled plot. Main grasses are *Cymbopogon plurinodis, Bothriochloa insculpta* and *Themeda triandra.* (Photo by O. West).

FIG. 10. The same view—October 1967. *Themeda triandra* and species of *Cymbopogon* are the dominant perennials but the cover is poor and there are many annuals. Small acacias are becoming established as fire is no longer effective in controlling them. (Photo by S. Daniels).

FIG. 11. Thornveld. Burnt every fifth year at the end of the dry season before first rains—October 1948. *Themeda triandra* is dominant but *Cymbopogon plurinodis* is very common. Many young trees are concealed by the tall grass. (Photo by O. West).

FIG. 12. The same view—August 1969. *Themeda triandra* and *Cymbopogon plurinodis* are still the dominant grasses. Control of bush has been got but some young acacias are evident in this picture. (Photo by A. Stead).

TABLE 4. PERCENTAGE BASAL COVER AND PERCENTAGE SPECIES CONTRIBUTION—1949, 1957 AND 1963—SANDVELD. (AVERAGE OF 3 PLOTS)

		% Basal Cover			% Species Contribution		
Treatment	Species	1949	1957	1963	1949	1957	1963
Complete protection	*Brachiaria nigropedata*	0.13	—	—	5.53	—	—
	Digitaria pentzii	1.07	0.13	0.27	45.53	12.26	11.74
	Eragrostis rigidior	—	0.03	0.13	—	2.83	5.65
	Heteropogon contortus	0.26	0.10	0.33	11.49	9.43	14.35
	Hyperthelia dissoluta	0.40	0.37	0.90	17.02	34.91	39.13
	Loudetia simplex	—	0.23	—	—	21.70	—
	Pogonarthria squarrosa	0.20	—	0.07	8.51	—	3.04
	Rhynchelytrum repens	—	0.17	0.30	—	16.04	13.04
	Schizachyrium jeffreysii	—	—	0.13	—	—	5.65
	Other Grasses	0.28	0.03	0.17	11.91	2.83	7.39
	Total	2.35	1.06	2.30			
Burnt annually in autumn	*Digitaria pentzii*	0.20	0.10	0.17	7.33	6.13	6.32
	Heteropogon contortus	0.80	0.33	1.57	29.30	20.25	58.36
	Hyperthelia dissoluta	0.27	0.17	0.07	9.89	10.43	2.60
	Pogonarthria squarrosa	0.33	0.20	0.13	12.09	12.27	4.83
	Rhynchelytrum repens	0.40	0.17	0.07	14.65	10.43	2.60
	Stereochlaena cameronii	0.20	0.03	—	7.33	1.84	—
	Schizachyrium jeffreysii	0.33	0.43	0.43	12.09	26.38	15.99
	Trichoneura grandiglumis	—	0.10	—	—	6.13	—
	Other Grasses	0.20	0.10	0.25	7.33	6.13	9.29
	Total	2.73	1.63	2.69			
Burnt annually at the end of the dry season before first rains	*Digitaria pentzii*	0.60	0.37	0.13	16.04	15.16	4.13
	Eragrostis rigidior	—	0.07	0.30	—	2.87	9.52
	Heteropogon contortus	1.33	0.77	0.83	35.56	31.56	26.35
	Hyperthelia dissoluta	0.33	0.23	1.13	8.82	9.43	35.87
	Hyparrhenia filipendula	—	0.23	0.10	—	9.43	3.17
	Pogonarthria squarrosa	0.20	0.10	0.27	5.35	4.10	8.57
	Rhynchelytrum repens	0.40	0.17	0.10	10.70	6.97	3.17
	Stereochlaena cameronii	0.47	0.17	—	12.57	6.97	—
	Other Grasses	0.41	0.33	0.29	10.96	13.52	9.21
	Total	3.74	2.44	3.15			
Burnt annually in spring before the rains set in	*Brachiaria nigropedata*	0.13	—	—	5.42	—	—
	Digitaria pentzii	0.67	0.30	0.13	27.92	11.11	4.11
	Eragrostis rigidior	—	—	0.17	—	—	5.38
	Heteropogon contortus	0.33	0.47	0.73	13 75	17.41	23.10
	Hyperthelia dissoluta	0.07	0.03	0.20	2.92	1.11	6.33
	Hyparrhenia filipendula	0.13	0.20	—	5.42	7.41	—
	Loudetia simplex	0.53	0.57	1.57	22.08	21.11	49.68
	Pogonarthria squarrosa	—	0.20	—	—	7.41	—
	Rhynchelytrum repens	0.20	0.20	0.17	8.33	7.41	5.38
	Schizachyrium jeffreysii	0.13	0.60	0.13	5.42	22.22	4.11
	Other Grasses	0.21	0.13	0.06	8.75	4.81	1.90
	Total	2.40	2.70	31.6			

Table 4 (Continued)

