Land Resource Study

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An Ecological Survey of Western Province, Zambia Volume 2 The Grasslands and their Development

Land Resources Division/Directorate of Overseas Surveys

An Ecological Survey of Western Province, Zambia Volume 2

Foreign and Commonwealth Office
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An Ecological Survey of Western Province, Zambia, with Special Reference to the Fodder Resources

Volume 2. The Grasslands and their Development

by

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THE LAND RESOURCES DIVISION

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PREFACE TO VOLUME 2

This report describes an ecological survey of parts of Western Province (formerly Barotseland) carried out by W. C. Verboom in 1964, when he was Ecologist in the Zambian Ministry of Agriculture. The maps accompanying the report were published by the Directorate of Overseas Surveys and the report was subsequently amplified and revised by M. A. Brunt of the Land Resources Division.

This revised report of the ecological survey is published as Land Resource Study No. 8 by the Directorate of Overseas Surveys, with the permission of the Government of Zambia.

Volume 1, The Environment, contains Parts 1, 2 and 3, that is the introductory matter, the history of the project and the description of the environment of Western Province. The account of the climate is abbreviated in this report; further details are being issued for very limited distribution as a Supplementary Report by S. H. Walker.

Volume 2, The Grasslands and Their Development, contains Parts 4 to 6. The fodder resources are described and the future agricultural development of the area is discussed in this volume. There are also appendixes containing soil profile descriptions, lists of botanical species and notes on the chemical analysis of fodder samples.

PARTS 4 - 6

PART 4. THE FODDER RESOURCES OF WESTERN PROVINCE AND THEIR UTILISATION

THE RESOURCES

THE VEGETATION COMMUNITIES OF THE GRASSLANDS

The vegetation-soil survey of Trapnell *et al.* (1950) was largely concerned with woody vegetation, only slight attention being paid to the herbaceous and grass cover. They nevertheless recognised and mapped three grassland types:

Kalahari Sand Plain and Watershed
Valley and Floodplain
Swamp and Papyrus Sudd

In a more detailed report, Trapnell and Clothier (1957*) distinguished six grassland types which, unlike the three types listed above, include woodland communities with appreciable grass cover:

Plateau
Kalahari
Sand Plain and Dambo
Valley
Black Clay and Flood Plain
Seepage Streamside and Lagoon (including the Swamp and Papyrus Sudd listed above)

The present survey was principally concerned with fodder resources, particularly during the period when the main Bulozi Plain is flooded. For each geomorphological-soil unit already described (see Table 9) the grassland type and the commoner plant species are indicated below. The arrangement is according to soil type because, in this area of predominantly sandy soils, differences in soil-moisture retention have a greater influence on grassland composition than any other factor. Thus, for example, the Lake-dune Barotse Sands carry a fairly uniform and distinctive grass cover, despite the wide range of associated woody vegetation.

Relationships between land facets, soils and grassland communities are shown in Table 35 for the Mulonga and Matabele Plains.

In Appendix 2 detailed floristic lists are given for all the main vegetation types, which are cross-referenced with Trapnell's (1950) soil-vegetation groups.

Soil type I(c) is not described in the present survey.

* The report was first issued in 1937 and was revised in 1957.

I(a) Mankoya Terrace. Upland Sedentary Soils

The Mankoya area is the only part of Western Province where these soils occur in association with *Julbernardia-Brachystegia* woodland; the grass associations correspond with Trapnell and Clothier's (1957) Plateau Type Grassland.

The commoner grasses, sedges, legumes and browse trees occurring on this soil unit are as follows:

Grasses

Andropogon amplectens
A. brazzae
A. gayanus
A. schirensis
Brachiaria brizantha
Chloris pycnothrix
C. virgata
Cymbopogon densiflorus
Dactyloctenium aegyptium
Digitaria milanjiana
D. sp.
Eleusine indica
Eragrostis chapelieri
E. viscosa
E. sp.
Heteropogon melanocarpus
H. contortus
Homozeugos eylesii
Hyparrhenia diplandra
H. dissoluta
H. filipendula
H. grallata
H. newtonii
H. poecilotricha
H. rudis
H. rufa
H. variabilis
H. sp.
Melinis macrochaeta
Panicum maximum (hairy form)
Pennisetum polystachyon
P. typhoides
Pogonarthria squarrosa
Rhynchelytrum nyassanum
Rottboellia exaltata
Rhytachne robusta
Schizachyrium ursulus
Setaria pallidifusca
Sporobolus molleri
S. pyramidalis
Tristachya huillensis

Sedge

Scleria induta

Leguminous herbs/shrubs

Cassia absus
C. mimosoides
C. obtusifolia
C. occidentalis
Crotalaria amoena
C. natalitia
Desmodium velutinum
Dolichos africanus
D. trinervatus
D. sp.
Glycine javanica
Indigofera arenophila
I. emarginella
I. hirsuta
I. rhynchocarpa
I. spicata
I. subulata
Lablab niger
Rothia hirsuta
Rhynchosia holosericea
R. minima
R. sublobata
Zornia glochiata

Browse trees

Acacia sieberiana*
Piliostigma thonningii
Diplorhynchus condylocarpon

There is some variation in composition between sub-fire-climax conditions (more or less open grassland) and fire-climax woodland conditions. Trapnell noted that in the former *Hyparrhenia filipendula* and *H. dissoluta* were common. This

* An erroneous spelling 'sieberana' was used in Volume 1.

variation, which is due to the trees and shrubs of the fire-climax community having shaded out the more light-demanding species, is shown from collections made near Mankoya and listed below:

Sub-Fire-Climax		*Fire-Climax*	
Grasses		*Grasses*	
Andropogon gayanus var. squamulatus	f	Andropogon amplectens	f
Brachiaria brizantha	f	Eragrostis sp.	f
Cymbopogon densiflorus	f	Homozeugos eylesii	o
Digitaria sp.	f	Hyparrhenia diplandra	f
Eragrostis chapelieri	o	H. sp.	f
Heteropogon contortus	f	Rhytachne robusta	o
Hyparrhenia filipendula	f	Tristachya huillensis	o
H. grallata	f	Urelytrum sp.	o
H. newtonii	f		
H. poecilotricha	f	*Sedge*	
H. rudis	f		
H. variabilis	f	Scleria induta	
H. rufa	o		
Schizachyrium ursulus	o		
Leguminous herbs		*Leguminous herbs/shrubs*	
Crotolaria sp.	r	Dolichos trinervatus	f
Desmodium velutinum	o	D. spp.	f
Dolichos africanus	o	Indigofera emarginella	o
Tephrosia rhodesica	o	I. rhynchocarpa	o

f = frequent, o = occasional, r = rare

On both Soils I(a) and I(b), *Hyparrhenia rufa* and *H. variabilis* tend to dominate where soil fertility is above average; when about 80% of the cover is composed of these species the local farmers will consider cultivating the ground again. When the soil is very impoverished *Pogonarthria squarrosa* becomes dominant.

I(b) Mankoya Terrace. Upland Mixed Sedentary and Barotse Sand Soils

The climax vegetation communities associated with this soil are *Cryptosepalum* forest, *Baikiaea plurijuga* forest and *Burkea-Copaifera-Baikiaea* woodland. Trapnell noted that, although some of the Kalahari Grassland species occur on these soils, the composition approaches that of the Plateau Grassland type. The species recorded during this survey are shown below. The commonest grasses are asterisked.

Grasses

Andropogon amplectens
A. brazzae
A. gayanus*
A. schirensis
Brachiaria brizantha*
Chloris pycnothrix
C. virgata
Cymbopogon densiflorus
Dactyloctenium aegyptium
Digitaria milanjiana*
D. sp.
Eleusine coracana
E. indica
Eragrostis chapelieri
E. patens
E. tenuifolia
E. viscosa
E. sp.
Heteropogon melanocarpus
H. contortus
Homozeugos eylesii
Hyparrhenia diplandra
H. dissoluta*
H. filipendula
H. grallata
H. newtonii
H. poecilotricha
H. rudis
H. rufa
H. variabilis
H. sp.
Melinis macrochaeta
Panicum maximum (hairy form)*
Paratristachya superba
Pennisetum polystachyon
P. typhoides
Pogonarthria squarrosa
Rhynchelytrum nyassanum
Rottboellia exaltata
Rhytachne robusta
Setaria pallidifusca
Sporobolus molleri
S. pyramidalis
Trichoneura grandiglumis
Tristachya huillensis

Leguminous herbs/shrubs

Cassia absus
C. mimosoides
C. obtusifolia
C. occidentalis
Crotalaria amoena
C. natalitia
Desmodium velutinum
Dolichos africanus
D. trinervatus
D. spp.
Glycine javanica
Indigofera arenophila
I. hirsuta
I. spicata
I. subulata
Lablab niger
Rothia hirsuta
Rhynchosia holosericea
R. minima
Zornia glochidiata

Browse trees

Acacia sieberiana
Swartzia madagascariensis
Diplorhynchus condylocarpon

Areas of recently disturbed land are often colonised by *Dactyloctenium aegyptium;* overgrazed land is usually dominated by *Sporobolus pyramidalis*. Depending on the degree of woodland destruction, scattered small trees of *Baikiaea plurijuga* and *Entandrophragma caudatum* may occur, together with components of the *Baikiaea* forest thicket (Mutemwa) which commonly include *Baphia obovata, Bauhinia macrantha, Popowia obovata, Grewia* spp., and *Combretum* spp.

I(d) Mankoya Terrace. Valley Alluvium (Dambos)

The vegetation associated with this soil is mainly grassland with very few woody species, corresponding with Trapnell's (1950) Valley and Floodplain Grassland type. The specific composition of the vegetation is dependent on variations in soil properties and the groundwater regime.

Species recorded during the survey included those listed below. The commonest grasses are asterisked.

Grasses

Alloteropsis semialata*
Andropogon eucomus*
A. huillensis
Apochaete hispida
Diandrochloa namaquensis
Eragrostis capensis*
Hemarthria altissima*
Hyparrhenia bracteata
Loudetia simplex
Monocymbium ceresiiforme*
Panicum sp. near P. subrepandum
Paspalum commersonii
Pennisetum purpureum
Phragmites mauritianus
Phyllorachis sagittata
Sacciolepis gracilis*
Sporobolus macotrix
Trachypogon spicatus*

Sedges

Ascolepis capensis
Cyperus aureobruneus
C. esculentus
C. longus
C. margaritaceus
C. sylvestris
C. tenax
Fimbristylis dichotoma
F. exilis
Fuirena stricta
Lipocarpa chinensis
Mariscus ochrocephalus
Typha sp.

Leguminous herbs/shrubs

Aeschynomene sp.
Desmodium salicifolium
Sesbania caerulescens
S. seban

Shrub

Ascocarydion mirabile

The more or less permanently wet patches of the dambo carry virtually nothing but *Andropogon eucomus*, and seasonally wet areas *Monocymbium ceresiiforme;* while the drier headward portions often show more *Apochaete hispida* and *Sacciolepis gracilis* in the sward. *Hyparrhenia bracteata* is characteristic of humic sites; Trapnell noted *H. dissoluta* as marking marginal dambo sands. Leached sandy dambos often have almost pure *Loudetia simplex* grass cover; while the courses of permanent streams may be lined with *Phyllorachis sagittata*. Trapnell (1957) noted that the edge of the sand bordering a dambo was often marked by a narrow fringe of *Hyparrhenia* spp. and *Trachypogon plumosus*, beyond which a zone of sedges (*Scleria* spp.), passing into tussocky *Miscanthidium* grassland, commonly occurred.

II(a) Mongu-Kalabo Terrace. Lake-Dune Barotse Sands

This soil type carries a wide range of climax woody vegetation including the following: *Cryptosepalum* forest, *Julbernardia-Brachystegia* woodland, *Brachystegia spiciformis* woodland, *Burkea* woodland, *Dialium* woodland and *Erythrophleum-Pterocarpus* woodland. In spite of this considerable range, the grass and herbaceous cover is very much less varied, and is consequently treated as one unit, equivalent to Trapnell and Clothier's (1957) Kalahari Grassland type. Where the woody vegetation has been virtually cleared, the grassland composition is as listed below. The most commonly occurring grasses are asterisked.

Grasses

Andropogon sp.
Anthephora acuminata
Aristida graciliflora*
A. meridionalis*
A. sp. (undescribed)
Brachiaria dura*
B. xantholeuca
B. distichophylla
Cenchrus biflorus*
Chloris pycnothrix
C. virgata
Craspedorhachis rhodesiana
Digitaria brazzae
D. milanjiana
D. perrottetii*
D. sp.
Dolichochaete nodiglumis
Eleusine coracana
Eragrostis arenicola
E. patens
E. rigidior
E. tenuifolia
E. tremula*
E. viscosa
E. sp. aff. E. pallens
E. sp.
Heteropogon melanocarpus
Hyparrhenia dissoluta
Leptocarydion vulpiastrum*
Loudetia lanata
L. simplex
Microchloa indica
Panicum maximum (hairy form)
Pennisetum typhoides
Perotis leptopus*
P. vaginata
Pogonarthria squarrosa
Rhynchelytrum nyassanum
R. subglabrum*
Schizachyrium jeffreysii*
S. sp. aff. S. jeffreysii
Setaria homonyma
S. pallidifusca
Sorghum sp. aff. S. roxburghii
Sporobolus molleri
S. pyramidalis
Tricholaena monachne*
Urelytrum squarrosum

Sedges

Cyperus amabilis
C. tenax
Mariscus laxiflorus

Leguminous herbs/shrubs

Bolusia rhodesiana
Crotalaria natalitia
C. ochroleuca
C. podocarpa
C. sphaerocarpa
C. stenoptera
C. sp.
Indigofera arenophila
I. baumiana
I. filipes
I. griscoides
I. hirsuta
I. microcalyx
I. nummulariifolia
I. spicata
I. spp.
Tephrosia cephalantha
T. lupinifolia
T. purpurea var. pubescens
Vigna dekindtiana
Zornia glochidiata

Other shrubs and herbs

Baissea wulfhorstii
Cassytha filiformis
Citrullus naudinianus
Erlangea sessilifolia
Gisekia pharnacioides
Polycarpaea eriantha var. effusa
Strobilanthopsis linifolia

The commonest browse species include the following trees and shrubs:

Acacia giraffae
Amblygonocarpus andongensis
Baikiaea plurijuga
Brachystegia spiciformis
Erythrophleum africanum
Guibourtia coleosperma
Pterocarpus angolensis
Pterocarpus antunesii
Ricinodendron rautanenii
Swartzia madagascariensis

Areas of marked disturbance are usually characterised by *Pogonarthria squarrosa*, and overgrazed areas by *Sporobolus pyramidalis*.

In the woodland areas the grass cover becomes both sparser and floristically poorer. The following were the commoner components noted in woodland near Mongu:

Grasses

Anthephora acuminata
Andropogon sp.
Brachiaria sp. aff. B distichophylla

Sedge

Mariscus laxiflorus

Herbs

Cassytha filiformis
Strobilanthopsis linifolia
Vernonia poskeana

In view of the importance of the grasslands on the Lake-dune soils for flood-time grazing, more detailed studies were made in the Mongu area. Two line intersects were laid out in annually burnt and slashed grassland, each 500 feet (152.4 m) long and forming a cross. Two hundred observations were made along these lines at five foot (1.52 m) intervals, the results of which are shown in Table 28.

TABLE 28 Percentage composition of the vegetation of the Lake-dune Barotse Sands

Type of ground cover	Percentage cover	
	Individual	Group
Grasses		
Brachiaria dura	16	
Digitaria milanjiana	6	
Tricholaena monachne	3	
Cynodon dactylon	3	
Eragrostis tremula	2	
Digitaria perrottetii	1	
Aristida graciliflora	present	31
Leguminous herbs		
Indigofera nummulariifolia	1	
Bolusia rhodesiana	present	1
Other herbs		
Erlangea sessilifolia	4	
Bidens pilosa	present	4
Shrubs and woody creepers		
Baphia obovata	1	
Bauhinia macrantha	present	
Baissea wulfhorstii	28	29
No vegetation		
Leaf litter	19	
Bare ground	16	35
Total	100	100

Thus approximately one third of the ground was uncovered by vegetation, one third was covered by shrubs and herbs, and only one third by grasses. Of the grass cover approximately half (sixteen per cent of the ground surface) was occupied by *Brachiaria dura*.

The total vegetative cover was also measured at a height of two feet (0.61 m) above the ground, and found to be 57 per cent.

II(b) Mongu-Kalabo Terrace, Lake Basin Alluvial Soils

These also carry a wide range of woody vegetation similar to that on the Lake-dune soils and including *Cryptosepalum* forest, *Julbernardia-Brachystegia* woodland, *Brachystegia spiciformis* woodland, *Burkea* woodland, *Dialium* woodland and *Erythrophleum-Pterocarpus* woodland. Trapnell included the grassland associated with these communities in Kalahari Grassland.

The composition of the grassland on this soil type, in the absence of woodland or forest cover, includes the following species:

Grasses

Andropogon amplectens
A. eucomus
A. huillensis
A. schirensis
A. sp.
Anthephora acuminata
Apochaete hispida
Aristida atroviolacea
A. graciliflora
A. meridionalis
A. sp. (undescribed)
Brachiaria dura
B. humidicola
B. nigropedata
B. xantholeuca
B. sp. aff. B. distichophylla
Craspedorhachis rhodesiana
Cynodon dactylon
Danthoniopsis viridis
Diandrochloa namaquensis
Diheteropogon grandiflorus
Digitaria brazzae
D. milanjiana
D. monodactyla
D. perrottetii
D. sp.
Dolichochaete nodiglumis
Eragrostis arenicola
E. gangetica
E. rigidior
E. tenuifolia
E. tremula
E. sp. aff. E. pallens
E. sp.
Heteropogon melanocarpus
Hyparrhenia dissoluta
Loudetia lanata
L. simplex
Megastachya mucronata
Melinis macrochaeta
Microchloa indica
Miscanthidium teretifolium
Monocymbium ceresiiforme
Oryza perennis
Panicum maximum (hairy form)
Paratristachya superba
Pennisetum polystachyon
Perotis leptopus
Pogonarthria squarrosa
Rhynchelytrum nyassanum
Rottboellia exaltata
Schizachyrium sp. aff.
S. jeffreysii
S. jeffreysii
Setaria anceps
S. homonyma
Sorghum aff. S. roxburghii
Sporobolus molleri
S. pyramidalis
S. sanguineus
S. subtilis
Trachypogon spicatus
Tricholaena monachne
Trichoneura grandiglumis
Tristachya eylesii
Urelytrum squarrosum
Vetiveria nigritana

Sedges

Ascolepis elata
Bulbostylis sp.
Cyperus amabilis
C. sylvestris
C. tenax
Mariscus deciduus
M. ochrocephalus
Scleria bambarensis
S. induta

Leguminous herbs/shrubs

Cassia obtusifolia
C. occidentalis
Crotalaria amoena
C. baumii
C. bequaertii
C. cephalotes
C. goreensis
C. gweloensis
C. natalitia
C. ochroleuca
C. podocarpa
C. pseudotenuirama
C. rhodesiae
C. stenoptera
C. sp. aff. tamboensis
C. sp.
Dolichos africanus
D. sp.
Eriosema psoraleoides
Glycine javanica
Humularia lundaensis
Indigofera baumiana
I. demissa
I. filipes
I. flavicans
I. griscoides
I. sp.
Rothia hirsuta
Rhynchosia minima
Smithia strobilantha
Tephrosia cephalantha
T. purpurea var. pubescens
T. rhodesica
Vigna dekindtiana

Other herbs and shrubs

Gisekia pharnacioides
Lepidagathis microchila
Oldenlandia herbacea
Polycarpaea eriantha var. effusa

Variations in the sandy soil cover may be reflected by variations in the composition of the grassland; thus damper areas will be marked by an increased quantity of *Andropogon eucomus* and *Monocymbium ceresiiforme*, and areas of looser sand by *Digitaria perrottetii*, *Perotis leptopus* and *Tricholaena monache*. *Hyparrhenia dissoluta* tends to dominate the open more frequently burnt areas, while *Cynodon dactylon* usually marks recently abandoned farm areas, where soils have been manured and have an above-average nutrient status.

The grass cover is markedly reduced within the woodlands and forests; under mature stands of *Cryptosepalum* forest the only grass found is *Danthoniopsis viridis*.

II(c) Mongu-Kalabo Terrace. Humic Soils

The grassland cover of these soils corresponds with Trapnell's (1950) Valley and Floodplain Grassland type. Woody vegetation is usually absent, although occasional relic patches of *Syzgium* forest remain. The grass cover includes the following species:

Grasses

Alloteropsis semialata
Andropogon eucomus
A. huillensis
Brachiaria mutica
Eragrostis capensis
E. sp. aff. E. denudata
Eriochrysis brachypogon
E. pallida
Hyparrhenia bracteata
Imperata cylindrica
Ischaemum arcuatum
Leersia hexandra
Loudetia simplex
Miscanthidium teretifolium
Panicum inaequilatum
P. parvifolium
P. sp. aff. P. coloratum
Schizachyrium jeffreysii
Trichopteryx dregeana

Sedges

Ascolepis capensis
Fimbristylis longiculmis
Fuirena glomerata
F. umbellata
Lipocarpa chinensis
Rhynchospora holoschoinoides
Scleria bambarensis
S. veseyfitzgeraldii

Leguminous herbs/shrubs

Desmodium salicifolium
Eriosema psoraleoides

Shrub

Ascocarydion mirabile

There is often a distinctive zoning of the vegetation from the dry edge of these humic soils to their damper or wet centres as follows:

1.	Edge of upland, seepage zone	Imperata cylindrica
2.	Deep humic soils	Hyparrhenia bracteata Eriochrysis pallida
3.	Permanently waterlogged	Leersia hexandra
4.	Edges of *Syzygium* forest relics	Panicum inaequilatum Trichopteryx dregeana

Where cultivation is causing the organic topsoil to degenerate, the *Hyparrhenia-Eriochrysis* association is replaced by one composed of *Alloteropsis semialata*, *Andropogon eucomus* and *Eragrostis capensis*. When the organic matter is almost exhausted this association is replaced by *Miscanthidium teretifolium*.

The sedge *Fuirena glomerata* may also occur in nearly pure stands growing in water; it is often found as a weed of rice fields on this soil.

II(d) Mongu-Kalabo Terrace. Recent Alluvium in Abandoned Watercourses

The grassland on this soil type corresponds with Trapnell's (1950) Kalahari Sand Plain and Watershed Grasslands.

The floristic composition of the community recorded during this survey was as follows:

Grasses

Acroceras macrum
Andropogon eucomus
A. huillensis
A. tumidulus
Brachiaria humidicola
B. nigropedata
B. platytaenia
Cynodon dactylon
Diandrochloa namaquensis
Diheteropogon grandiflorus
Digitaria scalarum
Echinochloa pyramidalis
Eragrostis capensis
E. lappula
E. mildbraedii
E. sp. aff. E. denudata
Hemarthria altissima
Leersia hexandra
Loudetia phragmitoides
L. simplex
Miscanthidium teretifolium
Monocymbium ceresiiforme
Panicum dregeanum
P. glabrescens
P. ianthum
P. juncifolium
P. repens
Paratristachya superba
Paspalum commersonii
Pennisetum polystachyon
Phragmites mauritianus
Rhytachne rottboellioides
Sacciolepis cinereo-vestitum
S. gracilis
S. typhura
S. scirpiodes
Setaria anceps
S. sphacelata
Sporobolus subtilis
Themeda triandra
Trachypogon spicatus
Vetiveria nigritana

Sedges

Ascolepis elata
Bulbostylis laniceps
B. sp.
Cyperus denudatus
C. esculentus
C. longus
C. margaritaceus
C. mwinilungensis
C. nudicaulis
C. sphaerospermus
C. sylvestris
C. tenax
C. sp.
C. sp. aff. C. angolensis
Fimbristylis longiculmis
F. squarrosa
F. triflora
Kyllinga erecta var. intricata
Lipocarpa albiceps
Mariscus deciduus
M. umbellatus
Pycreus lanceolatus
P. polystachyos
Rhynchospora candida
R. corymbosa
R. holoschoinoides
R. rugosa
R. glauca
Scirpus corymbosus
Scleria veseyfitzgeraldii
Typha sp. (australis?)

