Savanna ecosystem project— Progress report 1974/75

S M Hirst

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National Programme for Environmental Sciences

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PREFACE

The Savanna Ecosystem Project of the National Programme for Environmental Sciences is one of several national scientific programmes administered by the CSIR. The National Programme is a cooperative undertaking of scientists and scientific institutions in South Africa concerned with research related to environmental problems. It includes research designed to meet local needs as well as projects being undertaken in South Africa as contributions to the international programme of SCOPE (Scientific Committee on Problems of the Environment), the body set up in 1970 by ICSU (International Council of Scientific Unions) to act as a focus of non-governmental international scientific effort in the environmental field.

The Savanna Ecosystem Project being carried out at Nylsvley is a joint undertaking of more than thirty scientists from the Department of Agricultural Technical Services, the Transvaal Provincial Administration, the National Parks Board, the CSIR, the Transvaal Museum, and eight universities. As far as this is possible, participating laboratories finance their own research within the project. The shared facilities at the study area and the research of participating universities and museums is also financed from a central fund administered by the National Committee for Environmental Sciences and contributed largely by the Department of Planning and the Environment.

The research programme of the savanna ecosystem project was described in Report 1 of this series. The present report summarises the findings of the first year, July 1974 to June 1975.

CURRENT TITLES IN THIS SERIES

1. A description of the Savanna Ecosystem Project, Nylsvley, South Africa. December 1975. 24 pp.

2. Sensitivity analysis of a simple linear model of a savanna ecosystem at Nylsvley. W M Getz and A M Starfield. December 1975. 18 pp.

3. Savanna Ecosystem Project - Progress Report 1974/1975. S M Hirst. December 1975. 27 pp.

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INTRODUCTION

The period under review was devoted essentially to a pilot study of the *Burkea* ecosystem, which aimed at an initial, albeit crude, quantitative appraisal of the total system to define the overall structure and the most important energy and material flowpaths and ecosystem controlling factors. The direction and depth of study of separate components and processes will be largely determined by a review of pilot study results towards the end of 1975. Severe shortages of professional manpower limited the pilot study in certain areas, notably the measurements of the magnitudes and rates of plant litter accumulation and decomposition, and in studies of the major ungulate herbivores within the system.

Four projects were completed during the early part of 1975, these all related to studies of the structural features of the soils and vegetation of the study area (Coetzee et al. 1975, Harmse 1975, Lubke et al. 1975, Van Rooyen and Theron 1975).

CLIMATE AND WEATHER

The general climate prevailing over Nylsvley is well-documented (Weather Bureau 1954, 1965). Mean annual rainfall is 630mm. Rainfall is eratic, and over a period of 30 years several drought periods with concomitant severe moisture stress have been recorded. The mean number of rain days per year is 62, and 85-90 percent of the rainfall normally falls in the period October through March. Mean monthly maximum temperatures can reach 35°C during the period November through January, and mean monthly minimum can drop to -5°C during May, June and July. Ground frosts are common in June and July. Figure 1 summarizes the general climate of the Nylsvley area in the form of a climate diagram (Walter 1971).

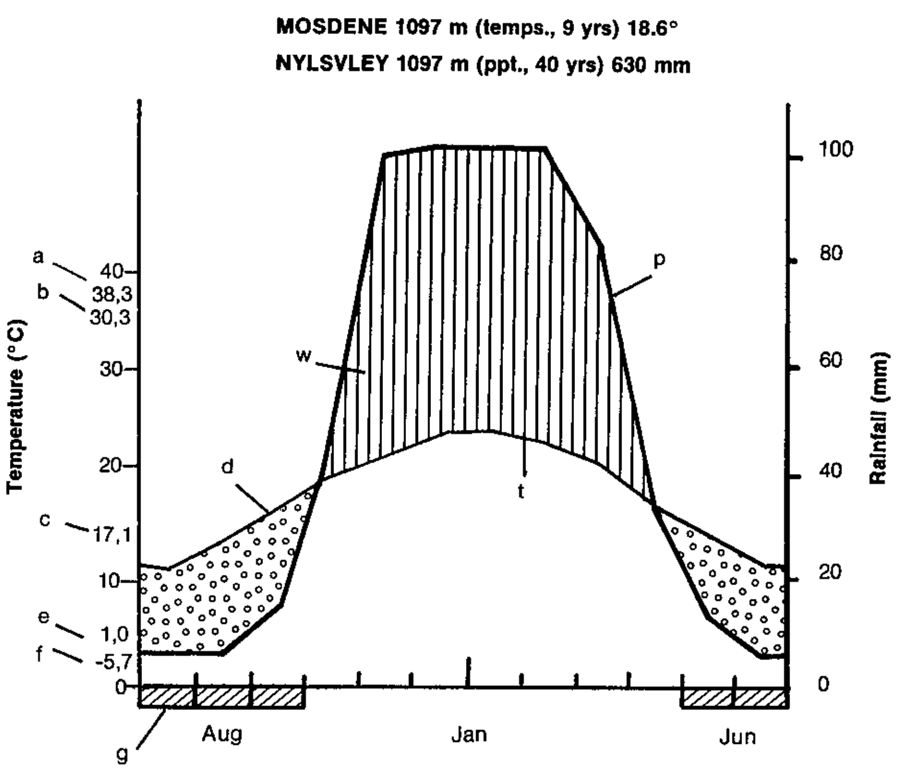

Figure 1. Climate diagram for Nylsvley showing mean monthly temperatures and mean monthly rainfall values. Key :- a - absolute maximum; b - mean daily maximum of the hottest months; c - mean daily range of temperature; d - arid period (dotted area); e - mean daily minimum of the coldest month; f - absolute minimum; g - months with an absolute minimum below 0°C; p - monthly means of precipitation; t - monthly means of temperature; w - humid period (hatched area).

A detailed study of the weather and microclimates on Nylsvley is being undertaken by De Jager (1975). This is being based on standard data from one second-order station near the intensive study site and two third-order stations situated on the eastern and western ends of the study area respectively. Detailed monitoring and summaries of the meso- and microclimates will be based on measurements made by an automatic recording weather station. Final installation of the station is not yet completed, but the equipment being installed will monitor the parameters indicated in Table 1. The system driving forces will be continuously monitored and electronically integrated over hourly periods.

Table 1. Weather parameters to be monitored by an automatic weather recording station, *Burkea* study area, Nylsvley. Data from De Jager (1975).