Treatment	Species	% Basal Cover 1949	% Basal Cover 1957	% Basal Cover 1963	% Species Contribution 1949	% Species Contribution 1957	% Species Contribution 1963
Burnt every second year in autumn	*Digitaria pentzii*	0.73	0.50	0.67	19.89	20.00	20.12
	Eragrostis rigidior	—	0.13	0.23	—	5.20	6.91
	Eragrostis patenti-pilosa	—	—	0.17	—	—	5.11
	Heteropogon contortus	0.47	0.37	0.90	12.81	14.80	27.03
	Hyperthelia dissoluta	1.40	1.00	0.77	38.15	40.00	23.12
	Pogonarthria squarrosa	0.40	0.07	—	10.90	2.80	—
	Rhynchelytrum repens	0.53	0.13	0.30	14.44	5.20	9.01
	Other Grasses	0.14	0.30	0.29	3.81	12.00	8.71
	Total	3.67	2.50	3.33			
Burnt every second year at the end of the dry season before first rains	*Brachiaria nigropedata*	0.20	—	0.03	7.14	—	0.75
	Diheteropogon amplectens	—	0.07	0.23	—	3.45	5.72
	Digitaria pentzii	0.33	0.13	0.43	11.79	6.40	10.70
	Heteropogon contortus	1.20	0.43	0.57	42.86	21.18	14.18
	Hyperthelia dissoluta	0.33	0.17	0.97	11.79	8.37	24.13
	Hyparrhenia filipendula	0.27	0.17	0.03	9.64	8.37	0.75
	Loudetia simplex	—	0.13	0.73	—	6.40	18.16
	Rhynchelytrum repens	0.13	0.30	0.47	4.64	14.79	11.69
	Schizachyrium jeffreysii	0.20	0.37	0.30	7.14	18.23	7.46
	Other Grasses	0.14	0.26	0.26	5.00	12.81	6.47
	Total	2.80	2.03	4.02			
Mown annually for hay	*Aristida vinosa*	0.27	—	—	5.61	—	—
	Brachiaria nigropedata	0.60	0.23	0.13	12.47	7.88	3.32
	Digitaria pentzii	0.87	0.27	0.50	18.09	9.25	12.76
	Eragrostis rigidior	—	0.20	0.20	—	6.85	5.10
	Eragrostis spp.	0.47	—	—	9.77	—	—
	Heteropogon contortus	0.33	0.50	0.80	6.86	17.12	20.41
	Hyperthelia dissoluta	0.80	0.30	0.90	16.63	10.27	22.96
	Rhynchelytrum repens	0.47	0.67	0.67	9.77	22.95	17.09
	Schizachyrium jeffreysii	—	0.27	0.37	—	9.25	9.43
	Themeda triandra	0.40	0.07	0.07	8.32	2.40	1.79
	Other Grasses	0.60	0.41	0.28	12.47	14.04	7.14
	Total	4.81	2.92	3.92			
Burnt every third year at the end of the dry season before first rains	*Aristida barbicollis*	—	—	0.13	—	—	6.91
	Brachiaria nigropedata	0.13	0.10	0.03	5.73	5.92	1.60
	Cymbopogon excavatus	—	0.17	—	—	10.06	—
	Digitaria pentzii	0.60	0.13	0.33	26.43	7.69	17.55
	Eragrostis rigidior	—	—	0.13	—	—	6.91
	Heteropogon contortus	0.33	0.43	0.67	14.54	25.44	35.64
	Hyperthelia dissoluta	0.47	0.10	0.10	20.70	5.92	5.32
	Perotis patens	—	0.10	0.10	—	5.92	5.32
	Pogonarthria squarrosa	0.27	0.23	0.03	11.89	13.61	1.60
	Rhynchelytrum repens	0.33	0.10	0.03	14.54	5.92	1.60
	Schizachyrium jeffreysii	—	0.23	0.20	—	13.61	10.64
	Schizachyrium brevifolium	—	—	0.13	—	—	6.91
	Other Grasses	0.14	0.10	—	6.16	5.92	—
	Total	2.27	1.69	1.88			

Table 4 (Continued)

Treatment	Species	% Basal Cover			% Species Contribution		
		1949	1957	1963	1949	1957	1963
Burnt every third year in spring before the rains set in	*Digitaria pentzii*	0.33	0.77	0.63	12.69	30.08	16.36
	Heteropogon contortus	0.87	0.73	2.40	33.46	28.52	62.34
	Hyperthelia dissoluta	1.07	0.43	0.67	41.15	16.80	17.40
	Hyparrhenia filipendula	—	0.23	—	—	8.98	—
	Pogonarthria squarrosa	0.13	0.07	0.03	5.00	2.73	0.78
	Rhynchelytrum repens	0.13	0.07	—	5.00	2.73	—
	Other Grasses	0.07	0.26	0.12	2.69	10.16	3.12
	Total	2.60	2.56	3.85			
Burnt every fifth year at the end of the dry season before first rains	*Cymbopogon excavatus*	—	0.10	—	—	6.94	—
	Digitaria pentzii	0.40	0.17	0.67	13.33	11.81	21.34
	Eragrostis sporoboloides	—	—	0.17	—	—	5.41
	Eragrostis spp.	0.33	0.20	0.10	11.00	13.89	3.18
	Heteropogon contortus	—	0.07	0.40	—	4.86	12.74
	Hyperthelia dissoluta	0.33	0.27	0.30	11.00	18.75	9.55
	Hyparrhenia filipendula	0.20	—	—	6.67	—	—
	Loudetia simplex	0.53	0.30	1.27	17.67	20.83	40.45
	Schizachyrium jeffreysii	—	0.17	0.07	—	11.81	2.23
	Unidentified Grasses	0.80	—	—	26.67	—	—
	Other Grasses	0.41	0.16	0.16	13.67	11.11	5.10
	Total	3.00	1.44	3.14			
Mown annually at the end of the dry season before first rains	*Cymbopogon excavatus*	—	0.13	—	—	6.34	—
	Digitaria pentzii	0.53	0.20	0.20	13.02	9.76	4.84
	Eragrostis sporoboloides	—	—	0.50	—	—	12.11
	Eragrostis spp.	1.33	0.40	—	32.68	19.51	—
	Heteropogon contortus	1.33	0.50	1.93	32.68	24.39	46.73
	Hyperthelia dissoluta	0.07	0.10	0.77	1.72	4.88	18.64
	Hyparrhenia filipendula	0.07	0.23	—	1.72	11.22	—
	Rhynchelytrum repens	0.47	0.07	0.17	11.55	3.41	4.12
	Schizachyrium jeffreysii	0.13	0.20	0.17	3.19	9.76	4.12
	Other Grasses	0.14	0.22	0.39	3.44	10.73	9.44
	Total	4.07	2.05	4.13			