Legume

Aeschynomene indica

This edaphic grassland is usually confined to micro-depressions in the present land surface, where water collects during the rainy season. The centres of these hollows often contain species (e.g. *Phragmites*) which will tolerate flooding; they are surrounded by roughly concentric zones of species progressively less tolerant of wet conditions, with normal dry-land species occurring at the depression margin. A typical sequence is illustrated in Table 29.

TABLE 29 The relationship between topographic position, flooding regime, pH and vegetation in hollows of the recent alluvium

Topographic position and pH					
Depression centre, seasonally flooded	Depression margin				Dry land
-	8.0	7.0	6.5	6.0	5.5
Phragmites mauritianus	Algae	Sedges	Panicum repens	Miscanthidium teretifolium ± Monocymbium ceresiiforme Eragrostis mildbraedii	Paratristachya superba Themeda triandra

There is usually a change in pH from acid to alkaline conditions as one moves from the edge to the centre of the depressions, the approximate range of which is indicated in Table 29. As on the Humic Soils the sedge *Fuirena glomerata* seems to thrive in areas seasonally flooded to a depth similar to that favoured by rice; it is therefore often found as a weed in rice fields.

III(a) Bulozi Terrace. Humic soils

The grass associations of these humic soils correspond with Trapnell and Clothier's (1957) Black Clay and Floodplain Grassland and their Seepage, Streamside and Lagoon types, and with Trapnell's (1950) Valley and Floodplain Type.

In general the floristic composition of the grassland found on this soil is as follows:

Grasses

Alloteropsis semialata
Andropogon eucomus
A. huillensis
Eragrostis capensis
E. sp. aff. E. denudata
Eriochrysis brachypogon
E. pallida
Hyparrhenia bracteata
Imperata cylindrica
Ischaemum arcuatum
Leersia hexandra
Miscanthidium teretifolium
Panicum inaequilatum
Panicum juncifolium
P. parvifolium
P. sp. aff. P. coloratum
Pennisetum purpureum
Trichopteryx dregeana

Sedges

Fimbristylis longiculmis
Fuirena glomerata
F. pubescens
F. umbellata
Rhynchospora holoschoinoides
Scleria veseyfitzgeraldii

Legumes

Desmodium salicifolium
Indigofera microcalyx

Shrub

Ascocarydion mirabile

The Lozi people distinguish three variants of this soil, on which different types of garden are cultivated, and which they have called the Dry Litongo, Wet Litongo and Sishanjo. Each of these types tends to carry a different grass cover, related to the groundwater regime of the site. This distinctive zoning parallels that found on the humic soils of Terrace II; the associated grass species are very similar (see II(c) above).

Dry Litongo	Edge of upland seepage zone	Imperata cylindrica
Wet Litongo	Humic soils	Hyparrhenia bracteata Eriochrysis pallida
Sishanjo	Humic (peat soils - permanently water-logged	Leersia hexandra

The shrinking and loss of organic matter which may occur after drainage leads to the replacement of the *Hyparrhenia-Eriochrysis* association by one dominated by *Andropogon eucomus* and *Eragrostis capensis*.

III(b) Bulozi Terrace. Floodplain Sandy Alluvium (Plains Litongo)

The grassland associations found on this soil type correspond with Trapnell and Clothier's (1957) Sand Plain and Dambo Grassland, and Trapnell's (1950) Kalahari Sand Plain and Watershed Grasslands.

Peters (1960), writing about the Plains Litongo, noted that the typical grasses were *Andropogon gayanus* and *Hyparrhenia rufa*, with *Aristida* sp. entering from the woodlands when fertility had been reduced by long periods of cropping. The grass cover was also described as often being scanty and dominated by *Loudetia simplex*, with *Miscanthidium* sp. entering at lower elevations, particularly on the Bulozi Plain.

The floristic composition of the community as determined during this survey of the Matabele and Mulonga Plains is as follows:

Grasses

Alloteropsis semialata
Andropogon eucomus
A. huillensis
A. schirensis
Apochaete hispida
Aristida atroviolacea
A. graciliflora
A. meridionalis
A. pilgeri
Brachiaria dura
B. humidicola
B. nigropedata
Chasmopodium caudatum
Cynodon dactylon
Diandrochloa namaquensis
Diheteropogon grandiflorus
Digitaria milanjiana
D. perrottetii
Elyonurus argenteus
Eragrostis atrovirens
E. capensis
E. lappula
E. mildbraedii
E. tremula
Loudetia lanata
L. simplex
Miscanthidium teretifolium
Monocymbium ceresiiforme
Panicum juncifolium
Paratristachya superba
Rendlia pseudoharpochloa
Rhytachne rottboellioides
Schizachyrium jeffreysii
Setaria anceps
S. sphacelata
Sporobolus macotrix
S. marginatus
S. molleri
Sporobolus pyramidalis
Themeda triandra
Trachypogon spicatus
Vetiveria nigritana

Sedges

Cyperus amabilis
C. tenax
Fimbristylis dichotoma
F. exilis
Fuirena glomerata
F. pubescens
F. stricta
F. umbellata
Kyllinga erecta var. intricata
Lipocarpa albiceps
Mariscus deciduus
M. umbellatus
Pycreus lanceolatus
P. polystachyos
Rhynchospora candida
R. corymbosa
R. holoschoinoides
R. rugosa
R. glauca
Scirpus corymbosus
Scleria veseyfitzgeraldii
Typha sp. (australis?)

Leguminous herbs/shrubs

Cassia occidentalis
Crotolaria pseudotenuirama
Indigofera daleoides
I. microcalyx
Rhynchosia venulosa
Vigna sp.
Zornia milneana

Other herbs and shrubs

Magnistipula eglandulosa
Parinari capensis
Polygala nambalensis
Sesamum angustifolium

Browse trees

Acacia giraffae
Diplorhynchus condylocarpon

On this sandy alluvial surface there are a series of levels at slightly different heights, the higher-lying land always having a lower soil moisture status. Three such areas (T1, T2 and T3) are shown on the 1:50 000 Ecological Survey maps of the Matabele and Mulonga Plains which accompany this report. The soils of T1 are wetter than those of T2, which in turn are wetter than those of T3. The floristic composition of these units is given below. The dominant grasses are indicated by the suffix (d).

T1	T2	T3
	Grasses	
Apochaete hispida(d)	Aristida graciliflora(d)	Aristida graciliflora (d)
Aristida atroviolacea	Aristida meridionalis(d)	Brachiaria dura(d)
Brachiaria dura	Apochaete hispida	Digitaria milanjiana
Diheteropogon grandiflorus	Brachiaria dura	Eragrostis tremula
Elionurus argenteus	Digitaria perrottetii	Loudetia lanata(d)
Loudetia simplex(d)	Tristachya superba	Schizachyrium jeffreysii
Rhytachne rottboellioides		
Schizachyrium jeffreysii		
	Shrubs	
Annona stenophylla	Burkea africana	Burkea africana
Eugenia angolensis	Diplorhynchus condylocarpon	Combretum imberbe
Lannea gossweileri	Terminalia sericea	Diplorhynchus condylocarpon
Magnistipula eglandulosa		Terminalia sericea
Ochna spp.		
Parinari capensis		
Syzygium huillense		

Minor depressions in the surface of the sandy alluvium are usually damper than the surrounding areas. This variation in soil moisture is also often accompanied by a zoning of the grass cover. Areas of higher soil fertility are often distinguished by their cover of *Cynodon dactylon*, while overgrazed areas are usually dominated by *Sporobolus pyramidalis*.

III(c) Bulozi Terrace. River Levee Alluvium

The grass associations growing on this soil type correspond with Trapnell's Bush-group types of vegetation on both Kalahari and Transitional Sand Plains. Some of the species are among those listed in his (1950) Valley and Floodplain Grasslands.

The characteristic members of the association are listed below. The most commonly occurring grasses are asterisked.

Grasses

Andropogon gayanus
Aristida eriophora
A. pilgeri
A. sp.
Brachiaria nigropedata
B. platytaenia
Chloris gayana
Chasmopodium caudatum
Cynodon dactylon
Digitaria scalarum
D. brazzae
Dolichochaete nodiglumis
Eleusine indica
Elyonurus argenteus
Eragrostis atrovirens
Eragrostis lappula*
E. lappula var.
E. rigidior
Hyparrhenia dissoluta
Panicum maximum (hairy form)*
P. repens
Pennisetum glaucocladum
Rendlia pseudoharpochloa
Setaria anceps*
S. sphacelata
S. verticillata
S. sp.
Sporobolus pyramidalis
S. spicatus
S. subtilis

Sedges

Cyperus auricomus
Fimbristylis exilis

Leguminous herbs/shrubs

Abrus fruticulos
A. indica
Canavalia ferruginea
Cassia absus
C. mimosoides
C. occidentalis
C. goreensis
C. mucronata
C. ochroleuca
C. rhodesia
C. shamvaensis
C. spinosa
Glycine javanica
Indigofera arrecta
I. demissa
I. gairdnerae
Lablab niger
Mimosa pigra
Rothia hirsuta
Rhynchosia minima
R. sublobata
R. venulosa
Sesbania sesban
S. sesban var. zambesiaca
Tephrosia linearis

Other herbs and shrubs

Jasminum fluminense
Ludwigia leptocarpa
Moringa oleifera
Sesamum angustifolium
Striga gesnerioides

The edges of the levees where the soil is usually damper are often characterised by *Brachiaria nigropedata* and *B. platytaenia*, the latter occupying the moister positions. Areas where *Chloris gayana* occurs in quantity in the sward are usually those of higher fertility; *Cynodon dactylon* is often found on old manured farm sites that have been abandoned. Farms still under cultivation are often heavily infested with *Eleusine indica*. Overgrazed areas are usually marked by *Sporobolus pyramidalis*.

The most important tree and shrub browse species are:

Acacia albida
A. giraffae
A. sieberiana
Albizia antunesiana
Guibourtia coleosperma
Lonchocarpus capassa
Parinari curatellifolia
Piliostigma thonningii

III(d) Bulozi Terrace. Recent Alluvium in Abandoned Watercourses

The grass associations found on this soil type correspond primarily with Trapnell's (1950) Valley and Floodplain Grasslands and the Swamp and Papyrus Sudd.

There is considerable variation in the micro-topography of this soil unit, as it includes abandoned river courses, partially silted-up ox-bows and shallow pans. These depressions act as foci for local surface drainage, and are usually marked by a distinctive zoning of the grasses, which will be discussed later. In general terms the floristic composition of the grassland on this soil is as follows:

Grasses

Acroceras macrum
Brachiaria humidicola
Digitaria scalarum
D. horizontalis
Diplachne fusca
Echinochloa holubii
E. pyramidalis
E. stagnina
Eragrostis atrovirens
E. lappula
R. rigidior
Hemarthria altissima
Leersia hexandra
L. sp.
Loudetia sp.
Miscanthidium teretifolium
Odyssea paucinervis
Oryza perennis
Panicum dregeanum
P. glabrescens
P. ianthum
P. maximum (hairy form)
P. repens
P. sp. aff. P. porphyrrhisos
Paspalidium sp. aff. P. platyrrhachis
Paspalum commersonii
Pennisetum glaucocladum
Phragmites mauritianus
Robynsiochloa purpurescens
Rhytachne rottboellioides
Sacciolepis africana
S. gracilis
S. typhura
S. sp. aff. S. typhura
Setaria anceps
S. sphacelata
Sorghum macrochaeta
Sporobolus acinifolius
S. spicatus
Vossia cuspidata
Willkommia sarmentosa

Sedges

Ascolepis capensis
Bulbostylis aphyllanthoides
B. schoenoides
Cyperus auricomus
C. compactus
C. denudatus

Sedges

C. difformis
C. esculentus
C. longus
C. margaritaceus
C. mwinilungensis
C. nudicaulis
C. papyrus
C. radiatus
C. sphaerospermus
Eleocharis sp.
E. dulcis
Fimbristylis complanaya
F. dichotoma
F. squarrosa
Fuirena glomerata
F. pubescens
F. stricta and F. umbellata
Juncus sp.
Kyllinga erecta var. intricata
Lipocarpa albiceps
L. chinensis
Mariscus deciduus
Pycreus aethiops
P. flavescens
P. mundtii
P. polystachyos
Rhynchospora candida
R. corymbosa
R. holoschoinoides
Scirpus corymbosus
S. cubensis
S. sp.
Scleria melanomphala
Typha sp.

Leguminous herbs/shrubs

Aeschynomene cristata
A. fluitans
A. indica
A. nilotica
Sesbania microphylla
S. sesban
S. sesban var. zambesiaca

Other herbs and shrubs

Commelina purpurea
Floscopa glomerata
Ipomoea aquatica
Polygonum salicifolium
Thalia welwitschii

The major variations in micro-topography of this soil unit were mapped at 1:50 000 scale during the survey of the Matabele and Mulonga Plains, three units being recognised.

(i) Recent river beds and old ox-bows

(ii) Recent low-lying alluvium - the flood plain of an old river course.

(iii) The old lake shore of the seasonally flooded plain. Grassland characterised by Bush-groups or termitaria.

These units are considered in detail below.

(i) **Recent river beds and ox-bows** These are the lowest-lying features on the plains, are often waterlogged and nearly always have damp soil. As a result they are characterised by moisture-loving grasses, which display a fairly distinctive zoning, reflecting the depth of water and/or variations in the dampness of the soil throughout the year.

Open water	Water lilies Cyperus papyrus
Increasing soil moisture and/or depth of flooding	Vossia cuspidata Echinochloa stagnina Sacciolepis africana Echinochloa pyramidalis Oryza perennis Leersia hexandra Acroceras macrum Panicum repens Pycreus mundtii (sedge) Paspalum commersonii Hemarthria altissima Digitaria scalarum (D. abyssinica)

The legume most commonly found in this association is *Aeschynomene fluitans*. Salt conditions, which occasionally occur, are usually characterised by *Diplachne fusca*. Trapnell and Clothier (1957) noted that *Oryza barthii* marks peaty accumulations in late flooded sites.

(ii) **Flood plain of an old river course** This is the most widespread of the subdivisions of the recent alluvium, and is characterised by the following association, of which the first two members are the usual dominants:

Grasses	*Legumes*
Themeda triandra	Sesbania microphylla
Setaria sphacelata	Aeschynomene indica
Trachypogon spicatus	Indigofera microcalyx
Brachiaria nigropedata	
Andropogon huillensis	
Eragrostis lappula	
Rendlia pseudo-harpochloa	

(iii) **The old lakeshore Bush-groups** Trapnell *et al* (1950) and Trapnell and Clothier (1957) included this vegetation in their Bush-group Formations. It consists of small circular clumps of bush spaced through seasonally wet grassland. The Lozi call these Bush-groups 'Mabumba'; and they are often found growing on anthills. The composition of the Bush-group varies with the woodland type of the area concerned; it is often fringed with *Syzygium* trees which, as Trapnell noted, mark the transition to wetter ground.

On the Matabele and Mulonga Plains the most important components of the grasslands, and browse species in the bush-clumps, were found to be as follows:

Grasses	*Browse shrubs and trees*
Chloris gayana	Acacia giraffae
Cynodon dactylon	A. sieberiana
Panicum repens	Capparis tomentosa
Sporobolus spicatus	Lonchocarpus capassa
S. subtilis	Piliostigma thonningii
Eragrostis lappula	Sansevieria desertii

Legumes

Rhynchosia sublobata
R. venulosa

The floristic composition of the Bush-groups themselves has been investigated in some detail by Fanshawe (1963a,b); details will be found in Appendix 2.

On the Siloana Plain, which Trapnell and Clothier (1957) noted as carrying a cover of *Tristachya*, the Recent Alluvium is characterised by a number of dried salt pans which have no visible drainage outlet. As one passes from the edge to the centre of one of these pans, minor grass zones coincide with increases in the amount of salt and soil moisture. The following is a typical sequence:

Edge of pan	Miscanthidium teretifolium
	Sporobolus spicatus
	Eragrostis rigidior
	Panicum sp. aff. P. porphyrrhisos
	Diplachne fusca
	Odyssea paucinervis
Toward pan centre	Willkommia sarmentosa

The actual centres of these pans are often devoid of any vegetation owing to the high concentration of salts.

III(e) Bulozi Terrace. Brown Mopane Alluvium

These soils, which support *Colophospermum mopane* woodland, were not investigated during the present survey. It was noted, however, that their grass cover was principally made up of *Enteropogon macrostachyus*, *Schmidtia bulbosa* and *Sporobolus panicoides*.

THE NUTRITIONAL STATUS OF THE VEGETATION COMMUNITIES

There are several ways of assessing the nutritional value of a plant community. Controlled grazing experiments can be carried out, and the feeding value of the pasture in terms of animal liveweight gain can be measured. This is a slow process, although ultimately it is the only satisfactory way of making such an assessment. In parts of Western Province grazing experiments will be difficult to design because the different grassland communities

are distributed in a complex mosaic of small units. An alternative is to analyse the fodder itself, the grasses and herbs of the different communities, to determine their levels of protein, fibre and mineral nutrients. The resulting data can be compared with theoretically adequate levels for cattle production. This method is satisfactory as a means of comparing one community with another, but may not take account of seasonal changes in food value nor of the availability of the fodder to the cattle.

With the exception of the upland forest grazing, representative samples of the various fodder plant communities were not collected during this investigation. Samples were collected, however, of the major species making up these communities, and the material was analysed at the Mount Makulu laboratory. The results are shown in Table 30.

The interpretation of such data requires care and, since it is important that a full understanding of the feeding value of the Western Province fodder resources can be obtained, a discussion of this subject by A. Blair Rains is included in Appendix 3. If this is read in conjunction with the Table 30 the better nutrient status of the wetland grasses will be apparent, with the notable exception of the phosphorus values which are very low. The dryland grasses have a markedly higher phosphorus content and a surprisingly low but adequate calcium content.

The problem of abnormally low levels of phosphorus and also of sulphate in the Barotse (Kalahari) Sands was the subject of an investigation by the now defunct Central African Agricultural Research Council. As this work is of importance, the following extract is quoted from their 1966 Annual Report:

> 'Impoverished siliceous sand of the Kalahari system covers wide areas in both Zambia and Rhodesia. Its natural vegetation provides low-quality grazing and the fecundity of the cattle pastured on it is abnormally low. The soil is known to be deficient in phosphate and sulphate, and it had been observed that the sulphate content of test-crops grown on it was below that usually encountered on unfertilised soils. The Soil Productivity Team has, therefore, had an experiment on the effects of phosphate and sulphate fertilisation of the natural herbage, in the same area as the Rhodesian Ministry of Agriculture has had a feeding trial with sulphur and supplementary carbohydrates. The fertiliser experiment was replicated in adjacent areas, one on the vlei margin and one higher up the catena.
>
> 'Small quantities, such as would be practical with aerial top-dressing, of phosphate (20 lb P_2O_5 per acre as triple super phosphate) and sulphur (20 lb S as sulphate) were applied in factorial combination with a minimal quantity of dolomitic lime (100 lb per acre) mixed into the fertiliser*. A basal dressing of 20 lb N was given. As the district was severely drought-stricken and the grass came away very late, one cut only was taken when the grass was mature in mid-May. Analysis of the herbage showed that the nitrogen and sulphur contents were low (0.4% N and 0.03%S) and the phosphate content proportionately lower still; the ash was loaded with silica.
>
> 'Only the phosphate fertiliser increased yields - by 40% on the vlei site and 20% on the slope. It was observed that legumes and other dicotyledons were more abundant on phosphate-treated plots. Apparently nitrogen

* 1 lb per ac = 1.12 kg per ha

TABLE 30 Percentage dry matter composition of selected Western Province fodder species

Name	Remarks	Crude protein	Crude fibre	Ether extract	Total ash	Nitrogen free extract	Ca	Mg	Na	P	K	Cl	Lab. No.	Herbarium no.	Date of collection 1964
Wetland grasses															
Acroceras macrum	)	6.25	33.19	2.03	13.70	44.83							5188	1160	18.4
Brachiaria nigropedata	)	4.94	32.25	2.23	5.75	54.83	0.32	0.18	0.35	0.10	0.33	0.16	5178	1162	8.4
Digitaria scalarum	)	8.69	31.48	3.00	6.17	50.66							5189	1163	13.5
Echinochloa stagnina	)	2.19	36.24	1.63	8.40	50.54	0.39	0.12	0.13	0.05	0.66	0.47	5174	1151	19.3
Echinochloa pyramidalis	)	2.94	32.82	2.49	5.92	55.83							5185	1153	18.4
Hemarthria altissima	) Flowering stage,	2.50	31.98	1.39	5.31	58.82							5209	1114	14.5
Leersia hexandra	) maximum bulk	7.50	30.34	2.98	9.42	49.76	0.48	0.14	0.17	0.11	0.40	0.27	5176	1154	8.4
Oryza perennis	)	4.31	34.26	1.84	15.70	43.89	0.32	0.14	0.17	0.10	0.73	0.25	5175	1152	8.4
Panicum glabrescens	)	4.13	35.93	3.42	6.69	49.83							5187	1157	20.5
Paspalum commersonii	)	11.63	28.82	3.10	11.48	44.97							5186	1156	18.3
Sacciolepis africana	)	5.44	29.38	2.07	9.47	53.64	0.54	0.08	0.35	0.11	1.18	1.26	5177	1155	8.4
Vossia cuspidata	)	3.57	35.08	1.46	5.94	53.95	0.27	0.15	0.04	0.07	0.45	0.36	5174	1150	19.3
Vossia cuspidata	Young shoots	14.60	33.50	1.80	7.80	50.20							-	1150	30.11
Wetland legumes															
Aeschynomene fluitans	Young shoots	26.2	12.3	2.8	8.1	50.2							-	1202	30.11
Aeschynomene fluitans	Mature: flowering	14.81	22.92	2.59	9.31	50.37	1.48	0.09	0.14	0.15	1.14	0.91	5180	1202	8.4
Convolvulus sp.	Non-legume, creeper	7.88	16.88	3.01	12.66	59.57	1.66	0.11	0.41	0.10	1.77	1.44	5179	1201	8.4
Sesbania microphylla	Mature: flowering	4.75	49.92	2.52	4.36	32.70	0.92	0.21	0.05	0.09	0.33	0.18	5180	1205	2.4
Dryland grasses															
Composite mixture of grasses	Flowering stage	4.44	43.07	2.05	3.49	46.70	0.16	0.13	0.03	0.21	0.35	0.10	5184	-	21.4
Brachiaria dura	Young shoots	7.56	41.33	2.40	2.85	45.92	0.16	0.05	0.04	0.25	0.23	0.05	5182	1319	21.4
Brachiaria dura	Flowering stage	6.38	43.34	2.20	2.37	45.71	0.36	0.05	0.04	0.19	0.28	0.25	5183	1319	21.4
Chloris gayana	Young shoots, Siloana	-	-	-	-	-	-	-	-	-	-	-	-	-	30.11
Woodland fodder trees: pods															
Acacia albida	E. Province	11.5	23.4	1.4	3.2	55.1							-	-	-
Acacia giraffae	Sesheke district	15.69	27.12	6.06	4.63	46.5							6263	-	15.10
Acacia sieberiana	E. Province	10.3	24.8	1.0	3.4	51.9							-	-	-
Piliostigma thonningii	S. Province	6.4	24.0	2.4	3.3	59.4							-	-	-
Swartzia madagascariensis	N. Province	6.9	25.5	0.8	1.5	60.5							-	-	-
Woodland tree fruits															
Guibourtia coleosperma	Seed coatings	2.4	48.9	32.6	15.2	0.9							-	-	-
Parinari curatellifolia	Kernels	23.4	17.3	48.9	8.1	2.3							-	-	-
Parinari curatellifolia	Porridge	3.1	14.9	0.2	79.6	2.2							-	-	-
Ricinodendron rautanenii	Kernels roasted	17.8	29.7	40.5	7.6	4.4							-	-	-
Ricinodendron rautanenii	Meal, porridge	7.6	3.2	0.6	83.1	5.5							-	-	-

became the limiting factor when phosphate had been applied. The phosphate fertiliser doubled the phosphate content of the herbage from 0.02 to 0.04% P and reduced the nitrogen content, while the total production of protein was slightly increased on the phosphate plots. The sulphate fertiliser doubled the sulphur content of the herbage but had no effect on yield of dry matter or protein and the lime had no effect on the uptake of nutrients.'