Radiation	Direct total
	Diffuse
	Photosynthetically active
	Net
	Soil heat flux
Moisture	Precipitation (rain and dew)
	Evaporation
Temperature	Air (various hights above ground)
	Soil(various depths)
Atmosphere	Humidity
	Pressure
Wind	Direction
	Speed

GEOLOGY AND SOILS

Geology

No specific geological survey of Nylsvley or the specific *Burkea* study area has been undertaken, but the chief geological formations in the area are well known. The northern areas of the reserve represent an epicrustal phase of the Bushveld Igneous Complex (Harmse 1975, Coetzee et al. 1975) while the southern areas, which include the *Burkea* savanna, are underlain by sandstones, conglomerates and grits of the Waterberg System. The two broad areas are separated by a narrow alluvial plain.

The topography of the *Burkea* area is very gently rolling with a slightly steeper slope to the north where the sandstone adjoins the alluvial plain. Maximum slope does not apppear to exceed 2 percent.

Soils

Harmse (1975) has surveyed the soils of the whole reserve in detail, and has recognized 17 soil forms and 34 soil series (following the descriptions of the South African National Soil Classification System). These are indicated in Table 2.

Table 2. Main soil forms occurring on Nylsvley. Data from Harmse (1975).

Arcadia	Fernwood	Sterkspruit
Avalon	Glencoe	Valsrivier
Bonheim	Hutton	Wasbank
Clovelly	Inhoek	Mispah
Dundee	Longlands	Glenrosa
Estcourt	Oakleaf	

Table 3 summarizes briefly the known characteristics of the soils occurring in the Ecosystem study area. Characteristic of the *Burkea* savanna soils are the good drainage, poor water-holding capacity and low phosphate content.

Table 3. Main characteristics of the upper 25cm soil layer within the *Burkea* study area, Nylsvley, as determined from representative profiles. Data from Harmse (1975).

From	Series	B-horizon clay content(%)	B-horizon N-content (%)	pH	Mean nutritional status (ppm) P	K	Mg	Ca	Na
Clovelly	Guttu	5,0	0,023	4,9	10	70	10	100	30
	Mossdale	8,0	0,030	5,0	2	35	15	70	30
	Springfield	6,0	0,034	4,3	2	35	5	70	21
	Sebakwe	2,0	0,027	5,1	7	30	8	60	10
Hutton	Bontberg	4,5	0,045	5,2	2	40	28	90	18
	Chester	2,5	0,024	4,9	2	5	5	50	17
	Middelburg	7,3	0,025	5,0	2	25	8	50	10
	Portsmouth	3,0	0,042	6,6	34	260	61	290	22
Mispah	Mispah	8,0	0,026	4,6	9	25	8	60	23

Soil moisture

Detailed studies of soil moisture dynamics are planned for phase 2 of the ecosystem project. During the pilot phase a survey of soil moisture content in the dry season and immediately after the spring rains was undertaken by Van Wyk (1975a). The results (Table 4) indicate a considerable deficit of moisture in the sandy soils of the study area, and probably a marked moisture stress on the plants. Although the canopies of trees and shrubs have a marked effect on the heterogeneity of precipitation on the soil surface, soil moisture appears to be fairly uniform across the study area (Table 5).

Table 4. Soil moisture content in the *Burkea* study area, Nylsvley, during the dry season (July - August)and after first (September) rains. Data from Van Wyk (1975a).

Period	Soil depth(cm)	Mean moisture content (%)	Range of moisture content (%)
July-August	7	3,6	1,3 - 5,1
	25	2,9	1,7 - 4,8
	50	2,7	1,7 - 4,4
	75	3,4	2,3 - 7,6
	100	3,1	2,3 - 9,6

Contd....../

Period	Soil depth(cm)	Mean moisture content (%)	Range of moisture content (%)
September	7	4,0	2,6 - 7,8
	25	3,8	2,6 - 5,7
	50	2,7	1,9 - 3,9
	75	not measured	not measured
	100	not measured	not measured

Table 5. Soil moisture content in dry season in different sites within *Burkea* study area Nylsvley. Data from Van Wyk (1975a).

Soil depth(cm)	Soil moisture content (%)		
	Under trees	Near trees	Open
0 - 12	2,0	2,2	1,6
13 - 24	2,0	2,3	2,1
25 - 36	2,0	2,4	2,1
37 - 48	2,1	2,3	2,2

VEGETATION

Coetzee et al. (1975) have reported on the vegetation of the Nylsvley Nature Reserve, including the *Burkea* savanna. The Zürich-Montpellier method of plant phytosociological survey (Werger 1974) was used as a basis for the surveys. The ecosystem study area was intensively sampled with 108 systematically (or as near-systematic as possible within the confines of plant community homogenity) sited 10 x 20m quadrats, and the remainder of the Nylsvley vegetation sampled by 107 systematically sited quadrats. Height classes were differentiated amongst the woody species encountered in the *Burkea* community to provide some basic measure of woody canopy structure.

Vegetational patterns on Nylsvley show a close correlation with topography and soil types. Floristically, a large number of variations and transitional types occur (Coetzee et al. 1975), but the broad dominant communities can be listed as follows -

a. Broad-leaved savannas on elevated areas. These include the *Burkea -Terminalia-Ochna* types on non-litholitic sandstone soils where the Ecosystem study area is located, *Diplorhynchus* communities on the litholitic sandstone soils and a *Combretum*-dominated savanna on the felsite formations to the north and north-east of the alluvial flats.

b. Microphyllous thorn savanna on the bottomland alluvium and on upland termitaria.

c. Grassland and microphyllous thorn savanna on self-mulching vertic soils.

d. Secondary grasslands and thorn savanna on old settlement sites.

The ecosystem study area covers some 750 ha of *Eragrostis pallens-Burkea africana* tree savanna, occuring on soils of the Mispah, Hutton and Clovelly forms. Three variations within this vegetation type have been recognized. An *Eragrostis pallens-Dombeya rotundifolia* type occurs on well-drained slopes over Hutton and Mispah soil forms, with a total tree cover of 20 - 60 percent and an herbaceous cover of 15 - 65 percent. Several transitional forms of this type occur where soil forms adjoin or where the microrelief changes perceptibly. On the lower areas with Clovelly soil forms, an *Eragrostis pallens-Setaria perennis* savanna occurs, typified by tall *Faurea saligna, Burkea africana* and *Terminalia sericea* trees. Tree cover rarely exceeds 5 percent and shrub cover less than 10 percent. Tall grasses dominate the understory with a cover of 30 - 75 percent. The third variation is characterized by *Eragrostis pallens* and *Trachypogon spicatus* on coarse mesotrophic Clovelly soils. Tree cover reaches 20 percent and herbaceous cover 30 - 50 percent.