Note. "Other Grasses" included *Aristida barbicollis, A. congesta, A. meridionalis, A. pilgeri, A. vinosa, Brachiaria humidicola, B. nigropedata, Cynodon dactylon, Cymbopogon excavatus, Diheteropogon amplectens, Eragrostis chapelieri, E. rigidior, Eragrostis* spp., *Hyparrhenia filipendula, Loudetia simplex, Microchloa kunthii, Perotis patens, Pogonarthria squarrosa, Rhynchelytrum repens, Schizachyrium jeffreysii, Setaria pallide-fusca, Trichoneura grandiglumis*, and a few unidentified grasses.

Although many of these are also listed in the above table this has only been done where they happened to contribute more than 5% of total basal cover in one or more years in any one treatment. *Aristida barbicollis*, for instance, contributed 6.91% of total basal cover in 1963 in the "burnt every third year at end of dry season before first rains" treatment. It is thus listed individually under that treatment. It also occurred in four other treatments but, as its contribution was less than 5% in each of these, it was grouped, with other minor constituents, under "Other Grasses".

year, increased very slightly. The main change by 1971 was that *Hyperthelia dissoluta* although still common, was not so strongly dominant and that the amount of *R. repens* was much reduced.

Total basal cover was little affected by treatment in the plots burnt annually in autumn and no great change in composition occurred. However, *Heteropogon contortus*, the dominant in 1949, doubled both its cover and contribution and was very strongly dominant in 1963 at the expense of *Hyperthelia dissoluta*, *Rhynchelytrum repens*, *Pogonarthria squarrosa* and *Stereochlaena cameronii*, all of which decreased to some extent. *Schizachyrium jeffreysii* withstood the treatment imposed very well and showed a slight tendency to increase.

In this treatment *H. contortus* was still the dominant in all plots in 1971 and the basal cover was fairly good. *Aristida barbicollis*, however, was very common in one plot and fairly common in the other two, one of which also contained appreciable quantities of *Digitaria pentzii*.

Except for the fact that neither *Schizachyrium jeffreysii* nor *Stereochlaena cameronii* occurred in the plots burnt every second year in autumn the changes in this treatment were almost identical to those outlined above. In this case, *H. dissoluta* was the original dominant but, as with annual autumn burning, it decreased and *H. contortus* became dominant. *Digitaria pentzii*, a comparatively important species in the biennially burnt plots but a minor species in the annually burnt ones, behaved similarly in both cases and showed little change.

H. contortus was still very common throughout the treatment in 1971 but in two of the plots *Eragrostis rigidior* and other *Eragrostis* species were, together, dominant. In the third, *Digitaria pentzii* was very common but not as much so as *H. contortus*. *H. dissoluta* had virtually disappeared from both treatments.

H. dissoluta responded strongly to annual burning at the end of the dry season before first rains and was dominant in 1963, having been a minor contributor in 1949. *Eragrostis rigidior* was the only other species to increase to any extent with this treatment. Total cover deteriorated during the 14 year period as did the cover of *H. contortus*, which was dominant in 1949, *Digitaria pentzii*, *Rhynchelytrum repens* and *Stereochlaena cameronii*.

Further changes had taken place by 1971, by which time *H.*

dissoluta had largely disappeared (probably because of drought) and *H. contortus*, *Eragrostis rigidior* and *Aristida barbicollis* were the visual dominants.

Burning at the end of the dry season before first rains every second year also caused *H. dissoluta* to increase and become dominant. Other increasers were *Diheteropogon amplectens*, *Loudetia simplex* and *Rhynchelytrum repens*, the latter reacting differently to its behaviour in the annually burnt treatment discussed above. Total cover was much improved. The cover of *Hyparrhenia filipendula* and *H. contortus* which was the 1949 dominant, decreased quite considerably, but *Digitaria pentzii* showed little change. The latter grass, with *H. contortus* and, in one plot, *Aristidas barbicollis* were the dominants in 1971 *H. contortus* having largely disappeared.

Burning triennially at the same time of year resulted in reduced total cover and a reduction in the cover of species of *D. pentzii*, *H. dissoluta*, *Pogonarthria squarrosa* and *R. repens*, *H. contortus*, and *Schizachyrium jeffreysii* both increased, the former becoming dominant, at the expense of *D. pentzii. Schizachyrium brevifolium* (an annual), *Aristida barbicollis*, and *Eragrostis rigidior* were recorded for the first time in 1963, although all were still minor constituents. There was no obvious change in total cover by 1971 but *D. pentzii*, *H. contortus*, and *E. rigidior* were visually dominant.

The reaction of the grasses in this treatment, between 1949 and 1963, is at variance with that of grasses in the two preceding treatments and is difficult to explain. In particular, no reason can be advanced for the deterioration in total cover.