Data for the pods of certain trees commonly eaten by cattle are also included in Table 30; further information will be found in the Imperial Agricultural Bureaux publication (1947). Certain fruits are eaten not only by cattle but also by man; data on these are included in Table 30. The fat of pigs fed on *Ricinodendron rautanenii* kernels was found to be yellow and unsaleable.

THE PALATABILITY OF THE GRASSES

The assessment of grassland palatability is especially difficult because of the large number of variables involved, even if the results of carefully observed and recorded grazing trials are available. No such trials have been carried out in Western Province. However, in the course of the investigations the grazing habits of various herds of cattle were observed, and information was also gathered from herd boys. On this basis the grasses of the area have been arranged in three broad palatability groups:

High palatability

Acroceras macrum
Brachiaria brizantha
B. dura
B. humidicola
B. mutica
Chloris gayana
C. pycnothrix
C. virgata
Cynodon dactylon
Digitaria scalarum
D. brazzae
D. horizontalis
D. milanjiana
Diplachne fusca
Echinochloa crus-pavonis
E. holubii
E. pyramidalis
E. stagnina
Eragrostis mildbraedii
Hemarthria altissima
Oryza perennis
Panicum maximum (hairy form)
P. repens
P. sp. aff. P. coloratum
P. sp. aff. P. porphyrrhisos
Paspalidium sp. aff.
P. platyrrhachis
Paspalum commersonii
Pennisetum purpureum
Sacciolepis africana
S. cinereo vestitum
S. gracilis
S. typhura
S. sp. aff. S. typhura
S. scirpiodes
Setaria sphacelata
Sporobolus spicatus
Vossia cuspidata

Medium palatability

Alloteropsis semialata
var. ecklonii
Andropogon amplectens
A. brazzae
A. eucomus
A. gayanus var. squamulatus
A. huillensis
A. schirensis
A. tumidulus
Apochaete hispida
Aristida atroviolacea
A. graciliflora
A. meridionalis
A. pilgeri
Brachiaria nigropedata
B. platytaenia
B. xantholeuca
B. aff. B. distichophylla

Chasmopodium caudatum
Craspedorhachis rhodesiana
Dactyloctenium aegyptium
Danthoniopsis viridis
Digitaria monodactyla var. explicata
D. perrottetii
Dolichochaete nodiglumis
Eleusine indica
Enteropogon macrostachyus
Eragrostis arenicola
E. atrovirens
E. capensis
E. chapelieri
E. lappula
E. lappula var. divaricata
E. patens
Heteropogon melanocarpus
H. contortus
Homozeugos eylesii
Hyparrhenia bracteata
H. diplandra
H. dissoluta
H. filipendula var. pilosa
Hyparrhenia grallata
H. newtonii
H. poecilotricha
H. rudis
H. rufa
H. variabilis
Imperata cylindrica var. africana
Ischaemum arcuatum
Leersia hexandra
Leptocarydion vulpiastrum
Melinis macrochaeta
Odyssea paucinervis
Panicum dregeanum
P. glabrescens
P. ianthum
P. inaequilatum
P. juncifolium
P. parvifolium
P. cf. P. subrepandum
Pennisetum glaucocladum
P. polystachyon
Rhynchelytrum nyassanum
R. subglabrum
Rottboellia exaltata
Rhytachne robusta
R. rottboellioides
Schizachyrium ursulus
S. sp. aff. S. jeffreysii
S. jeffreysii
Schmidtia bulbosa
Setaria anceps
S. homonyma
S. pallidifusca
S. verticillata
Sorghum macrochaeta
Sporobolus subtilis
Themeda triandra
Tricholaena monachne
Willkommia sarmentosa

Low palatability

Anthephora acuminata
Aristida eriophora
Cenchrus biflorus
Cymbopogon densiflorus
Diandrochloa namaquensis
Diheteropogon grandiflorus
Elyonurus brazzae
Eragrostis gangetica
E. rigidior
E. tenuifolia
E. tremula
E. viscosa
E. sp. aff. E. denudata
E. sp. aff. E. pallens
Eriochrysis brachypogon
E. pallida
Loudetia lanata
L. phragmitoides
L. simplex
Megastachya mucronata
Microchloa indica
Miscanthidium teretifolium
Monocymbium ceresiiforme
Paratristachya superba
Perotis leptopus
P. vaginata
Phragmites mauritianus
Phyllorachis sagittata
Pogonarthria squarrosa
Rendlia pseudoharpochloa
Robynsiochloa purpurascens
Sporobolus acinifolius
S. macotrix
S. marginatus
S. molleri
S. panicoides
S. pyramidalis
S. sanguineus
Trachypogon spicatus
Trichoneura grandiglumis
Trichopteryx dregeana
Tristachya eylesii
T. huillensis
Urelytrum squarrosum
Vetiveria nigritana

When these ratings are compared with the information on the dominant grass cover of the different soil units, certain units stand out as carrying the more palatable cover. They are all units on the floodplains of Terrace III, while the upland soild in general carry less palatable grasses. In order of decreasing palatability the units can be arranged as follows:

III(d) Recent Alluvium in Abandoned Watercourses (i) Recent riverbeds and ox-bows: (iii) Old lakeshore, characterised by Bush-group vegetation

III(c) River Levee Alluvium

III(d) Recent Alluvium in Abandoned Watercourses: (ii) Floodplains of an old rivercourse

I(b) Upland Mixed Sedentary and Barotse Sand Soils

II(c) Humic Soils of the Floodplains and Dambo Margins

II(a) Lake-dune Barotse Sands

II(b) Lake Basin Alluvial Soils

I(a) Upland Sedentary soils

The palatability of all tropical grasses drops rapidly when they reach the flowering and seeding stage; this being especially the case with the upland grasses on Terrace I and II. In some years the cattle will be unable to reach units with the most palatable grasses because of abnormally high floods; this does not happen often, and herds of cattle will swim from one river levee to another to graze the more palatable grasses.

POISONOUS PLANTS

As far as is known no work has been done on the poisonous plants of Western Province. Shone (1966, 1967), in Rhodesia, screened seventy-three plant species and one fungus for toxicity to cattle, sheep, pigs and fowls. Twenty-two of the plants and the fungus were found to be toxic for one or more of the animal species. These are listed *below:

Bersama swynnertonnii Bak. f.
Canavalia ensiformis D.C.
Cestrum aurantiacum Lindl.
Chironia transvaalensis Gilg.
Combretum platypetalum Welw. ex Laws.
Datura tatula L.
Gnidia kraussiana Meisn.
Kalanchoe prolifera R. Hamet
Melia azedarach L.
Moraea erici-rosenii R.E. Fries
Nicotiana glauca R. Grah.
Nicotiana tabacum L.
Phalaris tuberosa L.
Phytolacca dodecandra I'Herit.
Ranunculus multifidus Forsk.
Senecio scleratus Schweik.
Solanum incanum L.
Solanum panduraeforme Diege ex Dun.
Trachyandra saltii (Bak) Oberm.
Urginea altissima Bak.
Urginea burkei Bak.
Vernonia ampla O. Hoffm.

The fungus found to be toxic was *Diplodia zeae* (Schw.) Lev. It is also thought that certain *Crotalaria* spp. are toxic after they have set seed.

* Also add *Dichapetalum cymosum* Eng. 1.

THE GRASSLAND SUCCESSION

No experimental work has been performed in Western Province on this important topic. The change in the composition of the open grassland, compared with the grass cover found under woodland in the Mankoya and Mongu areas under a fire regime, has already been noted. The tendency for many of the pastures to revert to a *Sporobolus*-dominated cover when overgrazed has also been noted. On the Lake-dune Barotse Sands and the Lake Basin Soils, where the grassland often includes a high proportion of *Brachiaria dura*, overgrazing may lead to the dominance of relatively unpalatable *Aristida* spp. and, unless the shrub growth of *Bauhinia mucronata* and *Baphia obovata* is slashed, it will slowly increase and shade out much of the grass cover.

In low-lying areas, the grassland succession, and hence the composition, is a function of the depth of flooding. Indeed, Lawton (1970) believes that it may be possible to maintain the most nutritious sward simply by controlling the depth of flooding and the level of the watertable.

CARRYING CAPACITY

In the absence of controlled experiments, the assessment of carrying capacity described in the later parts of this report is entirely subjective. It is therefore important to record the basis on which this assessment rests. This consisted in a study of pastures at the following places where the stocking rates over a period had been recorded:

1. Mazabuka: controlled experiments directed by Clyde A. Smith, with various stocking rates: 4, 8, 10 acres (1.62, 3.24 and 4.05 ha) per cow per annum on *Hyparrhenia* grassland, in *Combretum-Pterocarpus* woodland on Upper Valley Soils.

2. Ntguleni, Eastern Province: stocking rate trials on *Hyparrhenia* grassland, in *Brachystegia* woodland.

3. Kasama area, Northern Province: regular observation of selected pastures.

In addition, many discussions were held with local cattle owners in Western Province to determine how long, and at what stocking rate, they traditionally grazed certain areas.

During the survey a careful visual assessment was made of the pastures, comparisons were made with the trials and experiments noted above, account was taken of the 1964 census, and a provisional assessment of carrying capacity was thereby made.

Photo: W. C. Verboom

PLATE 4 Barotse herdsman in *Themedra triandra - Setaria sphacelata* grassland on recent alluvium on the floodplain of an old river course (See Unit 2, Ecological Survey map)

PLATE 5 Winter grazing on the Bulozi Plain: *Echinochloa pyramidalis - Acroceras macrum - Hemarthria altissima* grassland on recent alluvium (See Unit 1, Ecological Survey map)

FODDER UTILISATION AND CATTLE MANAGEMENT

THE DISTRIBUTION OF CATTLE IN WESTERN PROVINCE

The only statistics available on the cattle population of Western Province are those published by the Veterinary Department in their annual reports, on which the following tables (some taken from Maclean, 1964) are based.

Details of the composition of the total cattle population for the area are given in Table 31.

TABLE 31 Cattle population of the Western Province, 1943 to 1962 (Compiled from the Department of Veterinary Services Annual Reports)

Year	Bulls over 2 years	Cows and heifers	Oxen and tollies	Calves under 2 years	Total
1963	10 351	143 474	64 886	48 068	266 779
1962	9 797	145 223	63 400	48 604	267 024
1961	9 695	142 986	62 921	60 504	266 106
1960	9 509	133 228	56 975	48 309	248 021
1959	8 846	128 124	51 423	48 423	236 816
1958	8 809	121 121	49 137	45 688	224 755
1957	8 474	122 895	47 309	40 403	219 081
1956	9 507	124 007	47 906	41 512	222 932(3)
1955	10 358	128 468	47 260	46 049	232 135
1954	11 850(1)	124 025	44 274	48 377	228 526
1953	10 037(1)	125 462	44 599	48 674	228 772
1952	10 950(1)	123 541	43 148	44 002	221 641
1951	10 785(1)	120116	42 249	51 340	224 490
1950	11 095(1)	113 846	37 792	55 511	218 244
1949	10 683(1)	109 616	35 094	48 508	203 751
1948	12 409(1)	99 998	27 141	46 665	186 213
1947	11 507(1)	93 368	23 139(2)	43 953	171 967
1945	5 851(1)	56 498	11 743(2)	66 500	140 592
1944	9 668(1)	52 442	14 321(2)	58 436	134 867
1943	9 668(1)	67 391	10 858(2)	49 037	136 214

(1) Bulls over 3 years old.

(2) Calves under 3 years old.

(3) Over 10 000 head said to have died in 1955-56 owing to abnormal flooding.

There have been considerable fluctuations in the cattle population due to disease and starvation. In the 1930's the cattle population, which was often described as 'half a million head', was considerably reduced by pleuropneumonia. In 1955-56 prolonged flooding of the Zambesi confined the cattle to the uplands throughout the year, and resulted in some 10 000 deaths due to starvation. Serious flooding occurred again in 1963, and a further 7 000 deaths were recorded. However, there is some indication that the population had begun to stabilise at about 266 000 head from 1961 onwards. This cattle population is shown on a district basis in Table 32, which also shows the net annual increase for the period 1958-63.

TABLE 32 Cattle population and percentage annual net increase, by districts for the years 1958-63. Percentage increase in brackets

District	1958	1959	1960
Mongu	62 656	63 149(0.8)	67 179(6.4)
Kalabo	60 341	64 636(7.1)	70 064(8.4)
Senanga	63 912	66 513(4.6)	70 641(6.2)
Sesheke	31 720	33 743(6.4)	36 231(7.3)
Mankoya	7 950	8 761(0.3)	9 725(11.0)
Western Province	224 755	236 816(5.0)	248 021(4.7)
	1961	1962	1963
Mongu	71 646(6.6)	68 316(-4.6)	68 501(0.3)
Kalabo	70 743(1.0)	73 245(3.5)	70 460(-3.8)
Senganga	74 554(5.7)	74 574(0.03)	74 865(0.4)
Sesheke	39 300(8.5)	41 026(4.4)	43 181(5.3)
Mankoya	9 863(1.4)	9 863(0.0)	9 772(-0.9)
Western Province	266 106(7.3)	267 024(0.3)	266 779(-0.1)

It is clear however that this stabilisation did not occur in Sesheke district, the cattle population of which continued to increase throughout the period.

Table 33 relates the cattle population for each district in 1962 to the land area. These statistics, as Maclean (1964) has noted, are far from satisfactory in that the 'cattle population' has not been converted to animal equivalents; and the gross acreage per head includes all the townships, roads and arable areas, failing to take account of the fact that some 30% of Mongu district is flooded for about 5 months each year, and much of Kalabo District is also flooded or waterlogged. Mankoya is the district most distant from the floodplain grazing. The figures point to possible overstocking in Mongu and Kalabo and understocking in Mankoya.

TABLE 33 Cattle populations and gross stocking rates for 1962, by district

District	Area ha(ac)	Cattle population 1962	Gross acreage per animal	Cattle per 100 people
Mongu	1 490 105(3 682 000)	68 316	54	65
Kalabo	2 456 529(6 070 000)	73 245	83	76
Senanga	2 990 733(7 390 000)	74 574	99	102
Sesheke	2 927 195(7 233 000)	41 026	176	97
Mankoya	2 815 093(6 956 000)	9 863	700	21

THE SEASONAL MOVEMENT OF CATTLE IN WESTERN PROVINCE

Two distinct patterns of seasonal cattle movement occur in Western Province:

1. The Bulozi Plain and the Upland Area to the East

Some 75% of the cattle population graze the plain from about June to December, which is largely during the dry season. As the flood rises in late December and early January, the cattle and their owners move back to the woodlands on

the Lake-dune Barotse Sands and Lake Basin Alluvial Soils. During this period in the woodlands they lose condition rapidly. Maclean (1964) noted that, in the past, floodtime grazing took place far away from the Plain on pans and on the upper reaches of the larger river catchments: the Luena, Lui, Namitome and Lumbe were used for 4 or 5 months at a time. The decline in this practice is attributed, both to the disinclination of the herdsmen to stay away from the plain so long, and to the perennial flooding of the pans which at one time dried up completely in the dry season, the falling water continuously exposing green grass. The headwater areas have also become increasingly waterlogged due to the silting up of the old drainage channels, and the narrow belt of grassland between the swamp and the forest edge has diminished steadily in size.

2. The Mulonga, Matabele and Siloana Plains

The stocking rates on these plains are low; because they are not flooded to the same extent as the Bulozi Plain, and because the watertable seldom drops to more than 1.52 m (5 ft) depth, the cattle can live on these plains throughout the year without serious loss of condition. The cattle move about within the plains, particularly to the more elevated parts during the period of flooding (as shown in Table 34): there is, however, no major exodus of cattle away from the plains.

TABLE 34 Seasonal movement of cattle on the Matabele and Mulonga Plains in relation to the main soil types

<table>
<tr><th>Grazing season</th><th>Month</th><th colspan="2">Main soil types grazed</th></tr>
<tr><td rowspan="6">Summer
Rainy season
Grasses growing</td><td>Nov.</td><td rowspan="6">Recent Alluvium (Old Lakeshore Bush-groups)
and
Flood Plain Sandy Alluvium (Plains Litongo)
and
Lake-dune Barotse Sands
and
Mixed Soils</td><td></td></tr>
<tr><td>Dec.</td><td></td></tr>
<tr><td>Jan.</td><td rowspan="4">River Levee Alluvium</td></tr>
<tr><td>Feb.</td></tr>
<tr><td>Mar.</td></tr>
<tr><td>April</td></tr>
<tr><td rowspan="6">Winter
Dry season
Grasses flowering</td><td>May</td><td rowspan="2">Humic Soils (Wet Litongo)</td></tr>
<tr><td>June</td><td rowspan="3"></td></tr>
<tr><td>July</td><td rowspan="3">Flood Plain Sandy Alluvium (Plains Litongo)</td></tr>
<tr><td>Aug.</td></tr>
<tr><td>Sept.</td><td rowspan="2">Recent Alluvium in Abandoned Watercourses
and
River Levee Alluvium (when not cultivated)</td></tr>
<tr><td>Oct.</td><td></td></tr>
</table>

GRASSLAND MANAGEMENT

Maclean (1964) noted that grassland management was defective in Western Province, the practice of tethering cattle in order to manure farm sites or for ease of milking often preventing full utilisation of the available grazing. This is thought to explain the poor quality of the cattle in the Mankoya area where, on the whole there is adequate grazing. This is a minor problem, however, compared with the overall problem of the area: how to provide an adequate supply of floodtime grazing when the main Bulozi Plain is inaccessible.

Floodtime Grazing

The present survey was a consequence of the death of large numbers of cattle during the flood season due to inadequate alternative grazing. There are six major areas listed below which could provide alternative grazing during the flood period:

(a) The area north of the Luena Flats
(b) Inland pans and small river valleys
(c) Upland woodland grazing
(d) The Lui River Valley
(e) The Siloana Plain
(f) The Matabele and Mulonga Plains

(a) The area north of the Luena Flats To the south of the Luena Flats there are only modest fodder resources, and the cattle around Usaah, Sibeta and Lipoba are usually in very poor condition during the flood period. To the north of the flats there are an estimated 8 499 ha (21 000 ac) of little utilised grazing bordering the Sititi River. These lands were not investigated in detail, but two major grass associations were noted: a *Themeda triandra - Setaria sphacelata* association occupying about 4 800 ha (12 000 ac), and a *Miscanthidium teretifolium - Vetiveria nigritana - Echinochloa pyramidalis* association occupying about 3 600 ha (9 000 ac). Of this area, it is considered that some 7 700 ha (19 000 ac) would be available for winter grazing. The gradients of the area are slight, the land sloping gently down from the upland sands in the north to the Luena river; consequently floodwaters slowly recede from that part of the area which floods, thereby gradually exposing wetland grasses which could be progressively grazed by cattle. Unfortunately access for cattle from the south is made difficult by the Luena river, which has a particularly steep south bank with deep water immediately under it. It is estimated that, if problems of access could be overcome, this area could support 2 000 to 3 000 head of cattle during early winter (May and June), so providing succulent fodder after the floods somewhat earlier than the Bulozi Plain.

(b) Inland pans and small river valleys In general the grass associations of the pans and river valleys provide poorer grazing than the Bulozi Plain; added to this, many of the pans are now perennially flooded (which used not to be the case) and cattle are denied access to the succulent grasses which flourish as the floodwaters recede. In other cases, drainage has led to a loss of organic material from the humic soils often found in the pans; soil water retention has suffered, and the grazing has deteriorated. These pans and valleys may even be cultivated. Thus, although they provide useful local floodtime grazing, there is little room for their increased use and, in view of their declining status, they cannot be considered as an alternative source of floodtime grazing.

(c) Upland woodland grazing The woodland areas are the principal areas used for floodtime grazing. The value of this grazing is not high, as will be appreciated from the floristic details of the Lake-dune Barotse Sand communities already described. This is the main reason why alternative floodtime grazing should be developed.

A major component of the grazing is the grass *Brachiara dura* (as revealed by the transects near Mongu), which, not only appears to have a somewhat higher feeding value than the rest of the community (see Table 30), crude protein values being some 50% higher, but also remains green and palatable for a much

W. C. Verboom

PLATE 6 Herbarium specimen of *Brachiaria dura* Stapf.

longer period. This is a grass apparently well adapted to the dry conditions of the upland woodland areas; with leaves which become rolled during the dry season, a tufty ligule which directs dew to the root base, and a well developed, very fine hairy root system adapted for extracting the limited amount of moisture from the sandy soils. It is also noteworthy that the rumen contents of game from the Mulonga and Siloana Plains were found to have high percentages of *Brachiara dura* (see also Verboom, 1966b). *Brachiaria dura* thus appeared to be a grass worth investigating, and work has been started. This and other matters connected with its use are considered in Part 5.

(d) **The Lui River valley** This narrow valley, which runs from the Luampa Mission and joins the Zambezi below Senanga, has often been cited as a valuable area for floodtime grazing. There are many small villages along the valley whose occupants use a fair proportion of the seepage zone for cultivation and, as this is the land which produces the best grazing, there is competition for its use between the farmers and the would-be graziers. The humic soils in the valley are also shrinking; in order to secure an adequate compensatory supply of manure, cows are often tethered overlong and consequently become undernourished. A detailed survey of the valley has not been carried out, but there does not appear to be much unused floodtime grazing.

(e) **The Siloana Plain** It was not possible in the time available to make a detailed investigation of the area, which is estimated to cover about 3 885 km^2 (1 500 mi^2). This plain, which appears to be part of the floodplain of an earlier course of the Zambezi, is a branch of the Matabele Plain. It extends from 16 km (10 mi) west of Nangweshi to the Mashi River plain near Sinjembele, via the Kalongo stream. During high floods the old river course from the Matabele to the Mashi is still navigable by dug-out canoe.

The micro-topography of the Siloana Plain is somewhat different from that of the Matabele and Mulonga Plains. There are a larger number of shallow pans, separated from each other by lake-dune wind-deposited secondary features. The pans are thought to consist largely of silted-up river and stream channels, and old ox-bows. Some of the shallower pans dry out in the dry season, and a salt crust, consisting largely of sodium and magnesium sulphate, is formed. Some of the waterholes on the plain contain small quantities of these salts.

The vegetation commonly occurring on the pans consists of the usual riverine grasses *Vossia cuspidata* and *Echinochloa stagnina*, with the sedge *Cyperus papyrus* where deep standing water is fringed by *Pycreus mundtii*. The legume *Aeschynomene fluitans*, usually indicative of seasonal flooding, is also found. The salt pans can be distinguished by their typical grass cover, dominated by *Sporobolus spicatus, Willkommia sarmentosa, Diplachne fusca* and *Panicum porphyrrhisos*. The grass cover at the foot of the dunes is commonly dominated by *Panicum repens*. Higher up the dune slopes, this is replaced by *Tricholaena monachne* and *Leptocarydion vulpiastrum*, with the legumes *Tephrosia lupinifolia* and *Indigofera nummulariifolia*. Under favourable conditions the tree *Terminalia sericea* may establish itself on the dune sands. In the south-west corner of the Siloana Plain there are some patches of mopane woodland, with a grass layer dominated by *Enteropogon macrostachyus* on ant hills and *Schmidtia bulbosa* elsewhere.

The local cattle census of 1964 estimated the cattle population on the plain at 9 400 head. Assuming an area of 3 885 km^2 (1 500 mi^2), the stocking was approximately one beast per 40.5 ha (100 ac). Using the methods of assessing carrying capacity described earlier in this section of the report, the capacity

of the plain was rated at 1 beast per 20.25 ha (50 ac) given the present extensive system of management. It should therefore be possible to increase cattle numbers significantly on the Siloana Plain, particularly in the south-western corner which appeared to be lightly stocked. However, there are appreciable numbers of game; and tsetse flies are a problem, resulting in a regular need for inoculation against trypanosomiasis.

(f) **The Matabele and Mulonga Plains** (see maps*) These plains form one of the largest areas of relatively little used alternative floodtime grazing in Western Province with probably the highest potential for grazing development in the area. They were therefore investigated in detail. Together they cover 3 455 km^2 (1 334 mi^2), rather less than the area of 3 885 km^2 (1 500 mi^2) occupied by the Siloana Plain.