Some 30 percent of the study area is taken up by the *Barleria bremekampii* community of Maroela Kop, a sandstone intrusion, and by several *Acacia* patches on the sites of old Bantu settlements.

Vegetation structure

Detailed planning of future research, particularly with regard to studies on primary production of all vegetative strata, on water and mineral cycling and on microclimatic variations, necessitates a knowledge of the detailed structure of the study area vegetation. Lubke et al. (1975) and Van Rooyen and Theron (1975) have reported on detailed studies of woody plant and herbaceous structure respectively.

Five homogeneous regions of the *Eragrostis pallens-Burkea africana* woodland were selected as typical of the whole area, and within each region a 10 percent area was sampled intensively by means of belt transects made up of contiguous 5 x 5m quadrats. The parameters measured on each woody species are indicated in Table 6. Structure and pattern analyses of these data permitted an evaluation of the study site's woody growth forms, density, frequency and cover in terms of all the woody species present (provided each species encountered fulfilled certain minimum requirements relating to size -see Lubke et al. 1975). The areas sampled were permanently marked for future reference. Table 7 presents a list of the first ten important woody species, as determined by magnitude of the Importance Values.

The upper stratum is dominated by *Burkea africana,* and the woody shrubs and small tree layer by small *Ochna pulchra* and *Grewia flavescens*. *Burkea* dominates the area in terms of total canopy cover. A pattern was detectable in the case of smaller *Ochna pulchra* and *Grewia flavescens*, but no pattern of significance could be found for the larger trees. Mean woody plant density for the whole *Burkea* area (excluding the disturbed areas and Maroela Kop was 6 816 plants/ha, and mean percentage canopy cover was 7,7 percent.

Table 6. Structural data recorded for woody plants in intensively sampled areas, *Burkea* study area, Nylsvley. Data from Lubke et al. (1975).

1. Height (to nearest ½m)
2. Height of first branch
3. Circumference of stem at main branch
4. Circumference of stem at breast height
5. Position of canopy (vertical profile)
6. Canopy cover (m^2)
7. Height of lowest leaves
8. Leaf density (percentage of canopy crown area)
9. Amount of dead wood (percentage)
10. Amount of insect damage (scale estimate)
11. Amount of browsing (scale estimate)
12. Amount of lichen cover (scale estimate)
13. Presence of fire scars
14. Presence of parasites

Table 7. Characteristics of ten most important woody species[1] on *Burkea* study area, Nylsvley. Data derived from Lubke et al. (1975).

Species	Importance value [2]	Frequency percentage	Mean density (number/ha)	Total canopy cover (m^2) [3]
Ochna pulchra (less than 1m)	59,8	73,9	2 585	-
Ochna pulchra (from 1 to 3m)	46,6	60,8	1 953	-
Burkea africana (from 4 to 7m)	45,9	9,3	39	2820
Grewia flavescens (individuals)	22,6	27,2	993	-
Burkea africana (less than 4m)	18,4	43,8	368	-
Burkea africana (over 7m)	13,9	1,0	4	961
Grewia flavescens (clumps)	10,9	27,1	195	-
Ochna pulchra (over 3m)	9,3	2,1	16	464
Strychnos pungens (less than 1m)	8,2	19,3	170	-
Combretum zeyheri	6,2	2,8	19	302

[1]Separated by height classes for *Ochna pulchra*, *Burkea africana* and *Strychnos pungens*.

[2]Computed as the sum of relative percent frequency, relative percent density and relative percentage dominance (based on canopy cover and free height, after Louw and Grunow (1969).

[3]Canopy cover was not measured for shrubs or small trees.

Sampling of the herbaceous layer was based on the wheel-point method of Tidmarsh and Havenga (1955), and was done on exactly the same areas as sampled for woody plant structure. A total of 2 000 points per each sampled area provided data on basal cover, frequency of occurrence and presence. A bridge point apparatus was used to measure similar parameters in the area sampled for herbaceous primary productivity (Grunow 1975, Van Rooyen and Theron 1975).

Table 8 reflects the main charactersitics of the herbaceous layer. The total basal cover is 5,47 percent and the herbaceous layer is dominated by *Eragrostis pallens* and *Digitaria eriantha*. Forbs make up a very minor component of the herbaceous layer with frequencies and basal covers of species generally considerably below 0,5 percent and 0,05 percent respectively. Some variation is apparent from comparisons of results from different sampled sites, and this would have to be considered by future researchers having to deal with fine detail in spatial heterogeneity. (Table 9). Preliminary examination of wheel point data indicates that the difference in herbaceous composition between under-tree and open sites may not be as marked as was previously suspected.

Table 8. Frequency of occurrence, basal cover and relative presence of ten most abundant grasses on *Burkea* study area, Nylsvley. Data derived from Van Rooyen and Theron (1975).

Species	Frequency of occurrence (percentage)	Basal cover (percentage)	Relative presence (percentage)
Eragrostis pallens	29,07	1,59	21,62
Digitaria eriantha	26,69	1,46	28,04
Diheteropogon amplectens	7,32	0,40	5,31
Rhynchelytrum villosum	4,39	0,24	3,08
Andropogon schirensis	4,21	0,23	3,33
Perotis patens	3,66	0,20	4,22
Aristida argentea	3,48	0,19	4,34
Setaria perennis	3,29	0,18	1,08
Elyonurus argenteus	2,93	0,16	1,28
Panicum maximum	2,01	0,11	1,91

$$\text{Relative presence} = \frac{\text{Presence}}{\text{Total points}} \times 100$$

Presence = Number of strikes + number of times recorded as nearest plant.

Table 9. Variation in relative presence of abundant grasses across *Burkea* study area, Nylsvley. Data derived from Van Rooyen and Theron (1975).