Where burning was done at the end of the dry season every five years there was little change in total cover but, because unidentified species contributed over 26 percent of the cover in 1949, it is difficult to assess the changes that took place with any accuracy. *Loudetia simplex* was the main increaser, with *D. pentzii*, *H. contortus* and *Eragrostis sporoboloides*, the last two not having been recorded in 1949. Decreasers were other *Eragrostis* species and *Hyparrhenia filipendula*. All grasses were identified in 1963 and some of the conclusions reached above may be wrong as it is difficult to believe that all those not identified in 1949 had disappeared. The cover was still fairly good in 1971 by which time *Schizachyrium jeffreysii* various species of *E. rigidior* and *D. pentzii* were the commonest grasses. In one plot *H. dissoluta* was also common but it was absent in the other two.

With the exception of *H. contortus*, grasses common to both treatments burnt in spring before the rains set in did not behave in similar fashion. Both annual and triennial burning seemed to favour *H. contortus*, which increased very considerably in both treatments but *D. pentzii* decreased a lot with annual burning but increased when burnt every three years. *H. contortus* acted oppositely by showing a slight increase when burnt annually and a decrease in the triennially burnt treatment. *Loudetia simplex* increased a great deal with annual burning but did not occur in the other treatment. Total cover increased in both cases and dominants changed from digitaria–loudetia to loudetia–heteropogon in the annual plots and from hyperthelia-heteropogon to *H. contortus* with some *H. dissoluta* and *D. pentzii* in the triennial.

No big changes had taken place in either treatment by 1971 but *Aristida vinosa* was common in one annually burnt plot as was *Eragrostis rigidior* in one triennially burnt plot. *H. dissoluta* was no longer an important constituent of the sward in the latter treatment.

Both mowing treatments favoured *H. dissoluta* and *H. contortus* and caused *D. pentzii* and *E. rigidior* to decrease. *R. repens* however, increased with summer mowing but decreased when mown at the end of the dry season. *Schizachyrium jeffreysii* also increased with summer mowing but its cover was little changed by dry season mowing. Some species only occurred in one of the treatments and, in the case of summer mowing, the most important of these were *Eragrostis rigidior*, which increased, and *Aristida vinosa, Brachiaria nigropedata*, and *Themeda triandra* which decreased. *Eragrostis sporoboloides* was recorded for the first time in the dry season mowing treatment in 1963, by which time it was one of the more important components of the sward.

Neither treatment seemed to have altered to any great extent when inspected in 1971 apart from the fact that *Aristida barbicollis* was fairly common in both.

Effect on trees and bushes:—As was the case in the Thornveld trial, neither the tree counts done in 1949 and 1964 in the quadrats, nor those done in 1963, in the plots as a whole, are of much assistance in assessing the effects of burning on the woody species. Numbers involved in the quadrats were too small to be meaningful, and the whole-plot counts are confused by the irregular distribution of trees when the experiment started. As previously stated, some plots fall within a poorly drained, and relatively tree-less, area and others contain large termitaria which invariably carry a dense tree population. Because of excessive competition from trees on termitaria these seldom produce sufficient grass to provide a fire sufficiently intense to affect the trees. Thus, in treatments so affected, the counts were high and in those where some plots fell within poorly drained areas, the counts were low. It is not possible to correct for these factors accurately, with the data available, but an attempt has been made to provide a more realistic picture of treatment effects by increasing the figures for total trees per treatment in those treatments affected by poor drainage and by decreasing those where termitaria occur within treatments. These adjusted totals, which are purely arbitrary estimates, but which are based on figures for plots not affected by these factors and on thorough knowledge of the plots concerned, are presented in brackets in the last column of Table 5. All other figures in the table are actual counts of tree and bushes in the quadrats (1949 and 1964) and in the plots as a whole (1963 only).

In four of the treatments (Table 5) it has been considered necessary to adjust total trees per treatment to allow for unusually large termitaria and/or areas of poor drainage. These adjustments cannot be taken as factual but are thought to give a more realistic impression of what the case would be had all plots within the treatment concerned been unaffected by large temitaria or poor drainage. In some other cases, when one plot of a treatment was poorly drained, whereas another contained a termitarium, no adjustment has been made as the data from the two plots were regarded as compensatory. Treatments with adjusted totals are:

Complete protection. The total number of trees in each of the three plots were 140 (a very poorly drained plot) 865 and 584, giving a total of 1589. It is considered that 2000 would be a more realistic, but conservative figure, were all plots well drained.

Burnt every second year in autumn. One plot in this treatment contains a very large termitarium and the total plot count was

TABLE 5. TREATMENT TOTALS OF TREES AND BUSHES IN QUADRATS (1949 AND 1964) AND WHOLE PLOTS (1963 ONLY) BY HEIGHT CLASSES—SANDVELD. (TOTALS FOR THREE QUADRATS OR PLOTS)