The plains, which are contiguous, lie between the Mashi and Zambezi rivers to the north of the Siloana Plain, and extend from Sititi in the east to Shangomba in the west: they are similar to the Siloana Plain in apparently being a former floodplain of the Zambezi River. It is unlikely that they once formed part of the Mashi floodplain, because their size is out of proportion to the catchment of that river. At times of very high flood, there may still be a flow of water from the Zambezi along the old river course of the Matabele and Mulonga Plains to the Mashi river.

Nine land facets were distinguished: the associated landforms, soils and vegetation types have already been described. The distribution of the facets on the plains is shown on the 1:50 000 scale maps which accompany this report. The area occupied by a land facet constitutes a map unit. A summary of the land facet information appears in Table 35.

The estimated annual carrying capacity of the Matabele and Mulonga Plains can be calculated from the estimated summer and winter carrying capacities (Table 36) of the various land facets.

The various land facets are mostly undergrazed, and only used for a limited period, as indicated in Table 36. It is assumed that, except in years of abnormal flooding, each unit would support the cattle numbers indicated in the table over a six-month period. Thus the Matabele Plain (69 000 ha, 171 00 ac) has some 40 500 ha (100 000 ac) of summer grazing with an estimated carrying capacity of 4 250 head for the six months, well balanced by some 27 000 ha (67 000 ac) of winter grazing with a carrying capacity estimated at 4 270 head. The 1964 local cattle census indicated a cattle population of 2 246 head, which suggests that a further 2 000 head could be grazed on the plain given the present extensive system of management. This would not include the dissected river levees and large anthills (Map Unit 4, 1900 ha or 4 811 ac) allocated to dwelling sites and permanent agriculture. If the cattle numbers are to be increased some additional watering points would be required, mainly to avoid overgrazing around the existing water points.

The grazing resources of the Mulonga Plain (some 275 000 ha, 682 000 acres) are not so well balanced. There are about 170 000 ha or 419 000 ac of summer grazing with an estimated carrying capacity of some 28 000 head, but only 93 000 ha (233 000 ac) of winter grazing which will merely support 13 000 head of cattle. Even so the 1964 census indicated a cattle population of only 6 252 head on this plain. (The dissected river levees 11 700 ha (29 900 ac) have again been allocated to permanent agriculture).

*Matabele Plain, Mulonga Plain: Ecological Survey, 1:50 000, in map folders.

TABLE 35 The land facets of the Mulonga and Matabele Plains

1:50 000 Map unit	Description (Local Lozi name)	Soil type (Representative profile nos.)	Vegetation		Time of grazing Summer: Nov.-April Winter: May-Oct.	Estimated carrying capacity, ac per beast per six months	Ha approx. (ac)	
			Grasses, sedges and legumes	Trees and shrubs			Mulonga Plain	Matabele Plain
1 S5-1*	Recent river beds and abandoned water courses (Mulapo-Dambo)	Recent Alluvium in Abandoned Water-courses (42)	Acroceras macrum Digitaria scalarum** Echinochloa stagnina Hemarthria altissima Leersia hexandra Oryza perennis Panicum repens Paspalum commersonii Sacciolepis africana Vossia cuspidata Pycreus mundtii (sedge) Diplachne fusca (salt conditions) Aeschynomene fluitans (legume)		Late winter, September and October	8	3 300 (8 237)	1 130 (2 818)
2 S5-2*	Old river courses on the floodplain (Wet, Plains Litongo)	Alluvium, including Humic Soils in ox-bows (48)	Andropogon huillensis Brachiaria nigropedata Eragrostis lappula Rendlia pseudo-harpochloa Setaria sphacelata Themeda triandra Trachypogon spicatus Aeschynomene indica) Indigofera microcalyx)(legumes) Sesbania microphylla)		Early winter, May and June	12	48 600 (121 217)	15 800 (39 769)
3 SK-3*	Old floodplain (lake) shore line (Sikanda)	Flood Plain Sandy Alluvium (32)	Chloris gayana) on ant Cynodon dactylon) hills Panicum repens) in Sporobolus spicatus) hollows Sporobolus subtilis Eragrostis lappula Rhynchosia sublobata) Rhynchosia venulosa)(legumes)	Acacia giraffae Acacia sieberiana Capparis tomentosa Lonchocarpus capassa Piliostigma thonningii Sansevieria desertii	Summer, November to April	8	72 800 (182 435)	7 690 (19 444)
T1 SK-4*	Old floodplain. Broad nearly flat interfluves, with increasing depth to the watertable (Plains Litongo of the Saana or floodplain)	Flood Plain Sandy Alluvium; mottling at about 760 mm (30 in.) (45)	Apochaete hispida Aristida atroviolacea Brachiaria dura Diheteropogon grandiflorus Elionurus argenteus Loudetia simplex Rhytachne rottboellioides Schizachyrium jeffreysii	Annona stenophylla Eugenia angolensis Lannea gossweileri Magnistipula eglandulosa Ochna spp. Parinari capensis Syzygium huillense	Mid-winter, July to September after burning	40	42 000 (103 943)	9 700 (24 328)
T2 SK-5*		Flood Plain Sandy Alluvium; mottling at about 914 mm (36 in.) (56)	Aristida graciliflora Aristida meridionalis Apochaete hispida Brachiaria dura Digitaria perrottetii	Burkea africana Diplorhynchus condylocarpon Terminalia sericea	Summer, November to April	50	23 470 (58 080)	3 640 (9 013)
T3 K8*		Flood Plain Sandy Alluvium; mottling not observed (58)	Aristida graciliflora Brachiaria dura Digitaria milanjiana Eragrostis tremula Loudetia lanata Schizachyrium jeffreysii	Burkea africana Combretum imberbe Diplorhynchus condylocarpon Terminalia sericea	Summer, November to April	50	4 500 (11 653)	Absent from Matabele plain
4 S5-4*	Dissected river levees; sometimes with large anthills (Lizulu)	River Levee Alluvium (59)	Chloria gayana Cynodon dactylon Eragrostia lappula Panicum maximum Setaria anceps	Acacia albida Acacia giraffae Albizia antunesiana Guibourtia coleosperma Hyphaene ventricosa Lonchocarpus capassa Parinari curatellifolia Phoenix reclinata Piliostigma thonningii	Late summer, March and April	12	11 700 (29 944)	1 900 (4 811)
K7 K7*	Mongu-Kalabo Terrace bordering Matabele and Mulonga plains	Lake-dune Barotse Sands (46)	Aristida graciliflora Brachiaria dura Digitaria perrottetii Eragrostis tremula Leptocarydion vulpiastrum Schizachyrium jeffreysii	Baikiaea plurijuga Brachystegia spiciformis Erythrophleum africanum Guibourtia coleosperma Pterocarpus angolensis Pterocarpus antunesii Ricinodendron rautanenii Swartzia madagascariensis	Summer, November to April during the rains	40	67 500 (167 259)	17 400 (43 866)
K6 K6*		Mixed Lake-dune Barotse Sands and Upland Sedentary Soils (60)	Andropogon gayanus *Brachiaria brizantha* Digitaria milanjiana Hyparrhenia dissoluta Panicum maximum Tristachya superba	Baphia obovata) Thicket Bauhinia macrantha) spp. Combretum spp.) (Mutemwa) Grewia spp.) Popowia obovata) Baikiaea plurijuga Entandrophragma caudatum	Summer, November to April during the rains	50	Absent from Mulonga Plain	10 900 (27 414)
Total acreages							275 000 (682 768)	68 000 (171 463)
Grand total acreage, Matabele and Mulonga Plains							344 000 (854 231)	

* Equivalent ecological units as shown on DOS Map 3012: Vegetation and Soil map of N. Rhodesia by C. G. Trapnell (Trapnell et al, 1950)
** (Digitaria abyssinica)

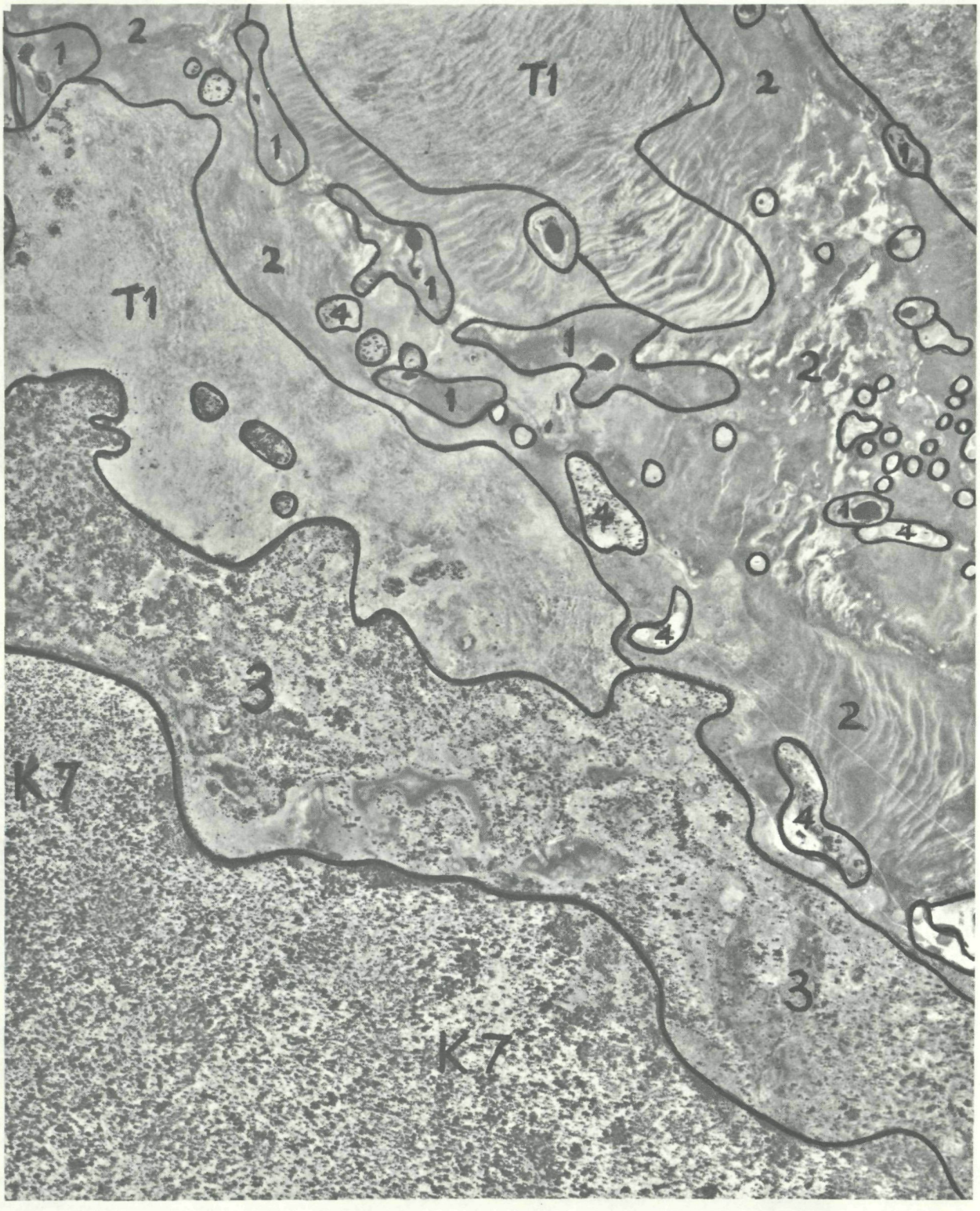
TABLE 36 Acreage*, carrying capacity (acres per animal) and estimated cattle numbers for the land facets of the Matabele and Mulonga Plains

Map units	Description	Matabele Plain				Mulonga Plain			
		Summer grazing		Winter grazing		Summer grazing		Winter grazing	
		Acres (carrying capacity)	Cattle numbers	Acres (carrying capacity)	Cattle numbers	Acres (carrying capacity)	Cattle numbers	Acres (carrying capacity)	Cattle numbers
3	Old floodplain (lake) shoreline	19 444 (8)	2 430			182 435 (8)	22 804		
T2	Old floodplain with increasing depth to the watertable	9 013 (50)	180			58 080 (50)	1 161		
T3		Absent from the Matabele plain				11 653 (50)	233		
K7	Mongu-Kalabo Terrace bordering Matabele and Mulonga plains	43 866 (40)	1 096			167 259 (40)	4 181		
K6		27 414 (50)	548			Absent from the Mulonga plain			
1	Recent river beds and abandoned watercourses			2 818 (8)	352			8 237 (8)	1 029
2	Old river courses on the flood plain			39 769 (12)	3 314			121 217 (12)	10 101
T1	Old floodplain with increasing depth to the watertable			24 328 (40)	608			103 943 (40)	2 598
4	Dissected river levees	Allocated to permanent agriculture							
Totals		99 737	4 254	66 915	4 274	419 427	28 379	233 397	13 728

* 1 ac = 0.405 ha

Fairey Air Surveys

PLATE 7 Land facets (see Table 35 and the Ecological Survey maps). Aerial photograph (1:30 000) of the eastern end of the Matabele Plain and the River Zambezi showing: grassland on the recent alluvial floodplain of an old river (2); river levees (Lizulu) (4); *Baikiaea plurijuga* woodland on Lake-dune Barotse Sands (K6)



Fairey Air Surveys

PLATE 8 Land facets (see Table 35 and the Ecological Survey maps). Aerial photograph (1:30 000) of the Matabele - Mulonga Plains showing: *Burkea - Guibourtia - Baikiaea* woodland on Lake-dune Barotse Sands (K7); old lake-shore grassland (3); floodplain sandy alluvium *Apochaete - Loudetia* grassland (Plains Litongo) (T1); recent alluvial floodplain of an old river (2); recent alluvium in abandoned watercourses (1); river levees (4)

Fairey Air Surveys

PLATE 9 Land facets (see Table 35 and the Ecological Survey maps). Aerial photograph (1:30 000) of the Matabele - Mulonga plain showing: two levels of the floodplain sandy alluvium (Plains Litongo) with *Aristida - Loudetia - Brachiaria dura* woody grassland (T3) and the wetter *Aristida gracifloris - A. meridionalis* grassland (T2); old lake-shore bush groups on anthills (3); grassland on a recent alluvial floodplain of an old river (2)

The Mulonga Plain is drier than the Matabele Plain, and is only flooded by the Zambezi at times of peak water levels. As indicated above, it is the dry season grazing which is the limiting factor to an increase in the cattle numbers using the plain. Notwithstanding this imbalance, the present fodder resources, aided by the construction of more watering points, should carry 1 300 head of cattle, which is twice the present number.

To summarise: it is estimated that the Matabele and Mulonga Plains, which together occupy some 344 000 ha (854 00 ac) and in 1964 carried an estimated cattle population of 8 498 head, could, with the addition of extra watering points, carry 17 000 head all the year round under the present system of extensive management.

Water Supplies and the Construction of Cattle Drinking Ponds on the Matabele and Mulonga Plains

The cattle on these plains mostly drink from naturally occurring, widely scattered, shallow, permanent pools. At the end of the dry season these pools are often drunk dry. When this happens the cattle try to reach the water in the shallow circular village wells, usually 1.2 - 1.8 m (4 - 6 ft) deep, from which the villagers obtain their domestic water. This results in the cattle trampling down the well surroundings and fouling the water. There is no serious shortage of water on the plains, and the watertable is seldom more than 1.8 - 2.1 m (6 - 7 ft) from the surface, yet the irregular distribution of cattle drinking points is perhaps the major limiting factor to the proper utilisation of these grasslands. The local cattle owners claim that the most rapid way of improving the plains grazing would be by the provision of more drinking facilities for the cattle.

In view of the high watertable, the construction of shallow cattle drinking ponds on the two plains presents no great problem. A trial pond constructed at a cost of £25 has proved successful, and similar ponds could be made at selected sites over the plains. The trial pond was made in loose sand by a D8 Caterpillar bulldozer in 3½ working hours. The pond's long axis was oriented in the direction of flood flow, and it was excavated to 0.6 m (2 ft) below the watertable, a total depth of 2.4 m (8 ft) below the surface. The approaches used by the cattle to reach the water, have a slope of 1:5, while the steeper pond sides have a slope of 1:2 to 1:3. The steep slopes were grassed over with *Panicum repens* (limanota), while the gentle 1:5 approaches were grassed over with *Cynodon dactylon* (couch grass). The pond, which is filled by seepage, usually holds 85 m^3 (3 000 ft^3) of water (30.5 x 4.6 x 0.6 m or 100 x 15 x 2 ft) or 18 600 gallons.

CATTLE DISEASE

Poor animal health in Western Province is mainly due to trypanosomiasis, liver fluke and worm infestation. Biting flies, notable *Tabanid* and *Stomoxys* spp., and the scouring caused by changing from a poor to lush diet, also contribute to loss of condition.

Trypanosomiasis This disease is particularly prevalent where large game populations mostly resistant to the disease, act as a reservoir for the trypanosomes which are transmitted to the cattle by tsetse flies. There are large populations of game both in the north-west and in the south-west of the

province. The latter area is a game reserve, and the former is proposed as one, the two to be linked by a game corridor. In the long term these areas may be developed for game ranching, while in the short term the most likely development would be as game/hunting reserves associated with tourism. The elimination of trypanosomiasis through the control and reduction of these game populations seems improbable, since large herds of eland, roan and tsessebe are not confined to Western Province but range over a large area including the adjacent parts of Angola, South West Africa and Botswana. A further focus of infection is the Kafue National Park. Maclean (1964) reported that cattle movement control and prompt treatment of clinical cases was containing this threat from the Park, but infection in the south-west of Western Province may well be on the increase, especially in Kalabo district, owing to the difficulty of formulating a control programme acceptable to the countries involved.

The Zambian Veterinary Department is tackling the problem in Kalabo by widespread inoculation of *Anthracide* and *Prothidium*, and prohibition of the movement of cattle out of the area. Tsetse control spraying has been employed in the Mashi area between the south-west corner beacon and Karunga village where the tsetse are very active; a cattle cordon has also been established. The long term development of the cattle industry will be dependent on the maintenance of adequate tsetse control.

Live fluke disease and worm infestation Maclean (1964) considered that 90% of the cattle population were infested with liver fluke; and the local butchers report that nearly all the livers of slaughtered cattle are measled. Infection with both liver fluke and worms occurs when cattle graze the swamp vegetation of the flood plain: this certainly contributes to the marked deterioration in condition when the grazing is sparse. There is no prospect in the immediate future of any control other than by systematic dosing.

Other diseases The following diseases are recorded by Maclean (1964) as occurring occasionally: foot and mouth disease, probably locally endemic, and last confirmed in 1959; anthrax, against which all cattle are vaccinated each year; heartwater *(Rickettsia ruminantium)*; contagious abortion; piroplasmosis; anaplasmosis; and streptothricosis (senkobo). Bovine pleuro-pneumonia, which caused many cattle deaths in the 1930's, was eliminated by a patrolled cordon (now discontinued) along the Angola border whence the disease came.

Scouring occurs when cattle move from the fibrous forest grazing to the rich plains grass, and may continue for three or four months, the period that usually elapses before they begin to regain condition. Scouring nearly always occurs when cattle first graze fresh pastures, but it continues in Western Province for a much longer period than in other parts of Central Africa and is a major contributing factor to loss of condition.

HERD MANAGEMENT

The low standard of herd management in Western Province has already been mentioned. The main problem stems from the practice of manuring by tethering cows to stakes. In some cases upland farmers who do not own cattle rent them for this purpose from cattle owners on the plains. Maclean (1964) noted that cattle may be so tethered for 16 or 17 hours a day; consequently they are severely undernourished. In addition, these tethered cows are often milked by their temporary owners, and some of the milk may be sold. The calves often suffer from a shortage of milk and mortality is high. Finally, when the cows

are untethered they may, in areas of dense cassava farming, have considerable distances to walk to better grazing. This practice thus contributes to the loss of condition, already severe, induced by the poor quality upland grazing during the flood period. Even in Mankoya district where there is probably sufficient grazing the cattle lose condition very badly during the dry season because of this practice.

In the past greater use was made of the grazing on pans and in the upper reaches of a number of the river valleys in the area. There was in fact a 4 to 5 month migration away from the floodplain. This has declined, partly from a general reluctance to herd the cattle in this way, partly because many men who would have done this work now prefer to work for wages, and partly because the grazing itself is often flooded for longer than it used to be. This is due to higher watertable levels, and to the failure of some of the old drainage systems in the headwater areas.

The present situation in Western Province is one of transition. Cattle, which traditionally were only owned for reasons of status, are now an important part of the farming economy. This, however, has not yet led to a general realisation that more careful management will be required if better quality animals are to be produced.

W. C. Verboom

PLATE 10 Barotse long-horned cattle

CONCLUSIONS

There is a marked contrast between the relatively rich floodplain pastures and the poor upland grazing. There may be possibilities for improving the latter by propagating the indigenous grass *Brachiara dura*. Alternative areas of flood-time grazing are at present underutilised, and could support larger numbers of cattle than at present, particularly if the number of water points is increased. Coupled with this, herd management must be improved. The implications and proposals are outlined in the next section.

PART 5. DEVELOPMENT AND RESEARCH

In any consideration of the development of Western Province, the following characteristics should be borne in mind: the area is remote, it has bad communications and the soils are generally very poor. The population are mostly cattle owners and, since the poor soils preclude significant cash crop production, the development of an efficient cattle industry is indicated provided that this is not detrimental to local food crop production. The major factor limiting the immediate development of a cattle industry is the lack of satisfactory alternative grazing to that on the floodplains when these are inundated.

The development of the cattle industry in Western Province should be integrated with the general development of the area.

Reference should be made to Map 2 which, as a result of this study, shows the land capability of Western Province, in the following broad terms:

1. Winter grazing areas on the plains, semi-intensive beef production. Arable areas for subsistence agriculture only.

2. Summer and floodtime grazing area; *Brachiaria dura* leys; complementary to winter grazing areas.

3. Arable farming areas: maize and groundnut production.

4. Timber production areas with control of burning and of hunting.

5. Game reserves with controlled cropping.

6. Game corridors with game control and game ranching.

The location of the proposed research stations, the Kalomo-Senanga road and additional narrow gauge timber transport railways are also shown on Map 2.

COMMUNICATIONS

The absence of good transport facilities within the province, and to and from it, is a hindrance to all forms of development. Consideration should therefore be given to the improvement and, if necessary, the creation of the major lines of communication detailed in Table 37, and listed in order of priority.

TABLE 37 Proposed development of communications in Western Province

Priority	Communication	Proposed development
1	Mongu - Mankoya - Mumbwa road. Approx. 440 km (275 mi).	Improvement to Class I all-weather road specification.
2	Senanga - Sesheke road, Approx. 190 km (118 mi).	Improvement to Class I all-weather road specification.
3	Mongu - Senanga road. Approx. 105 km (65 mi).	Improvement to Class I all-weather road specification.
4	Katima - Mulilo to Livingstone river barge transport	Speeding up of the service by fitting bigger engines to the boats; and construction fo a wharf or loading ramp at Katima.
5	Mongu - Kalabo road. Approx. 65 km (40 mi).	Both the dry and wet season routes to be improved.
6	Senanga - Kataba - Kalomo. Approx. 385 km (240 mi).	Construction of a New Class I all-weather road; the approximate alignment of which is shown on Map 2.
7	Nangweshi - Mwandi - Livingstone cattle route.	Provision of kraals at suitable intervals for the night herding of cattle, with Landrover access tracks to them from the existing roads to allow contact between drovers and herdsmen.
8	Near Bwina to Sesheke and Njoko, narrow gauge railway line. Approx. 210 km (130 mi).	Construction of narrow gauge railway line to link up with the existing line between Mulobezi and Kataba for the transport of redwood logs. The approximate alignment is shown on Map 2.

FOOD CROP PRODUCTION

There is an urgent need to increase the level of local food production to supply the growing population: this will be appreciated from the records of food imports quoted in Part 3 of this report. In view of the general unsuitability of the Western Province environment for the development of cash crops, it is desirable to use the best grazing land for animal production, restricting food crop production to the land most suitable for cultivation. Unfortunately this will not always be possible since some of the most valuable grazing land is also cultivable. For example, on the floodplains the humic soils provide good winter grazing; but they are also amongst the more fertile cultivable soils.

There is a limited potential for cash crop development, for example cashew nuts grow well in the sandy soils on the edge of the flood plains.