Species	Relative presence				
	Site A	Site B	Site C	Site D	Site E
Eragrostis pallens	29,15	21,30	15,60	18,05	24,00
Digitaria eriantha	25,45	22,45	43,10	23,45	25,75
Diheteropogon amplectens	3,10	2,20	6,15	6,00	8,20
Rhynchelytrum villosum	3,85	4,35	0,80	3,10	3,30
Andropogon schirensis	0,55	0,40	5,35	7,60	2,75
Perotis patens	2,20	3,70	4,10	3,70	7,40
Aristida argentea	3,75	3,85	3,35	5,10	5,15
Setaria perennis	2,00	2,75	0,05	0,50	0,10
Elyonurus argenteus	3,15	2,80	0,15	--	0,30
Panicum maximum	0,95	7,00	1,10	0,10	0,40

Several aspects of the herbaceous cover reflect the successional status of the area in general. Van Rooyen and Theron (1975) citing Coetzee et al. (1975), Rutherford (1972) and Theron (1973) consider the presence of high densities and cover of *Eragrostis pallens*, *Perotis patens* and *Aristida argentea* as indicative of heavy grazing, whilst *Digitaria eriantha* and *Setaria perennis* are regarded as likely climax species. The general picture is one of a zootic subclimax, possibly influenced by fire, which fits well the known management history of the site (Grunow 1974).

Dichapetalum cymosum (gifblaar)

The woody geophyte *Dichapetalum cymosum* presents a special problem to management of cattle in the *Burkea* savanna because of its extreme toxicity. The rotational grazing system of cattle in the study area is largely designed to make maximum use of the area while palatability of grasses is high and the probability of *Dichapetalum* intake by cattle is relatively low. Future studies will aim at studying the detailed phenology of the plant and factors governing its intake by cattle.

Grobbelaar (1975b), in the pilot phase of the project, has measured the toxicity of *Dichapetalum* throughout the year, as reflected by the monofluoroacetate content of fresh leaves. Provisional results indicate a marked drop in toxicity as the dry season progresses (Figure 2).

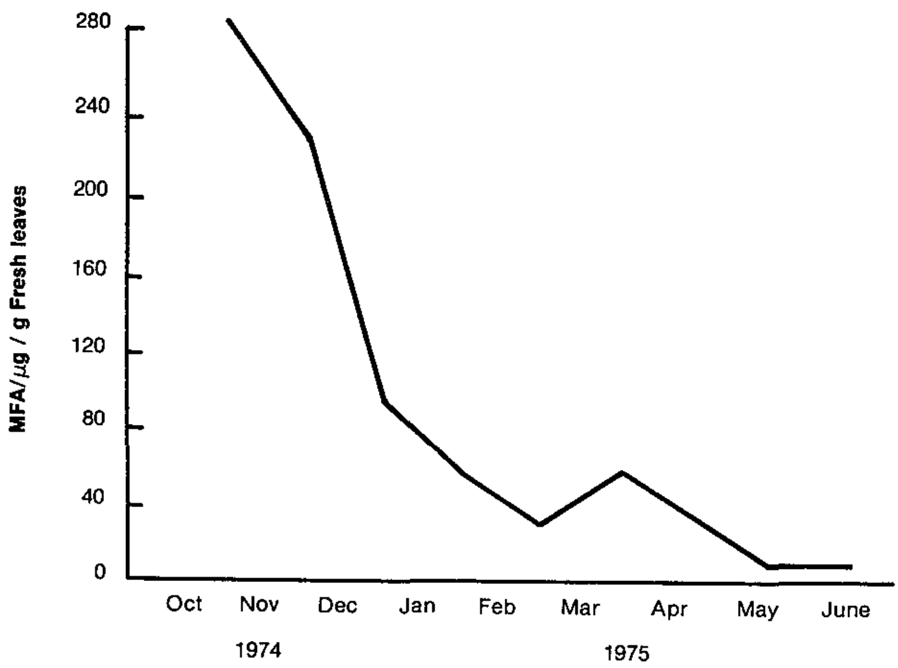

Figure 2. Monofluoroacetate (MFA) content of *Dichapetalum* leaves during the active growth and dry seasons.

PRIMARY PRODUCTION

Herbaceous above-ground biomass and production

Measurements of herbaceous seasonal biomasses and productivity in the 1974/75 season were obtained in a 0,88 ha exclosure fenced to exclude ungulate grazers (Grunow 1975). The area had been subjected to grazing on a seasonal basis (January - May) for many years prior to the erection of the exclosure (Grunow 1974). During the potential growth season (October through April) 30 0,5 m^2 quadrats are clipped 3-weekly in open sites and 6-weekly under trees and under shrubs respectively. During the dry season this regime is altered to 5 and 10 weeks respectively. A standard error of 10 - 20 percent of the mean for total number of plots is attained.

Provisional estimates of primary production can be made at this stage from data supplied on standing-crop biomasses of various categories by Grunow (1975). More precise estimates will be available from comparisons of paired plot data extracted from the data-bank when this becomes operational. Table 10 summarizes the main findings on standing crop thus far available.

Table 10. Above-ground standing crops (dry matter g/m^2) measured in three sites within an ungulate-proof exclosure, *Burkea* study area, Nylsvley, 1974/75. Data from Grunow (1975).

Site	Standing crop Minimum	Standing crop Maximum	Mean	Date of maximum biomass
Total standing-crop				
Open	140,9	246,7	194,1	February 4, 1975
Under trees	94,9	198,1	141,6	February 4, 1975
Under shrubs	101,4	146,0	126,1	March 17, 1975
Total standing green				
Open	30,6	123,4	67,8	February 4, 1975
Under trees	17,3	97,1	52,8	February 4, 1975
Under shrubs	20,3	64,3	49,0	February 4, 1975
Total standing dead				
Open	99,1	149,5	126,3	June 3, 1975
Under trees	70,8	101,0	88,8	February 4, 1975
Under shrubs	48,1	98,4	77,1	October 1, 1974

The standing green component of grasses and forbs in each of the three sites sampled (open, under trees, under shrubs) shows a marked increase from the commencement of the growth season (taken as October 1 for 1974/75) until the beginning of February, when a decline in green standing crop commences. The change in total above-ground standing crop parallels the green standing-crop suggesting a constant rate of change from standing-green to standing-dead to litter over this 120 day period. The rates of increase over this active growth period of standing green are given in Table 11. After the peak in early February, plant respiration plus transfer to standing dead exceeds primary production, resulting in declining standing crop biomasses.

Table 11. Productivity of herbaceous layer (grasses and forbs) during active growth season of 120 days on *Burkea* study area, Nylsvley. Data derived from Grunow (1975).

Site	Dry matter production (g/m^2 per day)
Open	0,7
Under trees	0,8
Under shrubs	0,3

Forbs generally contribute less than 10 percent of total above-ground standing crop.