Treatment		Height Class					
		0″–6″	6″–1′	1′–3′	3′–10′	Over 10′	Total
Complete protection	Quadrat—1949	5	—	1	—	—	6
	Quadrat—1964	2	—	5	1	—	8
	Plot —1963	201	317	651	354	66	1589 (2000)
Burnt annually in autumn	Quadrat—1949	2	—	1	—	—	3
	Quadrat—1964	—	—	2	—	—	2
	Plot —1963	161	260	249	13	17	700
Burnt annually at the end of the dry season before first rains	Quadrat—1949	8	1	—	—	—	9
	Quadrat—1964	2	4	2	—	—	8
	Plot —1963	141	255	369	9	15	789
Burnt annually in spring before rains set in	Quadrat—1949	2	2	—	—	—	4
	Quadrat—1964	3	3	—	—	—	6
	Plot —1963	149	221	261	25	27	683
Burnt every second year in autumn	Quadrat—1949	7	—	—	—	—	7
	Quadrat—1964	5	5	2	—	—	12
	Plot —1963	186	262	1284	141	37	1910 (800)
Burnt every second year at the end of the dry season before first rains	Quadrat—1949	—	—	—	—	—	0
	Quadrat—1964	1	—	—	—	—	1
	Plot —1963	94	208	417	37	14	770
Mown annually for hay	Quadrat—1949	3	2	—	—	—	5
	Quadrat—1964	8	5	—	—	—	13
	Plot —1963	246	467	279	0	1	993
Burnt every third year at the end of the dry season before first rains	Quadrat—1949	6	5	1	—	—	12
	Quadrat—1964	2	7	2	—	—	11
	Plot —1963	78	320	234	18	28	678
Burnt every third year in spring before rains set in	Quadrat—1949	2	4	3	—	—	9
	Quadrat—1964	2	1	1	—	—	4
	Plot —1963	138	477	434	33	39	1121 (700)
Burnt every fifth year at the end of the dry season before first rains	Quadrat—1949	1	5	—	—	—	6
	Quadrat—1964	—	3	5	—	—	8
	Plot —1963	45	213	210	20	15	503
Mown annually at the end of the dry season before first rains	Quadrat—1949	6	1	—	—	—	7
	Quadrat—1964	6	4	2	—	—	12
	Plot —1963	230	206	241	47	11	735 (600)

Note (1) Figures in brackets are *estimates* of tree numbers that could be reasonably expected if the treatment concerned was not affected by either poor drainage or by termitaria. They cannot be regarded in any way as factual and are, at best, calculated guesses.

(2) When the trees and bushes were counted in the plots as a whole in 1963 a total of 59 species from 50 genera were recorded. There were 10471 plants of which the commonest were *Terminalia sericea* (1754), *Burkea africanum* (1110), *Dombeya rotundifolia* (856), *Diospyros sericea* (825), *Euclea divinorum* (629), *Turraea nilotica* (597), *Grewia* spp. (423), *Pappea capensis* (408), *Flacourtia indica* (319), *Maytenus senegalensis* (287), *Combretum apiculatum* (209), *Securinega virosa* (200), *Pterocarpus rotundifolia* (161), *Dichrostachys cinerea* (157), *Bridelia mollis* (111), and *Acacia rehmanniana* (111).

1015; another with a smaller termitarium contained 523 trees. A total of about 800 for the three plots would be more realistic.

Burnt every third year in spring before rains set in. One plot contained a large termitarium and 704 trees, whereas the other two contained 266 and 151 trees. The total of 700 for the treatment would be generous.

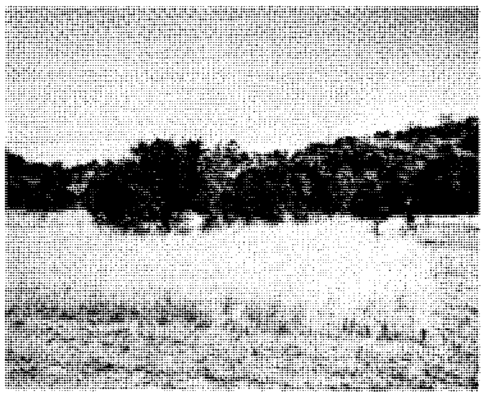
Mown every year at the end of the dry season. A small rocky outcrop in one plot, where mowing is impossible, contains numerous trees. The total for the treatment has been adjusted to 600.

The data (Table 5) show that, as in the Thornveld trial, more trees were present in the protected plots than in most other treatments (and, in fact, in all other treatments if the adjusted totals are accepted as fair estimates). They also show that a much greater proportion of the total trees in this treatment exceeded three feet in height, than in any other treatment. It can therefore be concluded that fire not only exercised a considerable controlling influence on the establishment of new plants but that it also retarded the growth of plants that existed when the trial started. Conversely, it can be concluded that, in the absence of any method of controlling bush encroachment, trees and bushes increase and quickly assume overwhelming dominance over the grasses.

Again, as in the Thornveld trial, more species (43) were recorded in the protected plots than in those of any other treatment, totals for those burnt or mown ranging from 29 to 41. Only two species, *Elephantorrhiza suffruticosa*, of which there were four plants, and *Erythrina tomentosa* of which there was only one, occurred solely in the protected plots and distribution of species appeared, again, to depend more on the original distribution of species and communities than on treatment. However, because most young specimens of certain species occurred within the protected plots it would seem logical to assume that these are less fire tolerant than most others. Nevertheless, all these also occurred in some of the burnt plots and are frequently encountered elsewhere in vegetation regularly subjected to burning and so it cannot therefore be said that they will *not* survive and multiply in vegetation that is periodically burnt. The species concerned were *Albizzia antunesiana*, *Rhus pyroides*, *R. erosa*, *Pappea capensis*, and *Pouzolzia hypoleuca*.