The Barotse Sand Soils are however in general unsiutable for cultivation, despite their local use for subsistence cropping. No attempt should be made to cultivate these soils more than is necessary. There are three soil types which might be considered for increased food production: the Upland Sedentary Soils, the Brown Mopane Alluvium and the Humic Soils of the plains.

Upland Sedentary Soils

These soils occur in the Mankoya area as pockets of darker brown soil, probably derived from basalt. From the data in Part 3 of the report it will be seen that these are soils of low fertility, which need to be manured in order to yield satisfactory crops. They have a slightly higher cropping potential than other soils in the area and, since the winter grazing in the Mankoya area is poor and the rainfall is adequate, these soils should be reserved for crop production (this has already been done on a minor scale). Little, if any, experimental work has been carried out on these soils under Mankoya climatic conditions: it is therefore proposed that a small research station (No. 4 on Map 2) should be established to undertake this work. The most important crops to be investigated would be maize and groundnuts. The training of future farmers will be equally important, and for this purpose consideration should therefore be given to the incorporation of a youth centre in a farm development scheme.

Brown Mopane Alluvium

In Sesheke district near the banks of the Zambezi there are areas of Brown Mopane Alluvium. It is thought that manuring could bring crop production on these soils to an acceptable level: the limiting factor is likely to be the relatively low rainfall - lower than that in the Mankoya area. Development of food crop production in the latter area should therefore be given precedence. Similar brown soils occur on the west bank of the Zambezi river near Nangweshi and Sioma, in areas where redwood production is relatively good. There is already a demand to use these soils for maize; if the present uncontrolled burning continues, so preventing the regeneration of *Baikiaea plurijuga*, the use of these soils for food crop production following the redwood harvest would seem to be advisable.

Humic Soils of the Plains

The importance of these soils both for food production and winter grazing has already been noted. Since cultivation leads to destruction of the organic matter and consequent loss of fertility, these soils should ideally be reserved for grazing. But in practice local farmers have been attracted by the initial fertility of the soils and have evolved a system of utilisation (described in detail by Trapnell and Clothier 1957). Unfortunately the careful water control required for the preservation of the organic material is not always carried out; it is this which requires attention.

These so-called tropical 'peats' accumulated under waterlogged, acid and anaerobic conditions, when temperatures may have been lower than today (Moreau 1963). With the destruction of most of the original vegetation and the annual burning of much of the present-day sedge and grass cover, the accumulation of vegetable debris has virtually ceased. When through the construction of drainage canals, the watertable is lowered to allow

cultivation, profile conditions become aerobic and rapid oxidation of the organic material ensues. Shrinkage occurs (undisturbed peat contains about 9 parts water to 1 part organic matter) and the 'peat' is slowly destroyed. In some of the inland pans and valleys in the Mongu district this has already happened, and the underlying bleached sands are exposed. These valuable soils are thereby lost for food crop production, and also reduced in value for winter grazing as the wetland grasses are replaced by the poorer upland grasses following the loss of the organic matter.

In order to reduce further losses as much as possible, attempts must be made to develop improved drainage control in these soils wherever they are used for cultivation. In the dambos and pans groundwater movement is both longitudinal and lateral from the sides to the centre of the dambo. The main canals constructed by the water department are longitudinal, while the farmers usually dig the side ditches. This division of responsibility should be generally adopted, and closer control of ground waterlevels effected by the construction of more sluices located on the main canals. The long profile of these valleys is usually slightly stepped and the sluices should be located at the steps. To reduce organic matter losses to a minimum, the land should be kept sufficiently dry to allow cropping, but not permitted to dry out. It is suggested that the watertable should be kept at a depth of about 457 mm (18 in) beneath cropland, and 304 mm (12 in) below grassland. Water control should be the subject of research: this could be carried out at the proposed research station No. 2 in the Kataba valley (see Map 2). It will not be a simple problem since the distribution of organic matter in the valleys is variable (see Figure 16, Volume 1). Research Station 3 should be located on the edge of the Humic Soils to investigate the horticultural aspects of their utilisation. The detailed research programmes for these stations are discussed later in this report under the heading 'Agricultural Research'.

IMPROVEMENT OF THE UPLAND FLOODTIME GRAZING AREAS

The upland floodtime grazing is of poor quality due to two major factors: the infertile nature of the Barotse Sands, and competition from the tree and shrub cover which tends to shade out the grasses. Given the existing low production levels and the extensive utilisation of the area, there is no easy way whereby the grazing can be improved, but certain aspects of the problem should be investigated experimentally: the improvement of the grass cover and the reduction of competition from trees and shrubs; this work to be linked with a limited experimental extension programme, which would also test the same ideas.

Observations have suggested that the grass *Brachiaria dura* is one of the better indigenous grasses in the area, and should be included in the experimental pasture improvement programme. If the proposed trials are successful, the results should be incorporated in an experimental extension programme whereby *Brachiaria dura* paddocks are established on new fallow. Some manuring would probably be required to get a good cover, with fencing to allow control of grazing during the flood period.

Owing to the existing scanty grass cover, the trees and shrubs would not be susceptible to burning control. Methods available for controlling these trees include cutting and poisoning. Both these possibilities require investigation.

EXPLOITATION OF THE FLOODPLAINS

Several general points should be considered, before specific development problems relating to the different plains areas are discussed.

Canalisation of the Zambezi between Senanga and Sesheke

Any plans to improve the navigability of the Zambezi by canalisation must take account of the effect that this could have on the ecology of the flood plains. The annual flooding of the plains brings the soil to field capacity and improves its fertility. If canalisation eliminated the flooding, the consequences for the farmers and the cattle would be serious. While some control of flooding is certainly desirable, any permanent lowering of the watertable could cause significant repercussions. It is very important therefore for the effects of canalisation on the ecology of the plains to be fully assessed before canalisation is undertaken. It would be unfortunate if problems developed like those in Florida, where drainage has led to desiccation in the Everglades.

Fishing

In the past, fish were a traditional export from the region: today very little is exported, and cured fish production from Western Province is unable to compete with that from Kafue and Lake Kariba. The export of fish could probably make a small but significant contribution to the economy; the fisheries department should be asked to consider the following points:

1. The improved protection of fish breeding grounds.

2. The use of larger mesh nets to prevent young fish being taken.

3. The improvement of curing methods.

Agricultural Extension

The present standards of animal husbandry could be improved and better finished animals should be produced for the market. The extension service should give a high priority to instruction in the schools, demonstrations and field meetings. Experimental work at the Bulozi Plain research stations (discussed below under 'Agricultural Research') will also be required to support this extension effort. The points which should be considered include:

1. Grassland management, paddocking, silage production and burning control. There is usually abundant fodder on the floodplains from June to January, much of which is not properly utilised or is lost by ill-considered burning. These are principally matters for investigation at the research stations.

2. Animal husbandry. Herd dispersal, kraaling and tethering. There is inadequate control of the herds which may result in local over-grazing. Animals are often left in kraals for longer than is desirable; they may also be tethered at one site for far longer than the local fodder resources warrant. These practices lead to malnutrition, with the result that even the modest liveweight gain that should be expected with the local resources is not achieved.

All these aspects of grazing control should receive the immediate attention of the extension service. Demonstrations of animal husbandry practices should be organised, including instruction in milking methods and management. Poor milking management, in conjunction with overlong tethering of the cows on one site, often causes the calves to be short of milk.

3. Breeding policy. A modest improvement could be made in the local herds by the elimination of inbreeding, the restriction of breeding as far as possible to selected animals, and the prevention of breeding from young animals. The castration of unwanted bulls should also be encouraged. All these proposals should be incorporated into an intensive extension service campaign.

Marketing

As improvements are made in grazing control and the utilisation of the floodplains, and in the communications of the region, it should be possible to increase the offtake from the national herd; particularly if the periodic loss of cattle during years of bad flooding can be prevented. It will be necessary to ensure associated improvements in the marketing facilities. Consideration should therefore be given to increasing the number of cattle sales from the existing sale yards, and also to creating new sale yards as the need for these arises. An abattoir should be constructed at Mongu.

The Bulozi Plain

This plain extending over some 5 000 km^2 (2 000 mi^2) is the heartland of Western Province and it is important that adequate research related to its development problems is carried out; hence the proposals for Research Stations numbers 2 and 3 on the Plain. In order that research results can be logically applied, an ecological survey of this plain should be undertaken. The natural features of the Bulozi Plain are similar to those of the Mulonga and Matabele Plains, and the techniques used in this survey could well be adopted. Land form - soil - vegetation maps at 1:50 000 scale should be constructed, based on interpretation of 1:20 000 air photographs and on field studies. The acreage of the different map units, each of which will have a different carrying capacity, should be computed. There should also be a census of the people and their cattle (preferably taken in October), so that the basic data necessary for land use planning will be available. Such a survey would also be of fundamental importance to the extension services which should be given priority owing to the general importance of the Bulozi Plain in the economy of Western Province.

The construction of special watering points is thought to be less vital than on the other plains.

The Matabele, Mulonga and Siloana Plains

The main factor limiting the use of these plains is the shortage of drinking water towards the end of the dry season. As the watertable is seldom more than 1.8 - 2.1 m (6 - 7 ft) below the surface, the construction of drinking ponds, already described, does not present serious problems. A programme of construction should therefore be initiated, following the satisfactory conclusion of construction trials using bulldozers. The villages are more

or less situated along the northern and southern borders of the plains and their inhabitants, who have considerable local knowledge of water resources, should be consulted concerning the siting of the ponds.

These plains are largely used on a migratory basis, which is unsatisfactory because the cattle lose condition during migration. Moreover, some pastures are overgrazed and friction with local graziers often results. Provided adequate watering facilities can be made available, and some grassland management developed, it should be possible to almost double the present cattle numbers on the plains and reduce, if not eliminate, the migration of the cattle.

Consideration should be given to a landform - soil - vegetation survey and resource assessment of the Siloana Plain.

The Luena River Flats

The well watered area to the north of the Luena River bordering the Sititi River is largely unused for grazing, whereas the cattle to the south in the Sibeta, Sitoya, Usaah and Lupande areas are often very short of fodder during the flood period in early winter. It appears that this area is unused because it is bordered by uninhabited woodland into which cattle may stray. There are also hyenas which prey on the young calves. These problems could be overcome by the provision of fencing, establishment of paddocks and control of the hyena. It is estimated that the area could support 2 - 3 000 cattle in early winter. The line of the proposed fence, some 27 km (17 mi) long, has been marked on photo-mosaics (Sheets 4, 5, 11 and 12; Mongu area) held by the Department of Agriculture. Consideration should be given to a community development project in order to construct the fence; the community supplying makusi fence posts and labour, and government supplying barbed wire (the cost of which would be about £2 000).

The Lui River and Inland Pans and Dambos

These areas are heavily utilised for gardens; the valuable humic soils already show signs of deterioration, and the winter grazing resources are fully exploited. There is no possibility of larger numbers of cattle being accommodated.

AGRICULTURAL RESEARCH

If the agricultural resources of Western Province are to be successfully developed, it is essential that the programme of research which has already been started at Namuschakende (Station 3) be extended and supplemented. It will be difficult for the extension service to function effectively unless improved methods of cultivation, manuring and pasture control have been successfully demonstrated experimentally. Owing to the diversity of soils in the region, it will be impossible to undertake all research at one station. Three additional stations are recommended, making a total of four. The proposed sites are shown on Map 2.

> Station 1 Adjoining the Bulozi Plain; Kataba Valley near Mulena Mukwae, five miles east of Namuschakende. The area is shown on air photographs numbers 76, 77 and 78 in strip 2 of the Senanga 1:30 000 photography taken in July 1961.

Station 2 Bulozi Plain; an island site near the Wenela pontoon, five miles west of Mongu, on the east bank of the Little Zambezi River. The area is shown on air photographs numbers 584, 585, and 586 in strip 19 of the Mongu 1:40 000 May 1960 air photography.

Station 3 Bulozi Plain; the Namuschakende agricultural station cum farm institute. The area is shown on air photograph numbers 143, 144 and 145 in strip 3 of the Senanga 1:30 000 photography taken in July 1961.

Station 4 Mankoya Terrace; about two miles west of Mankoya Boma, the area appears on print laydown (photo-mosaic) number J 14.

The detailed programme of work and administration of these research stations should be established by the Central Agricultural Research Station at Mount Makulu in collaboration with the local agricultural staff. The following outline proposals for the programme of each station are advanced for their consideration.

Station 1 near Mulena Mukwae, Kataba Valley

The programme should principally be devoted to drainage control, the utilisation of the valley humic soils and the improvement of the upland summer grazing on the Barotse Sand Soils.

The topographic survey of the Kataba Valley has been completed, and 'peat' soundings have been made (see Figure 16). These should assist in preparing a programme designed to investigate drainage control on the humic soils, along lines already indicated above under 'Humic Soils'. The dry-season irrigation of these pastures from shallow tube wells using portable pumps and sprinklers should be considered. This programme should incorporate routine meteorological and soil measurements to enable the water balance and soil moisture deficit (and hence the water requirement) to be calculated. Fertiliser trials should be included on the irrigated pastures.

Problems associated with the Barotse Sand Soils should also be investigated: improving their water-holding capacity and nutrient status, and the development of improved pastures for summer grazing. The first two problems are inter-related, and thought must be given to systems designed to increase the content of organic matter, both as a source of nutrients and as a retainer of moisture.

The possible use of the grass *Brachiaria dura* for improving upland grazing has already been mentioned. During this survey, trial plots were laid out at Mongu Boma and these should be continued. Further plots should be established on the Lake-dune Barotse Sand Soils at Station 1. *Brachiaria dura* apparently produces new sets of side shoots just after the first rains at the end of the dry season. Transplanting at Mongu, using these new shoots, was successful, whereas the use of older side-shoot material was not. Establishment from seed was not successful at Mongu, and a delayed germination mechanism is suspected. The optimum method of establishing this grass should be determined.

Once the problem of *Brachiaria* establishment has been overcome several lines of research should be considered:

1. Selection of improved strains of *Brachiaria dura*. There may be broad-leaved strains of this grass which produce greater amounts of fodder. If this possibility is substantiated, a breeding programme should be initiated. Attempts should be made to interest countries with comparable climatic conditions in testing *Brachiara dura*.

2. Production manuring trials of *Brachiaria dura*. Replicated fertiliser trials should be undertaken. The trial should test nitrogen at the following levels: 0, 50, 100 and 150 units of nitrogen which, because of the low cation exchange capacity of the soil, should be applied as urea rather than as sulphate of ammonia which would be quickly leached after rain. The effects of applying phosphorus, potassium and trace elements should also be tested. Consideration should be given to employing Australian pelleted fertilisers which were designed for grassland application under conditions similar to those in Western Province. Such a trial should be accurately costed.

3. Comparison with other grasses: Similar production trials employing *Cenchrus ciliaris*, *C. setigerus* (see Chakravarty and Bhati, 1968), *Setaria sphacelata* and *Chloris gayana* should be considered.

4. Legume trial. A trial of the legumes *Stylosanthes gayana* (*S. gracilis*) and *S. humilis* (*S. townsendii*) with controlled inoculation should be established. If these legumes prove successful, they should be included in the subsequent establishment trials. they

5. Establishment of improved grasses in fallow fields: as soon as sufficient information from the above trials is available, and assuming they are successful, methods of establishment should be investigated for large units and over wide areas.

6. Some attention to the pests and diseases (including leaf suckers, hoppers, beetles and smut, all of which have been observed) is also indicated.

Station 2 (near Mongu)

It would be desirable to use the floodplain grazing more intensively. The exact way in which this could be done must depend in part on more accurate information concerning the carrying capacity of the different landform-soil-vegetation units of the plain. The proposed site for the research station consists of four types of land (landforms), the extent and possible use for each being shown in Table 38. The landforms correspond approximately with the land facets already described for the Mulonga/Matabele Plains in Table 35 and shown on the 1:50 000 ecological survey maps.

TABLE 38 Landforms at Research Station 2 and their possible use

Map unit	Landform	Area		Possible use
		Ha	Ac	
1	Recent alluvium in abandoned water courses (Mulapo)	42.1	104	Late winter grazing, Oct. - Nov.
2	Humic soils of the floodplains. (Wet plain Litongo)	259.0	640	Mid winter grazing, July - Sept.
3	Floodplain sandy alluvium; old lake shore (Sikanda)	6.5	16	Early winter grazing, May - June.
4	River levee alluvium (Lizulu)	2.0	5	(1) Fodder trees, early flood-time grazing (2) Food gardens, mixed cropping with manure
	Open water	15.4	38	Fish production

Carrying capacity and grassland management trials, adjusted to the pattern of flooding, should be established on these units, attention being paid to methods of cattle control which would be both acceptable to the local cattle owners and economic. Fodder conservation and silage production should also be investigated.

At this stage, grassland management is probably more important than the investigation of pasture improvement. Two legumes, however, appear worth testing: *Aeschynomene fluitans* and *Neptunea oleracea*, both palatable to man and cattle and both adapted to flooding; trials of these should be initiated with a view to their more widespread establishment on the plains.

Systematic studies of cattle parasites should be established, aiming at a more rigorous control of worms and liver fluke in Barotse cattle.

If work on fish breeding and further work on rice is warranted, these could be undertaken at this station.

Station 3, Namuschakende Agricultural Station

The need to maintain local food production at a level to meet the needs of the growing population of the plains, without destroying the important Litongo and Sishanjo humic soils or impoverishing the alluvial soils, has already been stressed. The work on this problem which has already been started at the Namuschakende Agricultural Station should be continued, including trials on the use and costs of fertilisers. Drainage control experiments similar to those proposed for Station 1 could also be repeated here. Consideration should also be given to the investigation of horticultural crops, including citrus, on the seepage zone humic soils.

Station 4, near Mankoya Boma

The importance of increasing food production in Western Province, particularly in areas of least value for grazing, has already been stressed. The sedentary soils are particularly suitable for this purpose; hence the proposal to concentrate food production in the Mankoya area. The main programme should be designed to investigate the cultivation and manuring of maize and groundnuts.

DEVELOPMENT OF GAME RESERVES

Large herds of game, including eland, roan and tsessebe are to be found in the west of the area. In the south-west there is a zone of tsetse infestation. It is therefore proposed that the whole of the west and south-west should be excluded from use for farming and cattle and that two game parks linked by a game corridor should be developed. This idea has not been worked out in detail, and there would be many problems, not least of which is that the parks could form a reservoir of disease, from which the Western Province herd could be infected. Problems of game cropping and movement control, the building of access roads and airstrips, and the possible game ranching, hunting facilities and tourist accommodation, would have to be investigated in depth by the various government departments concerned.

EDUCATION

The development of Western Province will result in profound changes. The traditional methods of agriculture which were admirably suited to a static society are now being called into question. The challenge of an increasing population and of changes within society itself make it imperative that new agricultural practices should be adopted. Some of these have been indicated in this report; others will emerge as the result of research. It is vital that these new ideas be understood and accepted by the farmers and their families. Education is therefore at least as important as all the research and development work. As far as possible the programme of agricultural extension should be integrated with the educational and community development programme for all members of the community must be taught the value of soil conservation, water management, and improved methods of agriculture and animal husbandry. Only in this way will it be possible to develop to the full the resources of Western Province.

PART 6. REFERENCES AND RELEVANT WORKS

ACKERMANN, E. 1936 Dambos in Nordrhodesien. *Wiss. Veröff. Mus. Landerk. Lpz.* 4 147 - 157.

ALLMAN, R. T. and HAMILTON, T. S. 1948 Nutritional deficiencies in livestock. *F.A.O.agric. Stud* No. 5.

BAGNOLD, R. A. 1965 The physics of blown sand and desert dunes. London: Methuen.

BALLANTYNE, A.O. 1958 Preliminary agricultural-soils map of Northern Rhodesia. *Internal Rep. Dep. Agric. Nth Rhod.*

BARKER, M.D. 1960 Analysis of evaporation at Henderson Research Station. *Note agric. Met. Rhod. Met. Serv.* No. 4.

BAROTSELAND EXPLORATION LTD. 1967 Final Report of Barotseland Exploration Ltd. Lusaka: Barotseland Exploration Ltd.

BAWDEN, M. G. and STOBBS, A.R. 1963 The land resources of Eastern Bechuanaland. Tolworth, Surrey: Forestry and Land Use Section, Directorate of Overseas Surveys.

BAWDEN, M.G. ed 1965 Some soils of Northern Bechuanaland with a description of the main vegetation zones. Tolworth, Surrey: Land Resources Division, Directorate of Overseas Surveys.

BLAIR RAINS, A. 1963 Grassland research in Northern Nigeria 1952-62. *Samaru Misc. Pap.* No. 1.

BOND, G. 1954 Surface textures of sand grains from the Victoria Falls area. *J. Sedim. Petrol.* 24, 3, 191 - 195.

BOND, G. 1964 Pleistocene environments in southern Africa. *In* Clark Howell, F. and Bourlière, F., African ecology and human evolution. London: Methuen.

BOND, G. and STOCKLMYER, V. R. C. 1967 Possible ice-margin fluctuations in the Dwyka series in Rhodesia. *Palaeogeogr. Palaeoclim. Palaeoecol.* 3, 433-446.

BOUGHEY, A.S. 1964 Deciduous thicket communities in Northern Rhodesia. *Adansonia* 4, 239-261.

CACKETT, K. E. 1962 An analysis of evaporation at the Sabi Valley Experiment Station, 1957 - 1961. *Note Agric. Met. Rhod. Nyasald Met. Serv.* No. 8

CAHEN, L. and LEPERSONNE, J. 1952 Équivalence entre le système du Kalahari du Congo belge et les Kalahari Beds d'Afrique australe. *Mem. Soc. belge Géol. Sér. 8*, 4, 1 - 64.

CALVERT, G. M. 1963 Some notes on *Baikiaea plurijuga* regeneration. *For.Newsl. Nth Rhod.* No. 93, 9-12.

CARRODUS, B. B. and SPECHT, R. L. 1965 Factors affecting the relative distribution of *Atriplex vesicaria* and *Kochia sedifolia* (Chenopodiaceae) in the arid zone of south Australia. *Aust. J. Bot.* 13, 419-433.

CHAKRAVARTY, A. K. and BHATI, G. N. 1968 Selection of grasses and legumes for pastures of the arid and semi-arid zones. 1. Variations of morphological and physiological characters in the different strains of *Cenchrus setigerus* and selection of a promising strain for forage production. *Indian forester* 94, 667-674.

CHAPLIN, J. H. 1954a On the wet season in Northern Rhodesia. *Weather*. 9. 272-275.

CHAPLIN, J. H. 1954b Some aspects of rainfall in Northern Rhodesia, I. *Nth Rhod. J.* 4, 32-38.

CHAPLIN, J. H. 1955 Some aspects of rainfall in Northern Rhodesia, II. *Nth Rhod. J.* 6, 16-23.

CLARK, J. D. 1950 The stone age cultures of Northern Rhodesia. Claremont, Cape: The South African Archaeological Society.

COLE, M. 1963 Vegetation and geomorphology in Northern Rhodesia. *Geogrl J.* 129, 290 - 310.

CUMMINGS, D. G. 1959 Working plan for Rhodesian teak forests, 1957 - 1962, Parts I and II. *Internal Rep. Dep. For. Nth Rhod.*

d'HOORE, J. L. 1964 Soil map of Africa, scale 1:5 000 000. Explanatory monograph. *C.C.T.A./C.S.A. Joint Project.* No. 11.

DIXEY, F. 1944 The geomorphology of Northern Rhodesia. *Trans. geol. Soc. S. Afr.* 47, 9 - 45.

DIXEY, F. 1950 The geology of the Upper Zambesi Valley. *In* Clark, D. J., The stone age cultures of Northern Rhodesia, 9 - 29. Claremont, Cape: The South African Archaeological Society.

DOUGALL, H. W. 1958 Average estimates of digestible crude protein in Kenya feeding stuffs. *E. Afr. agric. J.* 23, 285 - 289.

du TOIT, P. J., LOUW, J. G. and MALAN, A. I. 1940 A study of the mineral content and feeding value of natural pastures in the Union of South Africa. *Onderstepoort J. vet. Sci. Anim. Ind.* 14, 123 - 327.

du TOIT, P.J., MALAN, A. J. and GROENEWALD, J. W. 1934 A study of the mineral content and feeding value of natural pastures in the Union of South Africa. *Onderstepoort J. vet. Sci. Anim. Ind.* 2, 607 - 648.