Table 10 reflects maximum standing crops measured. Allowing for a ratio of open : under trees and shrubs of 9:1 (derived from Lubke et al. 1975) a weighted mean maximum standing crop of roughly 240 g/m^2 for the whole study area is obtained. Since annual primary production is roughly double the maximum measurable standing crop attained during a year (J. Phillipson, personal communication) this indicates an herbaceous above-ground net primary production for the *Burkea* savanna of approximately 480 g/m^2 per year.

Tew and Cresswell (1975) have thus far investigated some of the detailed aspects of primary productivity in the dominant grasses on the study area. They have found a "Kranz" type anatomy in *Eragrostis pallens, Panicum maximum, Setaria perennis, Digitaria eriantha* and *Rhynchelytrum repens*, indicative of a C_4 photosynthetic pathway (i.e. higher photosynthetic rates than C_3 type). Net photosynthetic rates of *E. pallens* and *P. maximum* have been derived in the field from measurements of CO_2 production per individual plant and reference of this back to ground area using ratios of leaf area to basal area and basal area cover to total cover. *Eragrostis pallens* has given net primary production values of 2,0 g/m^2 per day in partial shade and 0,4 g/m^2 per day in shade. *Panicum maximum* has given the very high values of 15,9 g/m^2 per day in partial shade and 20,4 g/m^2 per day in shade.

Woody plant biomass and production

An intensive study site, representative of the whole study area in terms of structure of woody plants, has been selected by Rutherford (1975) for measurement of seasonal biomass changes of *Burkea africana, Ochna pulchra, Grewia flavescens, Terminalia sericea, Vitex rehmannii, Dombeya rotundifolia, Combretum molle, Lannea discolor* and *Strychnos pungens* of various height and stem diameter classes. Rates of biomass change will be determined for roots, stems, branches and terminal shoot growths of each of these species which together account for more than 80 percent of the woody mass on the study area. Continuous monitoring of the changes in these components will be done by data loggers. Extrapolation to the whole study area's woody vegetation will be possible at a later stage.

Testing of equipment has proceeded, but actual field application is being held up by the lack of electric power on the study area. Since it is uneconomical in terms of time and labour and severely disruptive to the study area to sample all individuals directly for biomass, an indirect method utilizing allometric relationships between dimensions and mass has been developed (Rutherford 1975). A large number of functions have been fitted to the data; to date the best relationships which have emerged for *Ochna pulchra* are whole mass to stem diameter, canopy diameter, height and number of twigs; branch mass to stem diameter, number of twigs and sum of branch diameter; stem mass to stem diameter; leaf mass to number of twigs. Transformations are frequently necessary to reduce relationships to linear form.

Features of the net primary productivity of dominant woody species which have thus far been investigated by Tew and Cresswell (1975) include photosynthetic characteristics and CO_2 compensation points. *Burkea africana* and *Terminalia sericea* show typical signs of C_3 types of photosynthesis, but *Ochna pulchra*, a very important woody plant on the study area in terms of density and biomass, shows evidence of an unusual change with age from C_4 to C_3. These functions are being studied in greater detail. Changes in photosynthesis with changes in temperature and light are also being studied.

Below-ground biomass and production

The pilot phase of the ecosystem study aimed at estimation of below-ground standing crop of all roots at various depths (Van Wyk 1975b). Production of root material and the dynamics, including changes from live to dead to root litter, will be investigated in depth during phase 2 of the project.

The profile soil pits (Harmse 1975) were used as a basis for soil core sampling, and horizontal cores removed from each at depths of 7cm, 25cm, 50cm, 75cm and 100cm respectively. Cores represented a soil volume sample of 0,00064 m^3 or an area of 0,0270 m^2 as projected onto the soil surface. Live and dead roots were not differentiated at this stage, nor were woody or herbaceous plant roots. An additional survey for root standing crop was undertaken in the site used for measurement of above-ground herbaceous production and standing crops, where one vertical core was removed to a depth of 50cm in each clipped plot.

Table 12 indicates some information on root standing crops gathered thus far. Variances measured are high because of the small cores utilized and the occasional large woody roots in cores. Most roots are however grass roots, and a provisional estimate of root crop (live + dead) is 990 g/m^3 soil volume or 990 g/m^2 projected onto the soil surface. The ratio of below-ground herbaceous crop to above-ground is thus of the order of 4:1 to 5:1.

Table 12. Mean root standing crops measured on *Burkea* study area, Nylsvley, August 1974. Data derived from Van Wyk (1975b).

Mean depth cm	g/m^2 Surface area	g/m^3 Soil volume
7	27,93	117,81
25	37,14	156,71
50	6,77	28,59
75	1,55	6,56
100	1,66	7,03

CONSUMERS

As in most savanna areas with many diverse available niches, the consumers within the *Burkea* savanna are both numerous and of great diversity. Hirst (1973) has reviewed the problems of approach and techniques facing animal ecologists in the savanna. The pilot phase of the project aimed at determining mean and seasonal biomasses and rates of population and biomass change in all groups of consumers within the study area, together with estimates of their total food intake rates and excretion rates.

In relation to the total system, some consumers are obviously of major importance. Cattle are significant both because of their large biomass and their economic significance. Wild ungulates such as impala will receive special attention for the same reasons. A preliminary model of the total system (Getz 1975) has shown invertebrate and small vertebrate consumers to be significant and sensitive ecosystem components.

Cattle

Cattle have been an integral part of the grazing consumer component on the *Burkea* savanna on Nylsvley for at least the past 60 years (Grunow 1974). A rotational grazing system has been applied in the area for the past 30 years to make maximum use of the area from January to May when danger of *Dichapetalum cymosum* (gifblaar) poisoning is minimized. From 300 to 400 head of cattle (steers + heifers or cows + calves) are normally maintained on the *Burkea* area for 4 months. This represents a standing-crop biomass (wet weight) of approximately 150 kg/ha (15 g/m^2) for the four months January through April.

The cattle grazing regime has been maintained during the pilot study phase to maintain the vegetation in a relatively "stable" condition. Additional water points have been established in two camps to ensure a more homogeneous grazing pressure.

Carr (1975) reports on some initial observations of behaviour of cattle in the study area. Feeding is fairly selective, with palatable species such as *Panicum maximum* being taken wherever available. Some browsing on *Terminalia, Ochna, Grewia* and *Dombeya* at night has been recorded.