Because the numbers involved were so small, little can be deduced





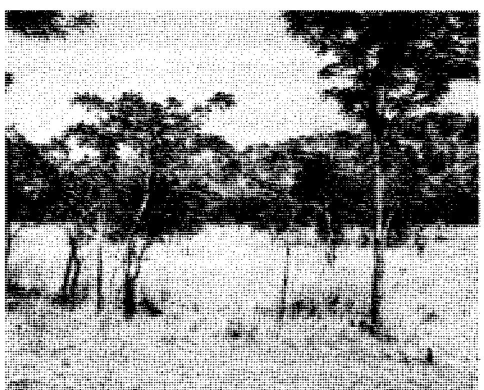



FIG. 13. Sandveld—complete protection—October 1948. *Digitaria pentzii* is the dominant grass. (Photo by O. West).

FIG. 14. The same view—October 1965. The trees of which there are a great variety, have increased considerably in density. Basal cover and vigour of the grasses has been reduced. (Photo by S.S. Daniels).

FIG. 15. Sandveld. Burnt annually in autumn–October 1948. *Heteropogon contortus* is the dominant grass. (Photo by O. West).

FIG. 16. The same view—May 1970. *Heteropogon contortus* is still dominant but *Aristida barbicollis* is now common. (Photo by A. Stead).

FIG. 17. Sandveld. Burnt annually in spring before rains set in. October 1948. (Photo by O. West).

FIG. 18. The same view—August 1969. Burning has had no apparent effect on the trees which were too big to be affected seriously by fire at the start of the trial. (Photo by A. Stead).

FIG. 19. Sandveld. Burnt every third year in spring before rains set in—October 1948. *Heteropogon contortus* and *Digitaria pentzii* are the chief grasses seen in the picture. (Photo by O. West).

FIG. 20. The same view—October 1967. Burning has improved the view by retarding the growth of small trees and bushes and by destroying some of the lower branches of the bigger trees, none of which show serious signs of damage. Basal cover is considerably improved and *Heteropogon contortus* is dominant. (Photo by S.S. Daniels).

FIG. 21. Sandveld. Burnt every fifth year at the end of the dry season before first rains. October 1948. (Photo by O. West).

FIG. 22. The same view—August 1969. Basal cover has improved and *Loudetia simplex* is the dominant grass. Although there is not much change in the vegetation some young trees have increased in height. (Photo by A. Stead).

from the quadrat counts, and for the same reason no conclusions regarding treatments effects can be drawn. Observations during the course of the trial, however, indicated that burning had much the same effect on the Sandveld trees as in the Thornveld and that, provided grass growth was sufficient to provide a hot fire, best control was obtained by burning frequently. Apart from some indication that burning biennially in autumn was ineffective in preventing encroachment and that burning triennally in spring had useful effects, there was little difference between the other burning treatments insofar as effect on trees was concerned. Mowing was apparently less effective than most of the burning treatments in preventing encroachment.

The condition of selected plots, photographed from the same place in 1948 and, again, 17 to 19 years later, is illustrated in Figs. 13–22.

CONCLUSIONS AND DISCUSSIONS

The effects of the various treatments in the two trials are somewhat confused and occasionally conflicting. Nevertheless, some conclusions based on the point quadrat and tree count data, and on visual observations, can be drawn.

THORNVELD

It is clear from the point quadrat data that total basal cover was reduced by annual burning and by complete protection. Observations showed that the vegetation in the annually burnt treatments usually collapsed suddenly, with the autumn burnt treatment collapsing first and the spring one last. In the protected plots deterioration was more gradual and came about as grasses became choked with dead top-hamper and as the encroaching trees became more dominant.

Reduction in basal cover in the annually burnt plots resulted from the destruction of useful perennial grasses but an increase of annual species provided partial compensation. The latter, however, have small basal attachments and were seldom struck by the pins when the botanical analyses were done, with the result that different impressions were gained from the figures and from visual observations. Data indicate that annuals made but a small contribution to basal cover in 1963 but, to the eye, these grasses were very common, if not dominant, in all annually burnt plots at that time. When these died at the end of each rainy season they soon disintegrated and left large areas of bare ground between the surviving perennial tufts. Lack of ground cover and crusting of the exposed soil surface led to excessive run-off during the subsequent rainy seasons and to a further loss of vigour in the perennial species, the effects being so marked that even the untrained observer could not but agree that these treatments had resulted in serious damage to cover and to a vast change in species composition.

Basal cover was also reduced to some extent in the treatment burnt triennially in spring. In this case, however, observations showed that the remaining perennials were extremely vigorous and that no, or very few, annuals were present in 1963, plots having a completely different appearance to those burnt annually. A study of the data indicates that the reduction in cover was brought about by the virtual disappearance of *Bothriochloa insculpta* (a grass very sensitive to burning and which was extremely common in this treatment in 1949) and by a large decrease in *Cymbopogon plurinodis*. These decreases were not entirely balanced by a very large increase of *Themeda triandra*.

Total cover improved in all other burning treatments between 1949 and 1963 and the greatest improvement was in the treatment burnt triennially at the end of the dry season. At the time of the last analysis it was apparent that those burnt biennially were beginning to react adversely to the treatments imposed and that the perennial species were losing vigour. Here again, although this is not reflected by the data, annuals had invaded to a considerable extent. In contrast the plots burnt triennially and every fifth year at the end of the dry season carried a very vigorous cover of perennial grasses and annuals were rare or non-existent.