EGGELING, M. D. 1964 Management book for Kalabo district. *Internal Rep. Dep. For. Nth Rhod.*

EGGELING, M. D. 1965 Management book for Mongu-Lealui District. *Internal Rep. Dep. For. Nth Rhod.*

ELLIOTT, R. C. and TOPPS, J. H. 1963a Studies of protein requirements of ruminants. 1. Nitrogen balance trials on two breeds of African cattle given diets adequate in energy and low in protein *Br. J. Nutr.* 17, 539 - 547.

ELLIOTT, R. C. and TOPPS, J. H. 1963b Studies of protein requirements of ruminants. 2. Protein requirement for maintenance of three breeds of cattle. *Br. J. Nutr.* 17, 549 - 556.

ELLIS, B.S. 1950 A guide to some Rhodesian soils II. A note on Mopani Soils. *Rhod. agric. J.* 48, 49 - 61.

ENDEAN, F. 1961 The occurrence of thickets and chipyas. *For. Newsl. Nth Rhod.* No. 66, 10-12.

ERICKSON, A. E. HANSEN, C. M. and SMUCKER, A. J. M. 1968 The influence of subsurface asphalt barriers on the water properties and the productivity of sand soils. *Trans. 9th Int. Congr. Soil. Sci.* 1, 331 - 337.

EXELL, A. W. 1963 Flora Zambesiaca. London: Crown Agents.

FANSHAWE, D. B. 1960a Mutemwa. *For. Newsl. Nth Rhod.* No. 55, 22 - 29.

FANSHAWE, D. B. 1960b Preliminary notes on *Baikiaea* regeneration. *For. Newsl. Nth Rhod.* No. 57, 12-14.

FANSHAWE, D. B. 1960c The origin of the *Baikiaea* forest. *For. Newsl. Nth Rhod.* No. 58, 9-10.

FANSHAWE, D. B. 1960d Old gardens in Mutemwa. *For. Newsl. Nth Rhod.* No. 60, 17-18.

FANSHAWE, D. B. 1961a *Baikiaea plurijuga. Internal Rep. Dep. For. Nth Rhod.*

FANSHAWE, D. B. 1961b The vegetation of Senanga district. *Internal Rep. Dep. For. Nth Rhod.*

FANSHAWE, D. B. 1961c Evergreen forest relics in Nothern Rhodesia. *Kirkia*, 1, 20 - 24.

FANSHAWE, D. B. 1962a The vegetation of Mongu district. *Internal Rep. Dep. For. Nth Rhod.*

FANSHAWE, D. B. 1962b Notes on *Baikiaea* woodlands of SR. *Internal Rep. Dep. For. Nth Rhod.*

FANSHAWE, D. B. 1962c Makusi forest on sandstone hills, *For. Newsl. Nth Rhod.* No. 81, 28

FANSHAWE, D. B. 1962d Thirty years later. *For. Newsl. Nth Rhod.* No. 81, 24-25

FANSHAWE, D. B. 1962e Riparian *Baikiaea*. *For. Newsl. Nth Rhod.* No. 83, 9-10

FANSHAWE, D. B. 1962f The mystery of the teak forests. *For. Newsl. Nth Rhod.* No. 84, 19-20

FANSHAWE, D. B. 1962g *Baikiaea* on basalt. *For. Newsl. Nth Rhod.* No. 84 17-18

FANSHAWE, D. B. 1963a The vegetation of Sesheke district. *Internal Rep. Dep. For. Nth Rhod.*

FANSHAWE, D. B. 1963b The vegetation of Kalabo district. *Internal Rep. Dep. For. Nth Rhod.*

FANSHAWE, D. B. 1963c *Baikiaea plurijuga. Internal Rep. Dep. For Nth Rhod.*

FANSHAWE, D. B. 1963d Succession in Mukusi forests in Sesheke and Senanga. *For. Newsl. Nth Rhod.* No. 88, 7-8.

FANSHAWE, D. B. 1963e Anthills and Mukusi mutemwa. *For. Newsl. Nth Rhod.* No. 91, 11-12.

FANSHAWE, D. B. 1964a The vegetation of Mankoya district. *Internal Rep. Dep. For. Zambia.*

FANSHAWE, D. B. 1964b The vegetation of Balovale district *Internal Rep. Dep. For Zambia.*

FANSHAWE, D. B. 1964c The vegetation of Kabompo district. *Internal Rep. Dep. For. Zambia.*

FANSHAWE, D. B. 1964d The vegetation of the Kafue National Park. *Internal Rep. Dep. For. Zambia.*

FANSHAWE, D. B. 1964e *Baikiaea* forest relics. *For. Newsl. Zambia* No. 97, 10.

FANSHAWE, D. B. 1964f Vegetation classification. *For. Newsl. Zambia.* No. 99, 6-7.

FANSHAWE, D. B. and SAVORY, B. M.	1964	*Baikiaea plurijuga* dwarf shell forests. *Kirkia* 4,185-190
FEDERATION OF RHODESIA AND NYASALAND, METEOROLOGICAL DEPARTMENT	1957	Totals of monthly and annual rainfall for selected stations in Northern Rhodesia. Salisbury: Government Printing and Stationery Department.
FEDERATION OF RHODESIA AND NYASALAND, METEOROLOGICAL DEPARTMENT	1963	Climatological summaries for Southern Rhodesia, Northern Rhodesia and Nyasaland. Salisbury: Government Printing and Stationery Department.
FLINT, R. F.	1959	Pleistocene climates in eastern and southern Africa. *Bull. geol. Soc. Am* 70, 343-374.
FLOHN, H.	1960	Equatorial westerlies; their extension and significance. *Proc. Symp. trop. Met. Afr. Muguga. 1960.*
GENTILLI, J.	1958	A geography of climate. Perth: University of Western Australia Press.
GLOVER, J. and ROBINSON, P.	1953	A simple method of calculating the reliability of rainfall. *E. Afr. agric. J.* 19, 11-13.
GLOVER, J. and ROBINSON, P.	1953	A simple method for assessing the reliability of rainfall. *J. agric. Sci. Camb.* 43, 275-280.
GLUCKMAN, M.	1941	Economy of the central Barotse Plain. *Rhodes-Livingstone Pap.* No. 7.
GREAT BRITAIN IMPERIAL AGRICULTURAL BUREAUX	1947	The use and misuse of shrubs and trees as fodder. *Joint publ. Imp. agric. Bur.* No. 10.
GRIFFITHS, J. F.	1966	Applied climatology: an introduction. London: Oxford University Press.
GROVE, A.	1968	Landforms and climatic changes in the Kalahari and Ngamiland. A preliminary study. Private Communication (Department of Geography, University of Cambridge).
GUERNSEY, J. D.	1950	A summary of the provisional geological features of Northern Rhodesia. *Colon. Geol. Miner. Resour.* 1. 121-151.
HATTLE, J. B.	1965	How to combat the frost hazard. *Note agric. Met. Rhod. Met. Serv.* No.12

HENNAUX, L. and COMPÈRE, R. 1955 Le ravitaillement en calcium et en phosphore et le comportement du squelette du bétail au Congo Belge. Bruxelles: Institut National pour L'Etude Agronomique du Congo.

HOLMES, A. 1965 Principles of physical geology. Edinburgh: Nelson.

HOWE, G. M. 1953 Climates of the Rhodesias and Nyasaland according to the Thornthwaite classification. *Geogrl. Rev.* 43, 525-539.

JOHNSON, D. H. 1962 Rain in East Africa. *Q. Jl R. Met. Soc.* 88, 1 - 19.

JOHNSON, D. H. and MÖRTH, H. T. 1959 Forecasting research in East Africa. *Proc. Symp. trop. Met. Afr. Muguga. 196 0.*

JUBB, R.A. 1965 Diurnal variation of surface wind speed in Rhodesia and Nyasaland. *Met. Notes Rhod. Met. Serv. Ser. B.* No. 34.

KIDD, G. C. H. 1963 The calculation of evaporation from a free water surface. *Proc. 6th Conf. Dep. Res. Spec. Services. Fed. Rhod. Nyasald.*

KIDD, G. C. H. and TORRANCE, J. D. 1965 Seasonal and mean monthly rainfall deficits, October-April. *Note agric. Met. Rhod. Met. Serv.* No. 9.

KING, L. C. 1951 South African scenery. London: Oliver and Boyd.

KING, L. C. 1962 The morphology of the earth. London: Oliver and Boyd.

KÖPPEN, W. 1931 Grundriss der Klimakunde. Berlin: Walter De Gruyter and Co.

LAMB, H. H. PROBERT-JONES, J. R. and SHEARD, J. W. 1962 A new advance of the Jan Mayen glacier, and a remarkable increase of precipitation. *J. Glaciol.* 4, 355 - 365.

LANGDALE-BROWN, I. and SPOONER, R. J. 1963 Land-use prospects of Northern Bechuanaland. Tolworth Surrey: Forestry and Land Use Section, Directorate of Overseas Surveys.

LAWTON, R. M. 1959 A pollen analysis of the Lake Bengweulu peat. *Nth Rhod. J.* 4, 33-43.

LAWTON, R. M. 1970 Private communication (Land Resources Division, Directorate of Overseas Surveys, Tolworth, Surrey, England).

LINEHAM, S. 1960 Expected dates of planting rains in Northern Rhodesia and Northern Mashonaland. *Note agric. Met. Rhod. Nyasald. Met. Serv.* No. 3.

LIVINGSTONE, D. F. 1950 The geology of the upper Zambezi valley. *Col. Geol. Min. Res.* 1 269 - 271.

LOGAN, R. T. 1960 The central Namib desert, S. W. Africa. *Publ. Nat. Acad. Sci. Washington* No. 758.

LUND, I. 1966 Methods for estimating the probability of clear lines-of-sight, or sunshine, through the atmosphere. *J. Appl. Met.* 5, 625 - 630.

MacLEAN, H. A. 1964 Barotseland stocktaking. *Internal Rep. Dep. Agric. Zambia.*

McCONNELL, R. B. 1959 Notes on the geology and geomorphology of the Bechuanaland Protectorate. *Proc. 20th Int. Geol. Congr.*, 175-186.

McCULLOCH, J. S. G. 1965 Tables for the rapid computation of the Penman estimate of evaporation. *E. Afr. agric. J.* 30, 286-295.

MANNING, H. L. 1950 Confidence limits of expected monthly rainfall. *J. agric. Sci. Camb.* 40, 169-176.

MARTIN, H. 1961 Hydrology and water balance of some regions covered by Kalahari sands in South West Africa. *C.C.T.A. Publ.* No. 66, 450-455.

MARTIN, J. D. 1932 The makushi forests of Northern Rhodesia. *A. Bull. Dep. Agric. Nth Rhod.* No. 2. 71 - 76.

MARTIN, J. D. 1940 The *Baikiaea* forests of Northern Rhodesia. *Emp. For. J.* 19. 8 - 18.

MARTIN, J. D. 1940-50 Barotseland, soil and geology. *Internal Rep. Dep. For. Nth Rhod.*

MARTIN, J. D. 1941 Report on forestry in Barotseland. Lusaka: Government Printer.

MEIGS, P. 1953 World distribution of arid and semi - arid homoclimates. *In* Review of research on arid zone hydrology. Paris: U.N.E.S.C.O.

MEREDITH, D. B. ed. 1955 The grasses and pastures of southern Africa. Johannesburg: Central News Agency.

MILFORD, R. and MINSON, D. J. 1966 Feeding value of tropical pastures. *In* Davies, W. and Skidmore, C. L., Tropical pastures. London: Faber and Faber.

MILLER, O. B. 1939 The makushi forests of the Bechuanaland Protectorate. *Emp. For. J.* 18 193-201.

MILLER, T. B. 1961a A preliminary study of the importance of carotene in the supplementary feeding of cattle during the dry season in Northern Nigeria. *W. Afr. J. Biol. Chem* 4 67-70.

MILLER, T. B. 1961b Recent advances in studies of the chemical composition and digestibility of herbage: part II. *Herb. Abstr.* 31, 163-167.

MITCHELL, B. L. 1960 Ecological aspects of game control measures in African wilderness areas. *Kirkia* 1, 120 - 128.

MOREAU, R. E. 1963 Vicissitudes of the African biomes in the late Pleistocene. *Proc. zool. Soc. Lond.* 141, 395-421.

MYBURGH, S. J. 1941 The carotene content of some South African feeds. *Onderstepoort J. vet. Sci. Anim. Ind. 16*, 199-210.

NAIK, A. H. 1965 Mineral status of grasses and soils in Tanzania in relation to animal health. *E. Afr. agric. For. J.* 31, 175-182.

NEW SCIENTIST 1968 Paving the way to better crops. *New Scient.* 40, 79.

PASSARGE, S. 1904 Die Kalahari. Berlin: Dietrich Reimar.

PENMAN, H. L. 1948 Natural evaporation from open water, bare soil and grass. *Proc. R. Soc. Ser. A*, 193, 120-145,

PETERS, D. U. SMYTH, N. W. ed. 1960 Land usage in Batotseland. *Communs Rhodes-Livingstone Inst.* No. 191-60.

PRENTICE, A. A. 1965 Potential evaporation in Rhodesia. *Note agric. Met. Rhod. Met. Serv.* No. 13.

RHODESIA, DEPARTMENT OF METEOROLOGICAL SERVICES 1952 Normal variation of rainfall. *Note agric. Met. Rhod. Met. Serv.* No. 1.

RHODESIA, DEPARTMENT OF METEOROLOGICAL SERVICES 1953 Rainfall sampling in a small catchment. *Note. agric. Met. Rhod. Met Serv.* No. 2.

RHODESIA AND NYASALAND FEDERAL METEOROLOGICAL DEPARTMENT 1957 Totals of monthly and annual rainfall for selected stations in Northern Rhodesia. Salisbury: Government Printer.

RHODESIA AND NYASALAND, METEOROLOGICAL SERVICE 1960a Mean surface winds over the Federation. *Clim. Inf. Sheet Rhod. Nyasld. Met. Serv.* No. 3

RHODESIA AND NYASALAND, METEOROLOGICAL SERVICE 1960b Daylight surface wind frequencies, January and July. *Clim. Inf. Sheet Rhod. Nyasald. Serv.* No. 15.

RHODESIA AND NYASALAND, METEOROLOGICAL SERVICE 1960c Daylight surface wind frequencies, October and April. *Clim. Inf. Sheet Rhod. Nyasald. Serv.* No. 18.

RHODESIA AND NYASALAND, METEOROLOGICAL SERVICE 1962 The agricultural climates of Northern Rhodesia. *Note agric. Met. Rhod. Nyasald. Met. Serv.* No. 7.

RHODESIA AND NYASALAND, METEOROLOGICAL SERVICE 1962 Maximum wind values, Rhodesia and Nyasaland. *Clim. Inf. Sheet Rhod. Nyasald. Met. Serv.* No. 6.

ROBINSON, P. and GLOVER, J. 1954 The reliability of rainfall within the growing season. *E. Afr. agric. J.* 19. 137-139.

ROSE, C. W. 1966 Agricultural physics, p. 204. London: Pergamon Press.

RUSSELL, F. C. and DUNCAN, D. L. 1956 Minerals in pastures: deficiencies and excesses in relation to animal health. *Tech. Commun. Commonw. Bur. Anim. Nutr.* No. 15.

SAVORY, B. M. 1961a The occurrence of thickets and chipyas. *For. Newsl. Nth Rhod.* No. 65 14-17.

SAVORY, B. M. 1961b The occurrence of thickets and chipyas. *For. Newsl. Nth Rhod.* No. 67, 9-12.

SAVORY, B. M. 1961c Final report on control plan No. 1 Study of site factors in the *Baikiaea* forests, Barotseland. *Internal. Rep. For. Dep. Nth Rhod.*

SAVORY, B. M. 1965 Sands of Kalahari type in Sesheke district, Northern Rhodesia. *In* Snowball, G. J. ed., Science and medicine in Central Africa. Oxford: Permagon Press.

SEWARD, J. L. A. 1950 The fauna of the Sesheke district. *In* Watson, H. S. A., Working Plan for Rhodesian teak forests in Sesheke district, Barotseland, 26-37. *Internal Rep. Dep. For. Nth Rhod.*

SHONE, D. K. 1966 Poisonous plants of Rhodesia. Part I. *Rhod. Zambia Malawi J. agric. Res.* 4. 81-94.

SHONE, D. K. 1967 Poisonous plants of Rhodesia. Part II. *Rhod. Zambia. Malawi J. agric. Res.* 5, 29-41

STANNARD, A. 1965 Private communication concerning spectrographic analyses of Bartoseland soils.

TAGUE, M. 1964a Pleistocene successions in the Western Kafue flats. *Internal Rep. Dep. Wat. Affairs Nth Rhod.*

TAGUE, M. 1964b An exploration into possible sub-surface losses in the western Kafue flats between Meshi-Teshi and Namwala, Northern Rhodesia. *Internal Rep. Dep. Water Affairs, Nth Rhod.*

THOMPSON, B. W. 1965 The climate of Africa. London: Oxford University Press.

THORNTHWAITE, C. W. 1948 An approach towards a rational classification of climate. *Geogrl. Rev.* 38, 55-94.

TORRANCE, J. D. 1962 The agricultural climates of Southern Rhodesia. *Note. agric. Met. Rhod. Nyasald Met. Serv.* No. 10.

TRAPNELL, C. G. 1933 Introduction to physiography and soils of Barotseland. *Int. Rep. Dep. agric. Nth Rhod.*

TRAPNELL, C. G. 1937 Ecological methods in the study of native agriculture in northern Rhodesia. *Kew Bull. Misc. Inf.* 1, 1-10.

TRAPNELL, C. G. 1953* The soils, vegetation and agriculture of north-eastern Rhodesia. Lusaka: Government Printer.

TRAPNELL, C. G. 1959 Woodland burning experiments in Northern Rhodesia. *J. Ecol.* 47, 129-168.

TRAPNELL, C. G. and CLOTHIER, J. N. 1957** The soils, vegetation and agricultural systems of north-western Rhodesia. Lusaka: Government Printer.

TRAPNELL, C. G., MARTIN, J. D. and ALLAN, W. 1950 Vegetation-soil map of Northern Rhodesia, with accompanying memorandum. Lusaka: Government Printer.

TROLLOPE, G. 1967 Geological data on N. E. Barotseland. Private communication (Chartered Exploration Ltd.)

UNITED STATES, DEPARTMENT OF AGRICULTURE 1960 Soil classification. A comprehensive system. 7th Approximation. Washington: United States Department of Agriculture.

van RENSBURG, H. J. 1968 Growth and seasonal composition of natural grassland in Zambia. *J. Br. Grassld Soc.* 23, 51-52.

van STRATEN, O. J. 1963 A note on the ground water potential of certain areas adjacent to the main internal drainage system of the northern Bechuanaland Protectorate. *In* Langdale-Brown, I. and Spooner, R. J. Land use prospects of Northern Bechuanaland. Tolworth, Surrey: Forestry and Land Use Section, Directorate of Overseas Surveys.

* Second, revised ed. First ed. 1943.

** Second, revised ed. First ed. 1937.

van ZINDEREN BAKKER, E. M., EWER, F. G., BOND, G. and CLARK, D. J. 1963 Symposium on early man and his environments in southern Africa. *S. Afr. J. Sci.* 59, 332-366.

VERBOOM, W. C. 1965a The Barotseland ecological survey, 1964. *Internal Rep. Dep. Agric. Zambia.*

VERBOOM, W. C. 1965b Legumes in Zambia. *Trop. Agric. Trin.* 42, 229-242.

VERBOOM, W. C. 1965c The use of aerial photographs for vegetation surveys in relation with tsetse surveys in Zambia. *Publ. Int. Train. Cent. Ser. B.* No. 28.

VERBOOM, W. C. 1966a The grassland communities of Barotseland *Trop. Agric. Trin.* 43, 107-115.

VERBOOM, W. C. 1966b Brachiaria dura, a promising new forage grass. *J. Range Mgmt.* 19, 91-93.

WALKER, C. A. 1957 Cattle of Northern Rhodesia I. Growth of steers under normal veld grazing. *J. agric. Sci. Camb.* 49, 394-400.

WALKER, H. O. 1957 Estimates of evaporation and potential evaporation. *Note Met. Dep. Ghana* No. 6

WALKER, S. H. 1970 The climate of Western Province, Zambia: notes and records. Supplement to Land Resource Study No. 8. *Unpublished Suppl. Rep. Land Resour. Div.* No. 1.

WATSON, H. S. H. 1951 Working plan for Rhodesian teak forests in Sesheke district Barotseland. *Internal Rep. Dep. For. Nth Rhod.*

WEBSTER, R. 1959 Genesis and classification of upland soils in Northern Rhodesia. *C.C.T.A. Publ.* No. 50.

WHITE, F. 1965 The savanna woodlands of the Zambezian and Sudanian domains. *Webbia* 19,651-681.

WILLATT, S. T. and TICHE, R. 1966 Improvement of grazing on Kalahari sand. *A. Rep. Agric. Res. Coun. Cent Afr. 1966* 25.

WOOD, A. A. 1963 Management book for Senanga district. *Internal Rep. Dep. For. Nth Rhod.*

WORLD METEOROLOGICAL ORGANISATION 1960 Guide to climatological practices. Geneva: World Meteorological Organisation.

YAGER, T. 1968 Barotse series. *Internal Rep. Mt Makulu Res. Stn Minist. Agric. Zambia.*

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APPENDIX 1

APPENDIX 1 SOIL PROFILE DESCRIPTIONS AND ANALYSES

I(a) UPLAND SEDENTARY SOILS: MANKOYA TERRACE

I(b) UPLAND MIXED SEDENTARY AND BAROTSE SAND SOILS: MANKOYA TERRACE

Pit no.	29a	31	2	3	4	5	7
Lab. sample no.	11116	11118	10702	10703	10701	10705	10707
Site	17 miles N. of Sesheke, probably partly derived from Karroo Sandstone and basalt	Sioma Falls, derived from Karroo Sandstone	35 miles E. of Mankoya-Lusaka Road	35 miles N. of Mankoya on Kasempa Road	4 miles N.W. of Mangango Mission. Near outcrop of igneous rocks and laterite	22 miles W. of Mankoya-Mongu Road	17 miles N.E. of Lukulu
Vegetation T : Trees Th : Thicket S : Shrubs G : Grasses L : Legumes	S : Colophospermum mopane G : Heteropogon contortus	T : Acacia nigrescens	Woodland T : Brachystegia spiciformis G : Hyparrhenia rufa H. filipendula H. newtonii H. poecilotricha Monocymbium ceresiiforme Brachiaria brizantha	Woodland T : Brachystegia spiciformis G : Andropogon amplectens Hyparrhenia poecilotricha H. newtonii	Cultivation; good stand of maize and sorghum	Woodland T : Brachystegia spiciformis Cryptosepalum pseudotaxus G : Hyparrhenia rufa H. newtonii Andropogon amplectens Schizachyrium jeffreysii Anthephora accuminata	T : Brachystegia spiciformis Isoberlinia tomentosa Cultivation: cassava fields
Depth cm (in)	15.2 (6)	15.2 (6)	15.2 (6)	15.2 (6)	15.2 (6)	15.2 (6)	15.2 (6)
Colour	5 YR 4/3 reddish-brown	7.5 YR 4/2 dk. reddish-grey	7.5 YR 5/4 brown	10 YR 5/3 brown	2.5 YR 4/6 red	10 YR 5/6 yellowish-brown	7.5 YR 6/6 reddish-yellow
Texture	Sandy loam	Loamy sand	Sand	Sand	Sand	Sand	Sand
Mottling	-	-	-	-	-	-	-
Coarse sand 200μ - 2mm %	22.0	24.0	45.9	41.1	78.4	47.7	54.5
Fine sand 20μ - 200μ %	49.0	70.0	45.1	49.9	20.1	47.8	41.0
Silt 2μ - 20μ %	16.1	1.1	4.2	4.1	0.7	1.6	0.5
Clay <2μ	13.9	4.9	4.8	4.9	0.8	2.9	4.0
Organic C %				0.99	0.98	0.72	
Total N %	0.108	0.054	0.041	0.050	0.083	0.028	0.023
C/N Ratio				19	11	22	
pH in M/100 $CaCl_2$	6.6	6.6	5.7	5.7	3.9	5.4	4.5
Exch. Ca meq %	12.18	4.34	1.35	2.57	0.18	1.22	0.28
Exch. Mg meq %	7.70	1.61	0.35	0.61	0.17	0.58	0.17
Exch. K meq %	0.46	0.09	0.10	0.10	0.03	0.05	0.06
Exch. Na meq %	-	-	-	-	-	-	-
Cation Exch. Capacity meq %	22.10	6.40	1.90	2.80	1.76	2.60	1.30
Base Saturation %	92.0	94.4	94.7	100.0	21.6	71.2	39.2
P ppm air-dry soil	12.4	8.8	-	-	-	-	-

I(b) UPLAND MIXED SEDENTARY AND BAROTSE SAND SOILS: MANKOYA TERRACE (contd.)