A sample of cattle of mixed age and sex composition, weighed at regular intervals from mid-February to late April (Table 13) revealed a marked rise in body weight. The total secondary production from mid-February to end of March was 9,6 kg/ha (0,96 g/m^2), for a mean rate of 0,27 kg/ha per day (0,027 g/m^2 per day). For the whole sampled period, February through April it averaged 12,4 kg/ha (1,24 g/m^2) for a mean rate over 70 days of 0,18kg/ha per day (0,018 g/m^2 per day). The biomass of cattle on the study area remained almost constant at 116 kg/ha (11,6 g/m^2) from early February to late April due to an estimated 5 to 10 percent loss from *Dichapetalum* poisoning.

Table 13. Mean weights of 150 cattle of mixed sex, age and race composition on *Burkea* study area, Nylsvley, as measured during the period February through April 1975. Data derived from Carr (1975).

Date of weighing	Mean weight (kg)
February 2, 1975	292
March 12, 1975	302
March 26, 1975	316
April 2, 1975	317
April 16, 1975	317
April 30, 1975	323

Small mammals

Small mammals occupy several trophic levels in the *Burkea* savanna, including the herbivore, granivore, fructivore, carnivore and insectivore components. The most important in terms of biomass and population turnover rates are the small rodents, hares (*Lepus* sp.), and springhares (*Pedetes* sp.) (Bragg 1975). Species such as aardvark (*Orycteropus* sp.) and porcupine (*Hystrix* sp.) occur in small numbers but have a marked localized impact on the vegetation due to digging. Repeated trapping and transect data will in due course provide estimates of population and biomass fluctuations.

Insects

As expected, the numbers and diversity of insect consumers in the *Burkea* savanna far exceed that of any other consumer group (Holm 1975). Biomasses have not yet been computed, but 1 150 arthropod species had been collected by July 1975, for a total of 8 800 specimens and 2 100 of these mounted and labelled.

A variety of techniques are being used (Holm 1975) to sample arthropod consumers in various sites within the study area - these include the use of Malaise traps, beating of branches to collect browsing species, sweep-netting and drop-netting for species in the herbaceous layer. Insect numbers show a marked seasonal fluctuation from wet to dry season, and relationships to temperature, humidity and microclimate will become apparent as the study progresses.

Table 14 demonstrates proportional abundance in the dry period March through June as measured by malaises trap catches. It is likely that the ant genera *Crematorgaster*, *Pleidole*, *Ocymyrmex* and *Camponotus* (Table 15), together with phytophagous and omnivrous insects will prove to be of major importance, with sap-sucking insects playing an important role in the wet season. Ants are prominent as inhabitants of the woody stratum (Table 16).

Table 14. Proportional abundance of arthropod consumers on *Burkea* study area, Nylsvley, as measured by catches in Malaise traps, March through June. All figures expressed as mean numbers/trap per week. Data derived from Holm (1975).

Ecological role	Attractant trap	Non-attractant trap	Non-attractant trap in *Acacia* veld [1]
Predatory	3,46	1,91	1,50
Phytophagous	43,00	13,82	4,75
Detritivorous	32,00	0,82	0,63
Omnivorous	139,18	11,09	5,38
Sap sucking	190,00	9,27	3,00
Formicidae	79,00	62,91	13,25
Parasitic	0,55	0,36	0,38
Nectar feeding	0,36	2,09	0,50
Seed-boring	0,09	0,09	0
Wood-boring	0,09	0,09	0
Fructivorous/phytophagous	1,24	1,55	0
Bark-living	0,09	0	0,75
Arachnid (predatory)	9,09	6,5	3,25

[1] Sites of old settlements in *Burkea* savanna.

Table 16. Abundance of arthropods in trees and shrubs, *Burkea* study area, Nylsvley, in April 1975. Figures expressed as numbers per branch sampled. Data drived from Holm (1975).

	Woody species								
Ecological role	*Burkea africana*	*Terminalia sericea*	*Ochna pulchra*	*Dombeya rotundifolia*	*Combretum molle*	*Vitex rehmannii*	*Securidaca longipendiculata*	*Strychnos pungens*	*Grewia flavescens*
Predatory	-	0,02	0,02	-	-	-	-	0,20	-
Phytophagous	0,96	0,42	0,22	0,90	0,30	0,40	0,40	-	-
Detritivorous	-	-	-	-	-	-	-	-	-
Omnivorous	0,04	0,40	-	-	0,10	-	-	-	0,30
Sap-sucking	0,06	0,32	0,02	-	0,20	0,10	1,20	0,20	-
Formicidae	5,70	5,70	4,78	0,3	-	2,90	0,70	0,80	0,40
Parasitic	-	0,04	-	-	-	-	-	-	-
Nectar-feeding	-	-	-	-	-	-	-	-	-
Seed-boring	-	0,16	-	-	-	-	-	-	-
Wood-boring	-	-	-	-	-	-	-	-	-
Fructivorous/ phytophagous	-	-	-	-	-	-	-	-	-
Bark-living	0,04	-	-	-	0,10	-	-	-	-
Arachnid (predatory)	0,58	1,48	0,50	-	1,10	1,60	1,00	0,90	0,90

Table 15. Density of ant colonies in *Burkea* study area, Nylsvley, measured in dry season. Data from Holm (1975).

Site	Colonies per m^2
Shaded grassland	0,040
Open grassland	0,056

Birds

Birds present a special problem in the *Burkea* savanna because of their mobility, especially over a relatively small-sized area, and because of their diversity. Nylsvley together with its adjacent bushveld has one of the greatest avian diversities in South Africa (Tarboton 1971), although the *Burkea africana* savanna is relatively poor in avian habitats.

Studies of bird populations in the *Burkea* study area are based on a 150 ha study plot, where intensive observation, capture and marking, censuses and nesting counts are carried out. The total number of species observed in the plot by July 1975 was 152 (Tarboton 1975).

Table 17 summarizes the main information available on birds thus far obtained (Tarboton 1975). Insectivores are more abundant than other ecological groups, but all groups appear in sufficient numbers to be important in the avian component. All groups are productive, with a mean reproductive rate of 0,54 individuals per parent individual per year. As anticipated there is considerable movement of birds from and to adjacent areas.

Reptiles and amphibians

Reptiles and amphibians are surprisingly numerous in the arid *Burkea* biotope, and Jacobsen (1975) has thus far captured and marked eight lizard and gecko species, nine snake species and four frog species. Random capture is effected over periods of 6 to 10 days with grids of traps covering 49 ha for snakes and 0,36 ha for lizards. Intensive searching of trees and digging of 1 m^2 quadrats provides additional information on arboreal and fossorial species. Stomach samples are collected for food analysis.