The two mowing treatments undoubtedly had the best effect on cover. In both cases cover improved very considerably immediately after the trees were removed in preparation for mowing and this improved still further during the course of the trial. In 1963 the grasses in both treatments were extremely vigorous and were almost all perennials.

The reaction of the various grasses to the treatments was somewhat variable and less clear cut. Also, because many only occurred in a few of the treatments no definite trends can be established for all species. Of the commoner species reactions were as follows:

Bothriochloa insculpta was found to be sensitive to burning and decreased considerably in all treatments. It also decreased in both mowing treatments and under complete protection. This would appear to be a grass that thrives best when grazed as it is clearly sensitive to fire, and quickly becomes choked by top-hamper when protected, but was found in a previous trial to persist strongly when heavily grazed for prolonged periods (Kennan, 1969).

Themeda triandra decreased a little with protection and to a considerable extent in the annually and biennially burnt treatments (except in the biennial autumn burn where it increased). In both mowing treatments and the triennial and quinquennial burns it increased strongly. It would thus appear to flourish with infrequent burning but to be destroyed when burning takes place frequently.

Heteropogon contortus was rather variable in its reaction and decreased considerably in the plots burnt annually in autumn and in both mowing treatments. It also decreased slightly with annual spring burning but increased a little with annual burning at the end of the dry season and with biennial autumn burning. In the remaining treatments it increased or showed little change and would therefore appear to be moderately sensitive to frequent burning and to mowing in either summer or in the dry season.

Cymbopogon plurinodis, too, varied in its reaction and, although it increased considerably with summer mowing and to a small extent with burning annually in autumn or in spring it decreased with protection and all other treatments. It would appear to be relatively tolerant of frequent burning but, perhaps because it is a species that accumulates a large amount of top-hamper when not defoliated for a period of years, intolerant of protection and of burning at intervals of two or more years. Its intolerance of late dry season mowing is difficult to explain but this may be due to the fact that it is a species that commences growth before the onset of the rains and is thus seriously affected by defoliation at that time. This could be a contributory cause, too, for its sensitivity to infrequent burning, at the end of the dry season and in spring.

No other grass contributed sufficiently to the sward, or occurred in sufficient treatments, for firm conclusions to be drawn. However, it was apparent that annuals such as *Brachiaria eruciformis* and *Digitaria ternata* were encouraged by frequent burning and were discouraged by infrequent burning. Other annuals that behaved similarly but that were not recorded were *Eragrostis patenti-pilosa* and *Aristida scabri-*

valis. The latter, in particular, was very common in the annually and the biennially burnt plots in 1963 but being extremely fine stemmed was never recorded.

The experiment clearly showed that fire has considerable retarding influence on the establishment and on the growth rate of trees and bushes and confirms the views of West (1965). In the protected plots trees increased rapidly in both number and size to the detriment of the grass cover, but in all burning treatments growth rate was retarded through the killing of the aerial parts of the plants and encroachment was slowed, if not prevented. Until the grass cover deteriorated and there was insufficient grass fuel, the best control of woody species was achieved with annual burning, but in the later stages of the trial these treatments became progressively less effective and there was evidence that trees were re-establishing or increasing rapidly in size, whilst control in the infrequently burnt plots remained satisfactory.

Burning usually caused complete defoliation of trees but permanent damage seldom occurred at heights in excess of about six feet. Thus, in the case of the bigger trees only the lower branches were killed but all aerial portions of smaller trees were frequently killed to ground level. Complete killing, except perhaps of seedlings, was extremely rare and the small trees thus damaged usually regrew vigorously and, by the time burning took place again, the height of the regrowth exceeded that of the stem killed in the previous fire.

Generally speaking, damage to trees was greatest when burning took place in spring, after the trees had flushed, but as complete killing was so rare this effect was difficult to assess.

The experiment confirms that Thornveld vegetation can be regarded as fire sub-climax. The species occurring have undoubtedly evolved and persisted under a regime of periodic burning and there is considerable evidence that, in the absence of fire, the succession advances.

It is also clear that this vegetation type is extremely sensitive and that, if misused or affected by severe drought, it rapidly becomes degraded. This opinion is substantiated by the fact that when the experiment was examined in 1971 the cover of all plots, irrespective of treatment, had deteriorated severely although these views cannot be verified factually (no measurements were made), it was clear that drought was the main contributory cause of over all collapse. Barnes (1971) holds the same view and asserts that grass cover in the Thornveld has deteriorated, in recent years, wherever it has been subjected to any form of use.

Other factors with a bearing on the results obtained have been the occasional grazing of early-burnt plots by wild animals and, in recent years, depredations by harvester termites (*Hodotermes mossambicus*). These insects are known to be capable of removing all grass encompassed by their very extensive feeding areas and Barnes (1971) has observed that they have recently invaded the experiment, especially the more frequently burnt plots, and that their harvesting activities have hastened the death of many useful perennial grasses.

The overall deterioration that has taken place since 1964 has resulted in poor fires and reduced competition from grasses. Trees have thus been enabled to grow with little hindrance and are becoming progressively more obvious in plots where, until 1963, bush was effectively controlled. Other notable changes are that *Themeda triandra* has largely disappeared from the experimental area and that *Eragrostis atherstonei* has increased, especially in some of the autumn burnt plots where it is now the dominant perennial. Annual grasses have increased throughout the trial but are rare in plots dominated by *Eragrostis atherstonei.*

Sandveld

The Sandveld vegetation was very much more resistant to the treatments imposed than that of the Thornveld. Changes were smaller and less spectacular and were more variable between treatments. Trends are therefore more difficult to define.