Pit no.	22	23	23a	29	40	60
Lab. sample no.	11107	11108	11109	11115	11131	11440
Site	Luampa kuta 5 miles S. of the road to Kataba	5 miles S. of Kataba	29 miles S. of Kataba in depression of unsuccessful water well	15 miles N. of Sesheke	Mumbwa road, near Western Province border	Nangweshi, Karroo Sandstone rapids
Vegetation T : Trees Th : Thicket S : Shrubs G : Grasses L : Legumes	T : Brachystegia spiciformis S : Baphia obovata Bauhinia macrantha	T : Baikiaea plurijuga Monotes glaber G : Paratristachya superba	T : Baikiaea plurijuga G : Digitaria milanjiana	S : Colophospermum mopane Piliostigma thonningii	T : Brachystegia spiciformis G : Hyparrhenia spp.	T : Baikiaea plurijuga
Depth cm (in)	15.2 (6)	15.2 (6)	15.2 (6)	15.2 (6)	15.2 (6)	15.2 (6)
Colour	10 YR 5/2 greyish-brown	10 YR 5/3 brown	10 YR 7/2 lt. grey	7.5 YR 3/2 dk. brown	7.5 YR 5/4 brown	7.5 YR 4/4 brown/dk. brown
Texture	Sand	Sand	Sand	Sand	Sand	Sand
Mottling	-	-	-	-	-	-
Coarse sand 200μ - 2mm %	53.2	45.1	50.6	50.1	57.8	51.0
Fine sand 20μ - 200μ %	43.8	51.9	46.6	48.1	34.1	49.0
Silt 2μ - 20μ %	0.4	0.7	0.0	0.0	2.2	0.0
Clay <2μ	2.6	2.3	2.8	1.0	5.9	0.0
Organic C % Total N % C/N Ratio	0.028	0.030	0.011	0.032	0.042	0.077
pH in M/100 $CaCl_2$	5.0	5.5	4.8	5.9	6.2	5.6
Exch. Ca meq %	0.59	0.81	0.22	1.46	2.45	1.43
Exch. Mg meq %	0.30	0.15	0.11	0.29	0.63	0.57
Exch. K meq %	0.03	0.03	0.02	0.06	0.15	0.12
Exch. Na meq %	-	-	-	-	-	-
Cation Exch. Capacity meq %	1.40	1.00	0.20	2.10	3.40	2.00
Base Saturation %	65.7	100.0	100.0	86.2	95.0	100.0
P ppm air-dry soil	1.4	-	-	3.2	18.6	5.0

II(a) LAKE-DUNE BAROTSE SANDS

Pit no.	6	8			14	18	19a	19b	21
Lab. sample no.	10706	10708	10799	10800	10801	10826	10827	10828	11106
Site	Nabowa Forest Reserve	Mongu Boma. Field at rear of Protectorate offices			Ushaa school. 30 miles N. of Mongu. Fringe of the Luena Flats	Lipoba, at road junction	Road Mongu - Namushankende (road)	Road Mongu - Namushankende (in bush)	Luampa mission
Vegetation T : Trees Th : Thicket S : Shrubs G : Grasses L : Legumes	Th : Baphia obovata Bauhinia macrantha Landolphia spp. G : Digitaria milanjiana L : Tephrosia lupinifolia	S : Baphia obovata Bauhinia macrantha Baissea wulfhorstii G : Brachiaria dura Digitaria milanjiana Tricholaena monachne			T : Baikiaea plurijuga Parinari curatellifolia S : Baphia obovata Bauhinia macrantha G : Loudetia simplex	T : Baikiaea plurijuga Diplorhynchus condylocarpon S : Baphia obovata		S : Baphia obovata Bauhinia macrantha Dialium englerianum Strychnos spinosa G : Brachiaria dura	T : Brachystegia spiciformis S : Baphia obovata Bauhinia macrantha G : Brachiaria dura Loudetia simplex Schizachyrium jeffreysii
Depth cm (in)	15.2 (6)	15.2 (6)	121.9 (48)	248.9 (96)	15.2 (6)	15.2 (6)	15.2 (6)	15.2 (6)	15.2 (6)
Colour	10 YR 5/6 yellow-brown	10 YR 7/2	7.5 YR 6/8	7.5 YR 6/8	10 YR 4/1 dk. grey	10 YR 5/1 grey	10 YR 4/1 dk. grey	10 YR 6/2 lt. brown-grey	10 YR 5/3 brown
Texture	Sand	Sand	Sand	Sand	Sand	Sand	Sand	Sand	Sand
Mottling	-	-	-	-	-	-	-	-	-
Coarse sand 200μ - 2mm %	63.1	81.0	83.0	65.0	72.0	75.4	79.3	79.4	60.4
Fine sand 20μ - 200μ %	33.4	17.0	16.8	34.8	28.0	24.6	20.7	20.6	36.6
Silt 2μ - 20μ %	1.5	1.0	0.2	0.2	0.0	0.0	0.0	0.0	0.7
Clay <2μ	2.0	1.0			0.0	0.0	0.0	0.0	2.3
Organic C %					3.57		0.52	0.08	
Total N %	0.066	0.054	0.004	0.005	0.290	0.071	0.036	0.052	0.026
C/N					12		14	1.5	
pH in M/100 $CaCl_2$	4.1	4.5	4.9	4.6	3.0	3.6	4.7	3.9	5.1
Exch. Ca meq %	0.35	0.22	0.08	0.06	0.25	0.29	0.40	0.16	0.78
Exch. Mg meq %	0.17	0.05	0.31	0.14	0.31	0.23	0.26	0.31	0.23
Exch. K meq %	0.04	0.02	0.01	0.06	0.01	0.03	0.03	-	0.03
Exch. Na meq %	-	-	-	-	-	-	-	-	-
Cation Exch. Capacity meq %	2.94	1.70	1.60	0.70	12.50	1.70	0.80	1.70	1.40
Base Saturation %	19.0	17.1	25.0	37.1	3.1	32.4	86.2	27.6	74.3
P ppm air-dry soil	-	-	-	-	-	-	-	-	1.2

II(a) LAKE-DUNE BAROTSE SANDS (contd.)

Pit no.	30	34	35	36	37	38	39c
Lab. sample no.	11117	11122	11123	11124	11125	11126	11129
Site	40 miles N. of Katima Mulilo, (Kalobolelwa)	Kaungakuta N. of Lweti River	Senanga-Kalabo districts border, road to Kalabo	2 miles N. of Senanga Boma	Road to Imaiokuta, 14 miles S. of main road	5 miles N.E. of bridge south bank of Lui River	Lipuwe dispensary at Lui River
Vegetation T : Trees Th : Thicket S : Shrubs G : Grasses L : Legumes	T : Brachystegia spiciformis G : Paratristachya superba	T : Parinari curatellifolia Guibourtia coleosperma G : Brachiaria dura	S : Dialium englerianum Baphia obovata Bauhinia macrantha G : Digitaria milanjiana	S : Baphia obovata Bauhinia macrantha G : Digitaria milanjiana	T : Brachystegia spiciformis Guibourtia coleosperma	T : Brachystegia spiciformis Guibourtia coleosperma G : Paratristachya superba	G : Cultivated cassava and millet with Eragrostis spp. Perotis vaginata Dactyloctenium aegypticum
Depth cm (in)	15.2 (6)	15.2 (6)	15.2 (6)	15.2 (6)	15.2 (6)	15.2 (6)	15.2 (6)
Colour	10 YR 4/3 brown-dk. brown	10 YR 5/2 grey brown	10 YR 4/3 brown/dk. brown	10 YR	10 YR 6/3 pale brown	10 YR	10 YR 5/3 brown
Texture	Sand	Sand	Sand	Sand	Sand	Sand	Sand
Mottling	-	-	-	-	-	-	-
Coarse sand 200μ - 2mm %	52.0	62.2	63.4	60.9	73.5	63.2	71.6
Fine sand 20μ - 200μ %	47.0	36.8	35.1	37.9	26.5	35.8	27.4
Silt 2μ - 20μ %	0.0	0.0	0.5	0.2	0.0	0.0	0.0
Clay <2μ	1.0	1.0	1.0	1.0	0.0	1.0	1.0
Organic C %		0.42					
Total N %	0.072	0.044	0.028	0.048	0.026	0.063	0.054
C/N Ratio		9.5					
pH in M/100 $CaCl_2$	6.1	4.4	5.1	5.6	4.7	3.9	5.1
Exch. Ca meq %	2.12	0.26	0.63	0.45	0.16	0.57	0.33
Exch. Mg meq %	0.54	0.21	0.31	0.37	0.15	0.18	0.15
Exch. K meq %	0.03	0.03	0.02	0.03	-	0.02	0.02
Exch. Na meq %	-	-	-	-	-	-	-
Cation Exch. Capacity meq %	2.50	1.50	1.40	1.0	0.40	3.30	1.10
Base Saturation	100	33.3	68.6	85.0	77.5	23.3	45.5
P ppm air-dry soil	3.2	8.0	5.8	10.8	2.0	4.0	5.4

I₁(a) LAKE-DUNE BAROTSE SANDS (contd.)

II(a) LAKE-DUNE BAROTSE SANDS TRANSITIONAL TYPE MONGU-KALABO TERRACE

Pit no.	39d	41	46	62	11	12	24
Lab. sample no.	11130	11016	11332	11442	10796	10797	11110
Site	Lipuwe dispensary at Lui River	Kataba Valley, road from Namushakende	30 miles N. of corner Mashi River/Angola border Litunda	S.W. corner beacon of Barotseland, Caprivi	5 miles W. of Kalabo	31 miles W. of Kalabo	5 miles S.W. of Machili
Vegetation Th : Thicket T : Trees S : Shrubs G : Grasses L : Legumes	T : Baissea wulfhorstii	T : Brachystegia spiciformis G : Brachiaria dura Paratristachya superba	T : Baikiaea plurijuga Brachystegia spiciformis	T : Baikiaea plurijuga G : Brachiaria dura Aristida meridionalis	T : Baikiaea plurijuga S : Baphia obovata Bauhinia macrantha	T : Baikiaea plurijuga S : Baphia obovata Bauhinia macrantha	T : Acacia giraffae
Depth cm (in)	15.2 (6)	15.2 (6)	15.2 (6)	15.2 (6)	15.2 (6)	15.2 (6)	15.2 (6)
Colour	10 YR 5/3 brown	10 YR 5/2 grey-brown	10 YR 6/2 lt. brownish grey	10 YR 5/2 grey-brown	10 YR 5/2 grey-brown	10 YR 5/1 grey	10 YR 6/2 lt. brown-grey
Texture	Sand	Sand	Sand	Sand	Sand	Sand	Sand
Mottling	-	-	-	-	-	-	-
Coarse sand 200μ - 2mm %	81.4	64.4	58.9	54.4	38.0	32.0	33.1
Fine sand 20μ - 200μ %	18.1	35.6	41.1	45.6	61.4	67.8	63.9
Silt 2μ - 20μ %	0.0	0.0	0.0	0.0	0.0	0.0	0.2
Clay <2μ	0.5	0.0	0.0	0.0	0.6	0.2	2.8
Organic C %		0.86			0.50	0.85	
Total N %	0.078	0.062	0.038	0.078	0.034	0.062	0.028
C/N Ratio		13			14	13	
pH in M/100 $CaCl_2$	4.6	3.7	4.2	4.9	4.7	3.7	5.6
Exch. Ca meq %	0.25	0.26	0.16	1.65	0.60	0.31	0.85
Exch. Mg meq %	0.32	0.15	0.08	0.38	0.15	0.34	0.15
Exch. K meq %	-	0.04	0.03	0.06	0.03	0.01	0.05
Exch. Na meq %	-	-	-	-	-	-	-
Cation Exch. Capacity meq %	1.10	3.10	0.76	2.20	1.70	3.90	1.30
Base Saturation %	51.8	14.5	35.5	95.0	45.9	16.9	81.50
P ppm air-dry soil	3.4	7.6	1.6	3.4	-	-	1.0

II(a) LAKE-DUNE BAROTSE SANDS TRANSITIONAL TYPE MONGU-KALABO TERRACE (contd.) — UPLAND SANDS (OUTSIDE SURVEY AREA)

Pit no.	25	26	27	28				
Lab. sample no.	11111	11112	11113	11114	12747	12748	12749	12750
Site	25 miles S.W. of Machili	Road junction Machili-Sesheke- Mwandi	11 miles E. of Mwandi	1 mile W. of Sesheke Boma	Kabompo 1	Kabompo 2	Solwezi 1	Balovale
Vegetation Th : Thicket T : Trees S : Shrubs G : Grasses L : Legumes	Th : Acacia ataxifolia thorn thicket G : Dactyloctenium aegyptium	Acacia thicket mixed with Combretum woodland	T : Hyphaene ventricosa G : Themeda triandra Setaria sphacelata	T : Brachystegia spiciformis G : Aristida graciliflora				
Depth cm (in)	15.2 (6)	15.2 (6)	15.2 (6)	15.2 (6)	15.2 (6)	15.2 (6)	15.2 (6)	15.2 (6)
Colour	10 YR 6/2 lt. brown-grey	10 YR 5/4 yellow-brown	10 YR 5/1 grey	7.5 YR 4/4 brown/dk. brown	10 YR 7/3 v. pale brown	10 YR 7/4 v. pale brown	10 YR 4/2 dk. greyish-brown	10 YR 7/3 v. pale brown
Texture	Sand	Sand	Sand	Sand	Sand	Sand	Sand	Sand
Mottling cm (in)	-	-	61 (24)	-	-	-	-	-
Coarse sand 200μ - 2mm %	44.1	46.6	39.0	37.2	71.30	63.20	50.70	67.10
Fine sand 20μ - 200μ %	52.9	51.4	53.0	58.8	25.50	31.80	44.80	29.70
Silt 2μ - 20μ %	2.2	1.2	5.2	1.2	0.50	0.80	1.30	0.50
Clay <2μ	0.8	0.8	2.8	2.8	2.70	4.20	3.20	2.70
Organic C %	0.99							
Total N %	0.0114	0.054	0.055	0.032	0.075	0.021	0.039	0.023
C/N Ratio	86							
pH in M/100 $CaCl_2$	4.9	5.8	5.9	5.8	5.80	4.90	4.00	4.10
Exch. Ca meq %	1.72	1.21	1.62	1.48	0.10	0.30	0.23	0.13
Exch. Mg meq %	0.35	0.32	1.14	0.51	0.05	0.25	0.22	0.04
Exch. K meq %	0.06	0.08	0.06	0.13	0.02	0.07	0.03	0.02
Exch. Na meq %	-	-	-	-	-	-	-	-
Cation Exch. Capacity meq %	4.90	2.20	3.60	2.40	0.56	0.80	2.46	1.00
Base Saturation %	43.5	73.2	78.3	88.3	30.36	70.00	19.51	19.00
P ppm air-dry soil	1.6	2.4	-	0.8	-	-	-	-

II(b) LAKE BASIN ALLUVIAL SOILS: MONGU-KALABO TERRACE

III(b) FLOOD PLAIN SANDY ALLUVIUM: BULOZI TERRACE

Pit no.	13	16	1	17	32	33	33a
Lab. sample no.	10798	10824	10701	10825	11119	11120	11121
Site	10 miles N.W. of Kalabo	Luena flats fringe, 7 miles N. of Sibetakuta	35 miles E. of Mongu, on Mankoya Road at junction with road to the S.	Luena flats, 5 miles N. of Sibetakuta. Old lake shoreline	Old lake shoreline. Anthills; salt flush of sodium and magnesium sulphate	Tsetse barrier Siloana Plain; near Sioma-Sinjembele Road	Tsetse barrier Siloana Plain; near Sioma-Sinjembele Road sample from an anthill
Vegetation T : Trees Th : Thicket S : Shrubs G : Grasses L : Legumes	S : Diplorhynchus condylocarpon G : Trystachya hispida	T : Open woodland of Diplorhynchus condylocarpon Burkea africana G : Loudetia simplex	G : Loudetia simplex Monocymbium ceresiiforme Andropogon eucomis Dolichaete nodiglumis Danthoniopsis virides Digitaria perrottetii L : Indigofera microcalyx	T : Hyphaene ventricosa G : Themeda triandra Setaria sphacelata	T : Acacia giraffae G : Chloris gayana	T : Guibourtia coleosperma Ricinodendron rautanenii G : Brachiaria dura	
Depth cm (in)	15.2 (6)	15.2 (6)	15.2 (6)	15.2 (6)	15.2 (6)	15.2 (6)	15.2 (6)
Colour	10 YR 5/1 grey	10 YR 6/2 lt. brown-grey	10 YR 6/2 lt. brown-grey	10 YR 5/4 yellow-brown	10 YR 5/2 grey-brown	10 YR	10 YR
Texture	Sand	Sand	Sand	Sand	Sand	Sand	Sand
Mottling	-	-	-	-	-	-	Lime nodules
Coarse sand 200μ - 2mm %	35.5	72.0	78.4	44.1	58.1	58.5	36.7
Fine sand 20μ - 200μ %	64.5	27.2	20.1	48.1	39.4	40.5	49.3
Silt 2μ - 20μ %	0.0	0.0	0.7	2.6	0.0	0.0	3.0
Clay <2μ	0.0	0.8	0.8	5.2	0.0	1.0	11.0
Organic C % Total N % C/N Ratio	0.080	0.038	0.62 0.083 7	0.055	0.078	0.066	0.023
pH in M/100 $CaCl_2$	3.7	4.4	3.9	4.3	6.8	4.7	7.2
Exch. Ca meq %	0.25	0.12	0.18	0.47	3.48	1.02	13.99
Exch. Mg meq %	0.35	0.14	0.17	0.42	0.99	0.11	2.62
Exch. K meq %	0.01	0.02	0.03	0.03	0.04	0.03	0.10
Exch. Na meq %	-	-	-	-	-	-	0.70
Cation Exch. Capacity meq %	3.20	0.60	1.76	2.30	2.70	2.00	10.0
Base Saturation %	19.1	46.7	21.6	40.0	100.0	58.0	10.0
P ppm air-dry soil	-	-	-	-	3.2	2.4	2.6

III(b) FLOOD PLAIN SANDY ALLUVIUM: BULOZI TERRACE (contd.)

III(d) RECENT ALLUVIUM IN ABANDONED WATERCOURSES : BULOZI TERRACE

Pit no.	44	45	49	56	57	58	42
Lab. sample no.	11029	11030	11335	11340	11341	11342	11017
Site	W. of Namushakende. Lake basin - Plain Litongo, bordering Sitapa	W. of Namushakende. Lake basin - Plain Litongo, bordering Saana	N. of Litunda. T1 subdivision of terrace with small anthills	Siloana Plain, E. of Mubula village. T2 subdivision of terrace	Siloana Plain, E. of Mubula village. T1 subdivision of terrace with anthills	Siloana Plain, T3 subdivision of terrace	Luena delta at junction with Zambesi River, old river course
Vegetation T : Trees Th : Thicket S : Shrubs G : Grasses L : Legumes	G : Miscanthidium teretifolium	G : Leersia hexandra	G : Apochaete hispida Paratristachya superba Diheteropogon grandiflora Brachiaria dura	T : Terminalia sericea	G : Apochaete hispida Loudetia simplex Diheteropogon grandiflora Brachiaria dura	T : Burkea africana	T : Hyphaene ventricosa G : Themeda triandra Setaria sphacelata
Depth cm (in)	15.2 (6)	15.2 (6)	15.2 (6)	15.2 (6)	15.2 (6)	15.2 (6)	15.2 (6)
Colour	10 YR 4/1 dk. grey	10 YR 6/1 lt. grey	10 YR 7/3 v. pale brown	10 YR 6/3 pale brown	10 YR 6/2 lt. brown-grey	10 YR 6/2 lt. brown-grey	10 YR 4/2 dk. greyish-brown
Texture	Sand	Sand	Sand	Sand	Sand	Sand	Sandy-clay-loam
Mottling, at cm (in)	15.2 (6)	61 (24)	76 (30)	91 (36)	76 (30)	-	46 (18)
Coarse sand 200μ - 2mm %	4.0	56.8	77.4	64.3	62.9	59.6	19.2
Fine sand 20μ - 200μ %	86.9	33.0	22.6	35.7	37.1	40.4	40.8
Silt 2μ - 20μ %	3.9	5.8	0.0	0.0	0.0	0.0	10.0
Clay <2μ	5.2	4.4	0.0	0.0	0.0	0.0	30.0
Organic C %					0.35		0.91
Total N %	0.06	0.029	0.048	0.028	0.030	0.049	0.148
C/N Ratio					11		6
pH in M/100 $CaCl_2$	4.5	4.6	5.5	4.5	5.0	4.1	4.4
Exch. Ca meq %	0.30	1.18	0.21	0.19	0.38	0.26	10.90
Exch. Mg meq %	0.18	1.30	0.07	0.12	0.11	0.16	4.61
Exch. K meq %	0.04	0.06	0.09	0.03	0.05	0.05	0.22
Exch. Na meq %	-	-	-	-	-	-	-
Cation Exch. Capacity meq %	1.30	5.10	0.36	0.56	0.66	1.36	21.00
Base Saturation %	40.0	49.8	100.0	1.2	1.6	34.6	74.9
P ppm air-dry soil	2.4	1.6	1.6	1.2	1.6	1.6	-

II(c)/III(a) HUMIC SOILS: MONGU-KALABO AND BULOZI TERRACES

	Dry Litongo	Wet Litongo	Sishanjo	Chebechebe		Ox-Bows (1)		
Pit no.	39b	39a	43	10	9	47	52	53
Lab. sample no.	11128	11127	11028	10710	10709	11333	11293	11337
Site	Lipuwe dispensary at Lui River	Lipuwe dispensary at Lui River	Half mile N. of Mongu at brick factory	Mawawa Pan, 10 miles N.E. of Mongu. Borrow pit for road building		20 miles N. of Litunda, riverbed	Matabele Plain, riverbed	Siloana Plain; riverbed permanently flooded
Vegetation T : Trees Th : Thicket S : Shrubs G : Grasses L : Legumes	Cultivated, manured; Maize and sorghum with G : Cynodon dactylon	G : Panicum repens Miscanthidium teretifolium Oryza perennis	Cultivated, with G : Acroceras macrum	Wet grassland and sedges		G : Echinochloa pyramidalis Panicum repens, in saline patches Diplachne fusca	T : Diplachne fusca in saline belt	G : Vossia cuspidata Aeschynomene fluitans
Depth cm (in)	15.2 (6)	15.2 (6)	15.2 (6)	60.9 (24)	213.4 (84)	15.2 (6)	15.2 (6)	15.2 (6)
Colour	10 YR 5/1 grey	10 YR 4/1 dk. grey	10 YR 3/2 dk. greyish-brown	10 YR 7/1 lt. grey	2.5 YR 7/2 lt. grey	10 YR 5/1 grey	10 YR 5/2 greyish-brown	10 YR 2/1 black
Texture	Sand	Sand	Peat	Sandy loam	Sandy clay-loam	Sand	Sand	Sandy clay-loam
Mottling, at cm (in)	91 (36)	Gley	Gley	91 (36)	-	30 (12)	30 (12)	15.2 (6)
Coarse sand 200μ - 2mm %	77.7	65.2	71.2	37.1	21.9	66.1	11.6	14.6
Fine sand 20μ - 200μ %	21.3	28.8	26.2	29.9	29.1	33.9	82.9	48.2
Silt 2μ - 20μ %	0.0	5.0	2.6	18.9	15.4	0.0	1.6	3.8
Clay <2μ	1.0	1.0	0.0	14.1	33.6	0.0	3.9	33.4
Organic C % Total N % C/N Ratio	0.072	0.108	0.846	0.009	0.019	0.58 0.082 7	0.052	0.530
pH in M/100 $CaCl_2$	5.9	4.6	4.3	5.4	5.1	7.3	3.7	5.5
Exch. Ca meq % Exch. Mg meq % Exch. K meq % Exch. Na meq %	1.43 0.16 0.23	1.57 0.38 0.19	4.15 2.08 0.96	0.60 1.00 0.06	3.95 5.30 0.60	1.69 0.66 0.06 1.44	4.28 4.20 0.06 -	12.93 7.52 0.03 -
Cation Exch. Capacity meq % Base Saturation %	1.90 95.8	6.10 35.1	62.60 4.5	3.10 53.5	11.60 84.9	1.76 100	4.0 100	32.76 62.5
P ppm air-dry soil	17.0	8.4	10.0			8.0	Trace	1.8

II(c)/III(a) HUMIC SOILS: MONGU-KALABO AND BULOZI TERRACES (Contd.)