The common dwarf gecko (*Lygodactylus capensis*) is the most abundant reptile found in the area to date (Jacobsen 1975). Few reptiles have been recaptured (five out of 186) indicating either a large population or else a great deal of movement on and off the study sites. The latter fact is checked by spoor counts on the study area boundaries - these are low with a mean of 11,8 crossings per day in both directions in May 1975 and only 4,8 per day in June 1975.

Table 17. Numbers and biomasses of each diet-group of birds in the avian study plot for the three periods of the year (breeding, post-breeding and non-breeding seasons). Also indicated is the number of bird species in each group, their mean group-weight and group-productivity. Biomass is expressed in g/ha, productivity in number of young produced/breeding adult per breeding season. Data from Tarboton (1975).

	Number of species	Mean group weight g	Productivity	Numbers			Biomass		
				Breeding	Post-breeding	Non-breeding	Breeding	Post-breeding	Non-breeding
Predator	16	1157	0,41	11	12	11	11,8	24,8	22,1
Predator/insectivore	7	136	0,56	41	47	27	32,7	39,8	20,1
Insectivore-foliage	27	39	0,50	139	193	118	24.3	23.5	15.4
-trunks	6	56	0,74	46	79	58	12,1	20,2	18,2
-aerial	10	30	0,69	82	111	48	13,5	16,5	7,1
-terrestrial	26	81	0,46	138	196	135	26,6	35,3	25,0
Insectivore-total	69	51	0,56	405	579	359	76,5	95,5	65,7
Insect/fructivore	12	40	0,89	104	65	60	33,2	23,8	22,9
Insect/granivore	16	237	-	148	155	97	201,5	119,2	91,3
Granivore	14	52	0,5	96	126	100	62,8	69,2	63,1
Fructivore	5	95	0,33	18	7	10	9,8	4,0	4,8
TOTAL	139		0,54	823	991	664	438,3	376,3	290,0

Consumer parasites

Important endo- and ectoparasites of cattle and impala only are being investigated during the pilot phase of the ecosystem project, because of their obvious importance to the productivity of these ungulate herbivores.

Ecto- and endoparasites are collected monthly from impala shot on the *Burkea* study area (Horak 1975) and from slaughtered calves. The incidence of endoparasites in adult cattle is also indicated by faecal examination for endoparasite ova. Cattle are dipped weekly whilst grazing the *Burkea* study area to reduce the incidence of tick borne diseases, particularly heartwater and redwater.

Horak (1975) has found that nematode and tick infestations on impala can reach levels where they could conceivably affect growth and bodily condition. Nematode infestation levels in cattle also reach significant levels, especially *Haemonchus* (wireworm) and *Cooperia*. Table 18 summarizes the main features of cattle and impala parasitism thus far detected. *Cooperia* is a genus which affects both cattle and impala to a significant degree, and cross infestations will be investigated closer as the study progresses.

Table 18. Important ecto- and endoparasites recovered from cattle and impala, *Burkea* study area, Nylsvley, February through April, 1975. Figures given are minimum and maximum numbers recovered. Data derived from Horak (1975).

Total parasites per individual animal	Impala (shot)	Cattle (slaughtered)	Cattle (live)
Ticks : adult	0-71[1]	53 - 88	
Ticks : nymphs	4-67	1 - 8	
Ticks : larvae	5-613	0 - 11	
Paramphistomum sp.	0-91	0 - 10	
Fasciola sp.	0-4	0	
Nematodes: adult	685-8418[2]	2180 - 4750[4]	
Nematodes: 4th stage	80-9910[3]	2559 - 8868[4]	
Nematodes: 3rd stage	0-120	0	
Nematode eggs per gram faeces -	200-6800		0-831

1 = mainly *Rhipicephalus evertsi*

2 = mainly *Impalaia* sp. and *Cooperia* sp.

3 = majority not identified, probably *Impalaia* sp.

4 = mainly *Cooperia* spp.

REDUCERS AND DECOMPOSERS

Breakdown and decomposition of plant litter would appear to be efficient in the arid sandy soils of the *Burkea* savanna. Despite large amounts of litter deposited on the soil surface, (Figure 3) the organic content of the upper soil layers is low as reflected by the nitrogen content (Steyn 1975), and much of this nitrogen appears to be due to the action of nitrogen-fixing soil micro-organisms (Grobbelaar 1975).

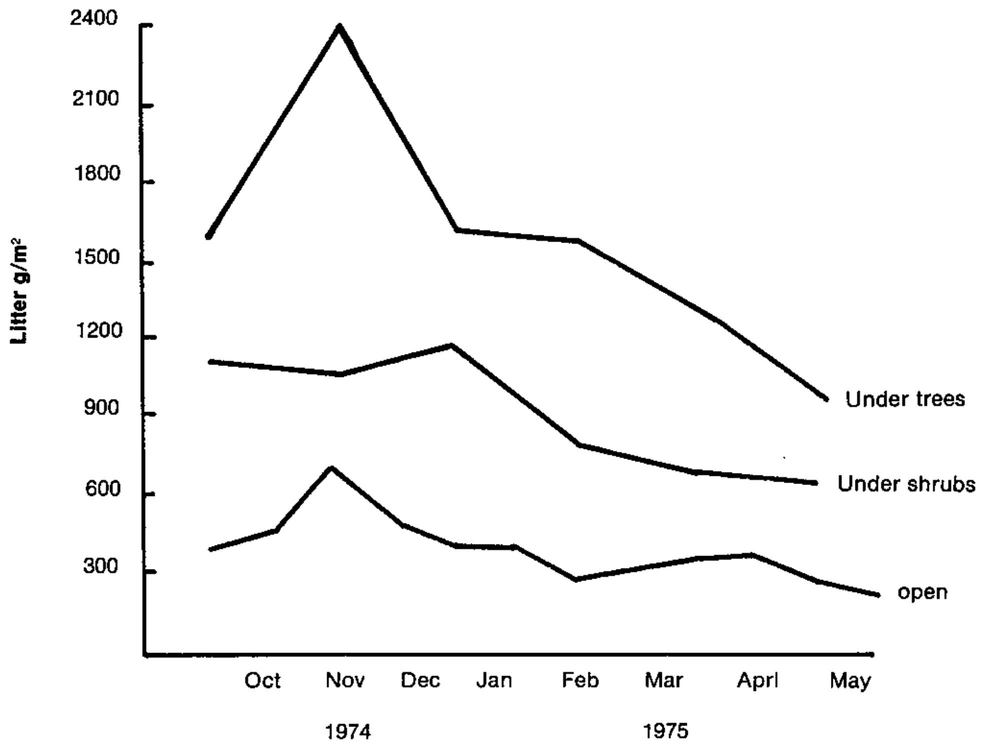

Figure 3. Amounts of plant litter on soil surface, *Burkea* study area, Nylsvley, October 1974 through June 1975 at 3-weekly intervals. Data from Grunow (1975).