In most cases changes in total basal cover, between 1949 and 1963, were relatively small. It decreased slightly with protection as well as with both autumn burnt treatments, annual summer mowing and annual and triennial burning at the end of the dry season, but improved to some extent in all other treatments. As these changes were mostly small, the somewhat variable reaction could have been partly due to operator error when the analyses were done but it seems clear that, in general, cover deteriorated under protection and with frequent burning, as it did in the Thornveld. No reason can be advanced for the apparently anomalous small decrease in cover as a result of summer mowing and triennial burning at the end of the dry season. Again, as found in the Thornveld, the grasses in the mown plots responded to the removal of the trees at the start of the trial and the cover in 1949 was good, as it still was in 1963.

The reaction of individual species was also variable and few trends emerged.

The cover of *Digitaria pentzii*, a low growing stoloniferous species, decreased considerably with protection and to a smaller extent with all other treatments except those burnt biennially and quinquennially at the end of the dry season and triennially in spring. Its adverse reaction to mowing is not understood but this could be partly due to the shading effects of taller grasses, which increased, and to damage to its extremely long and tenuous stolons, which are normally weakly rooted, by raking after mowing. This species has been found to be extremely resistant to prolonged heavy grazing (Kennan, 1969) but is apparently sensitive to protection, to mowing and to frequent burning.

Eragrostis rigidior increased in all treatments and although some of the changes were small no clear trend could be detected.

Heteropogon contortus was adversely affected by annual and biennial burning at the end of the dry season but its cover increased in all other treatments although this increase was very small with protection. The behaviour of this species, when burnt or protected, was similar to its behaviour in the Thornveld but opposite results were obtained in the mowing treatments and these cannot be explained. *Schizachyrium jeffreysii* did not occur in all plots but appeared to react in simiar fashion to *Heteropogon contortus*.

Hyperthelia dissoluta decreased in both autumn burnt treatments and in those where intervals between burns was three years or more, but increased in all others. It would thus appear to be tolerant of frequent burning in the late dry season or spring but to be sensitive to frequent autumn fires and infrequent late burning.

No other species occurred in sufficient treatments, or was common enough, for trends to be established.

The poor seasons experienced since 1964 had far less effect in the

Sandveld than in the Thornveld, further confirming the resistance of the Sandveld to use and adverse conditions. When the plots were examined in 1971 little change could be detected visually apart from the fact that *Hyperthelia dissoluta* had decreased considerably and that *Aristida barbicollis* and *A. vinosa* were more common, especially in the frequently burnt plots.

Trees and bushes in the experiment, although mostly different to those recorded in the Thornveld, behaved similarly in both vegetation types, the main finding being that fire exercised considerable control over the establishment and growth rate of woody species.

In a similar trial at Nyamandhlovu Experiment Station which is situated in country somewhat drier, but considerably hotter, than Matopos, results very similar to those of the Thornveld trial were obtained. After 15 years of treatment the cover of the more desirable species was found to be, in general, greatest in the mowing and infrequently burnt treatments and least in the frequently burnt ones. The less desirable species were found to have reacted oppositely and were especially numerous in the treatments burnt annually in autumn and at the end of the dry season. Annual species, because the Station enjoys a less effective rainfall than does Matopos, were more prevalent throughout. Again, although bush increased in all treatments, this increase was greatest in the protected plots.

At Grasslands Research Station, Marandellas, where the soils are sandy and derived from granite, and where the climate is considerably cooler and wetter (36 inches per annum) a trial was conducted to study the effects of burning, and burning assisted by mattocking, on coppice regrowth of *Brachystegia spiciformis* and *Julbernardia globiflora*. Plots were either not burned or burnt in October at intervals of one, two, three, and four years. In half of each the coppice growth was mattocked in the April preceding burning. Barnes (1965) who reported the results of the trial found that the rate of coppice regrowth decreased as burning frequency increased and that mattocking in the April preceding the burn in the following October resulted in a further reduction in vigour. He concluded that as burning is impracticable, in veld that is grazed, more frequently than once in three or four years, it alone is insufficient to control coppice growth of the species tested and that in the absence of any suitable chemical method, burning and mattocking should be regarded as complementary treatments.

A further burning trial was laid down in the Rhodesian low veld at Tuli Experiment Station, where temperatures are very high and rainfall is low (about 17 inches per annum) and extremely erratic. The bush, principally *Colophospermum mopane*, *Combretum* spp., and *Grewia* spp., is very dense and the grass cover is poor. A large proportion of the grasses are annuals. However, after a few years, the trial was abandoned as it was soon found that burning in any regular sequence was impossible owing to the enormous variation in rainfall, and consequently grass growth from year to year.

All the results reported above are derived from trials in which there has been no grazing. Numerous other trials, in which burning with grazing has been employed, have been conducted in various centres in Rhodesia and as a result of these, burning is commonly advocated as a management tool for the control of bush. Results indicate that fire can, indeed, be a useful tool if used wisely. Where grazing is withheld for a full growing season before burning and for six to eight weeks afterwards, and where burning is done very late in the dry season, at intervals of not less than about four years, good control of bush has been achieved without lasting damage to the grasses. Despite this, however, the results of the two burning trials reported above indicate that, if a run of adverse seasons occurs, damage that may take many years to repair can be caused, even with the most lenient of burning treatments. The need for other forms of bush control that are economic, safe and effective cannot, therefore, be too strongly stressed.

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