Detailed studies of litter production and microbial decomposition have not yet been undertaken on the *Burkea* study area, and this aspect remains a serious deficiency within the study. Studies have however commenced on the detritivores and other arthropod reducers which play an important role in litter breakdown.

Dung arthropods

Because of the grazing regime applied in the *Burkea* savanna, a large amount of cattle dung (estimated total dry weight of 20 to 24 g/m^2) is deposited over a period of 4 months. This is usually totally reduced by soil-living arthropods, often within a few days. Wild ungulate dung is similarly reduced, but the process may well involve different arthropod genera.

The pilot study of dung reduction has involved development of techniques to measure rates of removal of cattle dung pats from the field and techniques to capture the specific genera involved (Endrödy-Younga 1975). These will be applied during phase 2 of the project. Arthropods which probably play major roles in dung removal are the genera *Heliocopris*, *Copris* and *Onitis* and the tribes Oniticellini, Ontophagini, Scarabaeni and Gymnobleurini. Attention will be given to the role of beetles and other surface feeders in plant litter reduction.

Soil arthropods

Initial surveys for soil arthropod abundance and biomass were taken at random over a $100m^2$ sample area (Loots 1975, Prinsloo 1975). This was later stratified to sample equally within eight different micro-habitats where soil moisture, temperature and organic content may have differed significantly. The latter parameters are measured concurrently with soil arthropod sample cores. Considerable fluctuations in numbers of soil mites and small beetles are apparent, and the relationship of these changes to micro-habitat and soil physical habitat have yet to be determined.

MINERAL CYCLING

Quantitative studies of the rates of change in concentration and changes in bound forms of important elements within the *Burkea* ecosystem are regarded as being of high priority because of the great importance of elements such as nitrogen to the total system's productitivy and because of possible limitations imposed on the system by deficiencies of macro- and micro-elements such as phosphate and selenium. The project pilot phase has given attention to nitrogen only, and two aspects are being studied as a prelude to detailed studies on the nitrogen cycle.

Grobbelaar (1975) has reported on preliminary studies on overall nitrogen fixation in the soil. Ethylene reduction measurements based on 35cm cores with surface areas of $25cm^2$ is the standard technique employed. Grobbelaar reports nitrogen fixation as occurring primarily during December-April. During January, when the mean rate of nitrogen fixation appeared to have reached its peak, it was found to correspond to 2,2 mg/m/h. Some measurements of individual species are given in Table 19.

Steyn (1975) has routinely examined herbaceous plant and soil samples for nitrogen content during the growth season and notes that there is little seasonal variation detectable thus far. Samples from different localities within the savanna appear to differ significantly however (Table 20). Soil nitrogen is generally low, with a mean percentage content of 0,027.

Table 19. Nitrogen fixation of roots measured under important plant species in *Burkea* study area, Nylsvley, during daylight, January 1975. Data derived from Grobbelaar (1975).

Plant species [1]	Nitrogen fixed (range) $\mu g/m^2$ per hour
Legumes:	
Burkea africana[2]	1200 - 2220
Cassia mimosoides	240 - 9600
Elephantorrhiza sp.[2]	360 - 2720
Indigoferia oxytropis	1920 - 77200
Indigofera sordida	520 - 3760
Rhynchosia monophylla	920 - 9080
Tephrosia lupiniifolia	4240 - 23902
Non-legumes:	
Aristida argentea	0 - 3000
Dichapetalum cymosum	160 - 1480
Digitaria eriantha	0 - 440
Eragrostis pallens	160 - 3120
Hyperthelia dissoluta	40 - 1880
Ochna pulchra	800 - 3240
Parinari capense	40 - 7240
Pygmaeothamnus zeyheri	80 - 1840
Terminalia sericea	40 - 800
Xerophyta retinervis	0 - 0

[1] Roots of other species may occur under individual plants.
[2] No root nodules found on *Burkea* or *Elephantorrhiza*.

MODELLING

Two approaches to modelling the savanna ecosystem are being employed, viz, a crude model of the whole system and a series of more refined sub-models of important components and processes (Starfield and Furniss 1975). Development of such sub-models is still in the early stages.

Getz (1975) has reported in detail on the development of an overall linear model of the savanna ecosystem, using estimates of the biomasses and transfer rates applicable to the *Burkea* study site. Some estimates may not be as accurate as others, but the model provides an insight into the functioning and especially the sensitivity of some of the components, as reflected by relative rates of change in the magnitude of the components over time. Insect and small mammal herbivores were shown to be very sensitive to changes in plant biomass. The model correctly indicated that the grass component is the most sensitive plant component. No vegetation/temperature or vegetation/soil moisture interfaces were incorporated in the model; it is likely that knowledge of these will improve the stability and predictability of the overall model.

Table 20. Nitrogen content of various types of selected localities within *Burkea* study area, Nylsvley, collected during growth season 1974/1975. Data derived from Steyn 1975.

Locality	Type	Nitrogen content (% dry mass)
Open	Grass/standing green	0,95
	Grass/standing dead	0,49
	Other/standing green	1,70
	Other/standing dead	0,70
	Eragrostis pallens/standing green	0,73
	Eragrostis pallens/standing dead	0,43
	Digitaria eriantha/standing green	1,25
	Digitaria eriantha/standing dead	0,64
	"Litter"	0,94
Under trees	Grass/standing green	1,24
	Grass/standing dead	0,76
	Other/standing green	1,56
	Other/standing dead	1,05
	Digitaria eriantha/standing green	1,65
	Digitaria eriantha/standing dead	0,91
	"Litter"	1,29
Under shrubs	Grass/standing green	1,05
	Grass/standing dead	0,72
	Other/standing green	1,60
	Other/standing dead	0,93
	"Litter"	1,10

Data collection, storage and retrieval

A detailed and comprehensive system of data acquisition, storage and retrieval is currently being designed. Data will be stored on the Burroughs system of the Department of Agricultural Technical Services in Pretoria. Workers are required to provide the Coordinators with all field data entered on specially designed forms. Periodic edited printouts are provided to authors and to approved researchers.

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