	Ox-bows (1) (contd.)		Ox-bows (2)		
Pit no.	54	61	48	51	55
Lab. sample no.	11338	11441	11334	11292	11339
Site	Siloana Plain, edge of riverbed	Nangwezi pools, riverbed	18 miles N. of Litunda old riverbed	Matabele Plain, old riverbed	Siloana Plain, sandy fringe to old riverbed
Vegetation T : Trees Th : Thicket S : Shrubs G : Grasses L : Legumes	G : Panicum repens	G : Cynodon dactylon Setaria sphacelata	G : Themeda triandra Setaria sphacelata	G : Themeda triandra Setaria sphacelata	G : Eragrostis mildbraedii
Depth cm (in)	15.2 (6)	15.2 (6)	15.2 (6)	15.2 (6)	15.2 (6)
Colour	10 YR 7/2 lt. grey	10 YR 5/1 grey	10 YR 7/2 lt. grey	10 YR 5/1 grey	10 YR 6/2 lt. brownish-grey
Texture	Sand	Sand	Sand	Sand	Sand
Mottling at cm (in)	30.4 (12)	25.4 (10)	45.7 (18)	60.9 (24)	45.7 (18)
Coarse sand 200μ - 2mm %	67.0	52.9	69.7	22.9	47.5
Fine sand 20μ - 200μ %	33.0	47.1	30.3	70.6	52.5
Silt 2μ - 20μ %	0.0	0.0	0.0	2.6	0.0
Clay - 2μ	0.0	0.0	0.0	3.9	0.0
Organic C %	0.04				0.32
Total N %	0.008	0.090	0.132	0.044	0.034
C/N Ratio	5				9
pH in M/100 $CaCl_2$	7.5	4.6	5.5	4.9	6.0
Exch. Ca meq %	0.24	1.41	0.35	2.44	0.33
Exch. Mg meq %	0.15	0.89	0.14	0.71	0.14
Exch. K meq %	0.03	0.14	0.03	0.06	0.03
Exch. Na meq %	0.71	-	-	-	-
Cation exchange capacity meq %	1.06	3.60	0.46	4.40	0.76
Base saturation %	1.4	67.8	100	73.0	8.0
P ppm air-dry soil	1.4	2.2	6.8	2.4	8.0

III(c) RIVER LEVEE ALLUVIUM: BULOZI TERRACE

Pit no.	15a +			15b +				50	59	67	68
Lab. sample no.	8661	8662	8663	8667	8668	8669	8670	11336	11343	11447	11448
Site	2 miles W. of Mongu on flood plain. Cropped land, kaffir corn.			2 miles W. of Mongu on floodplain. Cropped land, velvet beans				Natukoma school	Siloana Plain, Mulele Kuta	S.W. corner Siloana Plain	N.W. corner Siloana Plain
Vegetation T : Trees Th: Thicket S : Shrubs G : Grasses L : Legumes	T : Acacia albida Lonchocarpus capassa			T : Acacia albida Lonchocarpus capassa				Cultivated maize garden with G : Cynodon dactylon Chloris gayana	Cultivated maize manured, with G : Cynodon dactylon	T : Lonchocarpus capassa Acacia giraffae G : Chloris gayana Cynodon dactylon Setaria sphacelata	T : Hyphaene ventricosa Phoenix reclinata S : Sansevieria sp. G : Cynodon dactylon Chloris gayana Setaria sphacelata
Depth cm (in)	0-60.9 (0-24)	60.9-91.4 (24-36)	>91.4 (>36)	0-15.2 (0-6)	15.2-30.4 (6-12)	30.4-60.9 (12-24)	>60.9 (>24)	15.2 (6)	15.2 (6)	15.2 (6)	15.2 (6)
Colour	10 YR 5/2 grey-brown	10YR 6/1	10YR 6/1	10YR 6/1 grey	10YR 6/1	10YR 7/1	10YR 7/1	10 YR 5/4 yellow-brown	10 YR 4/3 brown/dk. brown	10 YR 5/1 grey	10 YR 3/2 v. dk. greyish-brown
Texture	Sandy loam			Sandy loam				Sand	Sand	Sand	Sandy loam
Mottling cm (in)	60.9 (24)			76.2 (30)				-	-	-	-
Coarse sand 200μ - 2mm %	20.4	18.2	27.5	38.1	27.2	30.8	41.3	58.1	42.7	47.7	30.6
Fine sand 20 - 200μ %	45.4	38.6	32.5	39.9	44.8	41.2	35.7	38.4	51.9	49.9	57.2
Silt 2μ - 20μ %	20.4	21.2	20.6	14.0	17.8	18.4	15.8	1.6	1.3	2.4	5.6
Clay >2μ	13.8	22.0	19.4	8.0	10.2	9.6	7.2	1.9	4.1	0.0	6.6
Organic C %								0.33		0.38	
Total N %	0.100	0.07	0.08	0.124	0.086	0.090	0.042	0.070	0.094	0.238	0.108
C/N ratio								4.7		1.5	
pH in M/100 Ca Cl_2	7.2	7.1	7.1	5.10	5.00	5.55	5.95	5.8	7.0	7.3	7.3
Exch. Ca meq %	8.07	8.70	10.1	3.24	3.64	3.60	2.20	1.22	5.69	4.35	18.96
Exch. Ng meq %	1.86	2.56	3.15	1.47	1.07	1.53	0.85	0.46	1.27	0.82	3.34
Exch. K meq %	0.37	0.27	0.36	1.90	0.37	0.38	0.15	0.19	0.19	0.17	0.35
Exch. Na meq %	-			-				-	-	0.92	0.62
Cation exchange capacity meq %	11.76	12.60	16.4	8.00	9.70	8.10	6.40	1.80	4.96	5.20	19.40
Base saturation %	96.1	91.5	89.0	82.6	52.4	68.0	34.4	100	100	100	100
P ppm air-dry soil								2.0	30	5.6	8.6

+ Data from Namushakende Research Station not from present survey

III(e) BROWN MOPANE ALLUVIUM: BULOZI TERRACE

Pit no.	63	64	65	66
Lab. sample no.	11443	11444	11445	11446
Site	Kalongo bed, alluvium	E. of Sinjembele, alluvium	E. of Sinjembele. Alluvium, hardpan present	E. of Sinjembele Anthill on alluvium
Vegetation T : Trees Th : Thicket S : Shrubs G : Grasses L : Legumes	T : Colophospermum mpanne Schmidtia bulbosa	T : Colophospermum mopane Enteropogon macrostachyus G : Sporobolus panicoides	T : Colophospermum mopane	T : Colophospermum mopane
Depth cm (in)	15.2 (6)	15.2 (6)	15.2 (6)	15.2 (6)
Colour	10 YR 5/2 greyish-brown	10 YR 5/2 greyish-brown	10 YR 4/3 brown/ dk. brown	10 YR
Texture	Sand	Sand	Sand	Sandy loam
Mottling, at cm (in)	-	-	Hardpan 76.2 (30)	-
Coarse sand 200μ - 2mm %	38.6	52.4	50.6	30.1
Fine sand 20μ - 200μ %	57.0	47.6	45.0	50.5
Silt 2μ - 20μ %	4.4	0.0	4.4	5.6
Clay <2μ	0.0	0.0	0.0	13.8
Organic C %	2.60			
Total N %	0.045	0.032	0.022	0.064
C/N Ratio	5			
pH in M/100 Ca Cl_2	6.0	5.8	6.4	7.6
Exch. Ca meq %	1.74	1.41	1.36	21.20
Exch. Mg meq %	1.76	1.91	0.76	2.77
Exch. K meq %	0.41	0.19	0.44	0.91
Exch. Na meq %	-	-	-	0.35
Cation Exch. Capacity meq %	2.10	2.40	3.80	13.90
Base Saturation %	100	100	67.4	100
P ppm air-dry soil	2.4	4.0	2.4	6.8

METHODS OF ANALYSIS

Preparation of sample: all soils were air dried, and ground to pass a 2.0 mm sieve.

Mechanical analysis After dispersal, the coarse sand (2.0 - 0.2 mm) was retained on a suitable sieve; the fine sand, silt and clay were obtained by sedimentation analysis using a Bouyoucos hydrometer as follows:

International coarse sand	200μ - 2 mm
International fine sand	20μ - 200μ
International silt	2μ - 20μ
International clay	< 2μ

Organic matter The Walkley and Black method was used for estimating organic carbon. The result was multiplied by the factor 1.72 to obtain a value for organic matter, expressed as a percentage of air-dry soil.

Total nitrogen Obtained by using the macro-Kjeldahl technique, and expressed as a percentage of the air-dry soil.

pH measurements These were made electrometrically with glass electrodes in a suspension of 10 g of soil in 50 ml of 0.01 M calcium chloride solution.

Base exchange capacity 25 g of soil was leached with 250 ml neutral normal ammonium acetate solution, washing with alcohol and finally leaching with 250 ml normal sodium chloride solution to remove the ammonium ions from the base exchange complex. The amount of displaced ammonium was determined by the Kjedahl procedure to give the base exchange capacity expressed as milligram equivalents per 100 g of soil (meq %).

Exchangeable bases Appropriate aliquots of the original ammonium acetate leachate, containing the exchangeable bases were used for the following determinations expressed as meq %: calcium by 0.01 M EDTA titration, using calcein screened with thymolphthalein as indicator; magnesium by 0.01 M EDTA titration, using Eriochrome Black-T as indicator to give the sum of the calcium and magnesium ions, the amount of magnesium present being calculated; potassium by flame photometry.

Base saturation This value was obtained by calculation, using the formula:

$$\frac{\text{sum of exchangeable bases (meq \%)}}{\text{Base exchange capacity (meq \%)}} \times 100 = \text{\% base saturation}$$

'Available' phosphorus The soil mixed with water and resin was shaken overnight, during which time the 'available' phosphate was transferred from the soil to the resin. The resin carrying the displaced phosphate was separated and treated to remove the phosphate, which was determined by a colorimetric phosphomolybdate procedure, and expressed as parts of elemental phosphorus (P) per million parts of air dry soil (ppm) (See D. H. Sander and H. R. Meterlerkamp's paper C19 to the 1962 International Soil Conference in New Zealand).

APPENDIXES 2 AND 3

APPENDIX 2. SPECIES LISTS OF THE VEGETATION COMMUNITIES

Trapnell *et al* (1950) and Trapnell and Clothier (1957) mapped the main vegetation communities occurring in Western Province. These are the basic works of reference to which most subsequent work has been related. Details of the floristic composition of the main grassland communities will be found in Part 4 of Volume 2 of this report, and this information is cross referenced with Trapnell's vegetation-soil groups in this Appendix. The floristic lists draw heavily on the work of Fanshawe, particularly his notes on Senanga and Kalabo (1961b, 1963b) from which the following frequency ratings have been taken:

a abundant
c common
f frequent
o occasional
r rare
l locally

The units are shown below, Trapnell's map notation being shown in brackets*.

1. Evergreen and Semi-deciduous Forest and Woodland

Crytosepalum low forest	(K1)

2. Brachystegia - Julbernardia (= Isoberlinia) Woodlands and Other Woodlands and Forests

Julbernardia paniculata woodland	(K3)
Brachystegia spiciformis woodland	(K5)
Burkea - Guibourtea - Baikiaea woodland	(K7)
Burkea africana woodland	(K8)
Dialium engleranum (= *D. simii*) woodland	(K9)
Colophospermum mopane woodland	(S1 and L1)

3. Other Deciduous Woodlands and Forests

Baikiaea plurijuga forests	(K6)

4. Deciduous Thicket Types

Commiphora - Combretum - Pterocarpus thicket or forest	(K10)

5. High Grass Woodland and Chipya Types

Erythrophleum - Pterocarpus 'Chipya' vegetation	(K11)
Acacia - Combretum and allied vegetation	(K12)

* The 'units' here correspond approximately with the 'types' in Table 19, but owing to the composition of the floristic lists, some of the subtypes of Type 3 in the table are grouped together with Unit 2 here. Also Units 5, 6 and 7 correspond with Types 4, 5 and 6 respectively in the table.

6. Bush-group, Tree Grassland and Scrub Grassland Types

Hyphaene palm association	(SK1)
Bush-group types of vegetation	(SK2, 3, 4)
Diplorhynchus and other scrub grasslands	(SK5)

7. Grassland Types

Kalahari Sand Plain and Watershed Grasslands	(SK6 and S4)
Valley and Floodplain Grasslands	(S5)
Swamp and Papyrus Sudd	(SW)

1. EVERGREEN AND SEMI-DECIDUOUS FOREST AND WOODLAND

Cryptosepalum Low Forest and Woodland (Trapnell's K1)

This community occurs on the following soils distinguished during this survey: Upland Mixed Sedentary and Barotse Sand Soils (Ib), Lake-dune Barotse Sands (IIa) and the Lake Basin Alluvial Soils (IIb). The grass, sedge and herbaceous species in particular occur mainly on either one or the other of these soils, as shown in the species lists below.

Canopy trees

Albizia adianthifolia
Brachystegia longifolia
B. spiciformis
Cryptosepalum pseudotaxus
Guibourtia coleosperma
Julbernardia paniculata
Terminalia brachystemma

Small trees:

Canthium malacocarpum		Diplorhynchus condylocarpon	Ib
Diospyros batocana		Vangueriopsis lanciflora	
D. undabunda			

Shrubs

Acalypha chirindica		Erlangea sessilifolia	IIa
Alchornea occidentalis		Gisekia pharnaceoides	IIa, b
Baissea wolfhorstia	IIa	Lepidagathis microchila	IIb
Bauhinia mendoncae		Oldenlandia herbacea	IIb
Citrullus naudinianus	IIa	Paropsia brazzeana	
Chrysophyllum megalismontanum		Tricalysia angolensis	
Copaifera baumiana		Uvaria angolensis	

Subshrubs

Chamaeclitandra henriquesiana
Diospyros virgata
Leptactina benguelensis
Sansevieria kirki
Strobilanthopsis linifolia
Tricalysia cacondensis
Triumfetta dekindtiana

Climbers

Canthium venosum
Cassytha filiformis
Combretum grossweileri
Landolphia camptoloba
L. parrifolia
Strophanthus welwitschi

Herbaceous legumes

Bolusia rhodesiana	IIa	Humalaria lundaensis	IIb
Cassia absus	Ib	Indigofere arenophila	Ib, IIa
C. mimosoides	Ib	I. baumiana	IIa, b
C. obtusifolia	Ib, IIb	I. demissa	IIb
C. occidentalis	Ib, IIb	I. filipes	IIa, b
Crotolaria amoena	Ib, IIb	I. flavovirens	IIb
C. baumii	IIb	I. griscoides	IIa, b
C. bequaertii	IIb	I. hirsuta	Ib, IIa
C. cephalotes	IIb	I. microcalyx	IIa
C. goreensis	IIb	I. nummulariifolia	IIa
C. gweloensis	IIb	I. spicata	Ib, IIa
C. natalitia	Ib, IIb	I. subulata	Ib
C. ochroleuca	IIa, b	I. sp.	Ib, IIa, b
C. podocarpa	IIa, b	Lablab niger	Ib
C. pseucotenuirama	IIb	Rothia hirsuta	Ib, IIb
C. rhodesia	IIb	Rhynchosia holosericea	Ib
C. sphaerocarpa	IIa	R. minima	IIb
C. stenoptera	IIa, b	Smithia strobilantha	IIb
C. sp.	IIa, b	Tephrosia cephalantha	IIa, b
Desmodium velutinum	Ib	T. lupinifolia	IIa
Dolictios africanus	Ib, IIb	T. purpurea var. pubescens	IIa, b
D. trinervis	Ib	T. rhodesica	IIb
D. sp.	Ib, IIb	Vigna dekindtiana	IIa, b
Eriosema psoraleoides	IIb	Zornia glochidiata	Ib, IIa
Glycine javanica	Ib, IIb		

Grasses

Andropogon amplectens	Ib, IIb	Dactyloctenium aegyptium	Ib
A. brazzae	Ib	Danthoniopsis viridis	IIb
A. eucomus	IIb	Diandrochloa namaquensis	IIb
A. gayanus	Ib	Diheteropogon grandiflorus	IIb
A. huillensis	IIb	Digitaria brazzae	IIa, b
A. schirensis	Ib, IIb	D. milanjiana	Ib, IIa, b
A. sp.	IIa, b	D. monodactyla	IIb
Anthephora acuminata	IIa, b	D. perrottetii	IIa, b
Apochaete hispida	IIb	D. sp.	IIa, b
Aristida atroviolacea	IIb	Dolichochaete nodiglumis	IIa, b
A. graciliflora	IIa, b	Eleusine coracana	Ib, IIa
A. meridionalis	IIa, b	E. indica	Ib
A. sp.	IIa, b	Eragrostis arenicola	IIa, b
Brachiaria brizantha	Ib	E. chapelieri	Ib
B. dura	IIa, b	E. gangetica	IIb
B. humidicola	IIb	E. patens	Ib
B. nigropedata	IIb	E. rigidior	IIa, b
B. xantholeuca	IIa, b	E. tenuifolia	Ib, IIa, b
B. distichophylla	IIa, b	E. tremula	IIa, b
Cenchrus biflorus	IIa	E. viscosa	Ib, IIa
Chloris pycnothrix	Ib, IIa	E. sp. aff. pallens	IIa, b
C. virgata	Ib, IIa	E. sp.	Ib, IIa, b
Craspedorhachis rhodesiana	IIa, b	Heteropogon melanocarpus	Ib, IIa, b
Cymbopogon densiflorus	Ib	H. contortus	Ib
Cynodon dactylon	IIb	Homozeugos eylesii	Ib

Grasses (contd.)

Hyparrhenia diplandra	Ib
H. dissoluta	Ib, IIa, b
H. filipendula	Ib
H. grallata	Ib
H. newtonii	Ib
H. poecilotricha	Ib
H. rudis	Ib
H. rufa	Ib
H. variabilis	Ib
H. sp.	Ib
Leptocarydion vulpiastrum	IIa
Loudetia lanata	IIa, b
L. simplex	IIa, b
Megastachya mucronata	IIb
Melinis macrochaeta	Ib, IIb
Microchloa indica	IIa, b
Miscanthidium teretifolium teretifolium	IIb
Monocymbium ceresiiforma	IIb
Oryza perennis	IIb
Panicum maximum (hairy form)	Ib, IIa, b
Paratristachya superba	Ib, IIb
Pennisetum polystachion	Ib, IIb
P. typhoides	Ib, IIa
Perotis leptopus	IIa, b
P. vaginata	IIa
Pogonarthria squarrosa	Ib, IIa, b
Rhynchelytrum nyassanum	Ib, IIa, b
R. subglabrum	IIa
Rottboellia exaltata	Ib, IIb
Rytachne robusta	Ib
Schizachryrium sp., aff. jeffreysii	IIa, b
S. jeffreysii	IIa, b
Setaria anceps	IIb
S. homonyma	IIa, b
S. pallidifusca	Ib, IIa, b
Sorghum af. roxburgii	IIa, b
Sporobolus molleri	Ib, IIa, b
S. pyramidalis	Ib, IIa, b
S. sanguineus	IIb
S. subtilis	IIb
Trachypogon spicatus	IIb
Tricholaena monachne	IIa, b
Trichoneura grandiglumis	Ib, IIb
Tristachya eylesii	IIb
T. huillensis	Ib
Urelytrum squarrosum	IIa, b
Vetiveria nigritana	IIb

Sedges

Ascolepis elata	IIb
Bulbostylis sp.	IIb
Cyperus amabilis	IIa, b
C. sylvestris	IIb
C. tenax	IIa, b
Mariscus deciduus	IIb
M. laxiflorus	IIa
M. ochrocephalus	IIb
Scleria bambarensis	IIb
S. induta	IIb

Note: the sedge ground layer together with moss is particularly well developed in good examples of *Cryptosepalum* forest.

2. BRACHYSTGIA - JULBERNARDIA WOODLAND, AND OTHER WOODLANDS AND FORESTS

In his notes on the vegetation of the districts of Western Province Fanshawe (1961b, 1963b etc.) describes the woodland on the Barotse (Kalahari) sands as forming part of one long regression from *Baikiaea* forest to Watershed grassland as follows:

Baikiaea - Guibourtia woodland	(Trapnell's K7)
Burkea - Guibourtia - Erythrophleum woodland	(Trapnell's K8)
Burkea - Erythrophleum woodland	
Burkea - Diplorhynchus scrub	
Brachystegia spiciformis woodland	(Trapnell's K5)
Julbernardia paniculata woodland	(Trapnell's K3)

This *Julbernardia* association also occurs on the sedentary soils of the plateau (Ia) in Western Province as Trapnell's P5.

The dominant species in the above formations have already been noted in the section on vegetation in Part 3. Fanshawe (1961b, 1963b) however, did not distinguish between the formations in his floristic lists, instead they were all grouped under a general heading *Kalahari Sand Woodland*. Certain species were noted as occurring only in Senanga District (S) or Kalabo District (K), and these abbreviations are used below. The grass and sedge covers of the different formations distinguished by Trapnell have been recognised and these are shown separately.

In the southern part of Sesheke District the *Burkea* woodland (K 8) gives way to an allied *Dialium engleranum* woodland (Trapnell's K 9) on Lake Dune Barotse Sands (IIa) and Lake Basin Alluvial Soils (IIb). Details of the composition of the woodland apart from the dominance of *Dialium* are not available; the grass and sedge layer however is similar to that of the *Julbernardia paniculata* woodland (K 3) which also occurs on the Lake Dune and Lake Basin soils. The composition of this layer can therefore be worked out by reference to the soil notation in the grass and sedge community lists.

There are also occurrences of Trapnell's K 4 Southern *Julbernardia globiflora-Brachystegia* Woodland near Livingstone, but details of this community are not available.

Canopy trees

Acacia galpini	S	r	Dialiposis sp.	S	r
A. giraffae		1o	Dialium engleranum	S	o
A. sieberiana				K	o - 1f
Adansonia digitata	S	r	Erythrophleum africanum	S	o - f
Afrormosia sp.	S	r		K	f
Afzelia quanzensis	S	r - o	Ficus fischeri	K	r
	K	o -1f	Guibourtia sp.	S	1f
Albizia amara	K	r	Hyphaene sp.	S	r
A. antunesiana		o	Julbernardia paniculata	S	1c
A. versicolor		r - o	Kigelia sp.	S	r
Amblygonocarpus sp.	S	r - o	Parinari curatellifolia	S	o
	K	o		K	f
Baikiaea plurijuga	S	1o -1f	Pterocarpus angolensis	S	o - 1f
	K	f -1c		K	f
Brachystegia longifolia	S	1c	Ricinodendron rautanenii		1f
B. spiciformis	S	1c	Sclerocarya caffra		r - o
	K	a	Strychnos stuhlmannii		1c
Burkea africana	S	f	Syzgium guineense		
	K	c	ssp. barotsense	K	r
Combretum mechowianum	S	o - f	S. guineense ssp.		
			huillense	K	o - 1f
Commiphora angolensis	S	1o	Terminalia trichopoda	S	r
Cryptosepalum pseudotaxus	S	1f	T. sericea	K	1o
			Ziziphus mucronata	K	1o

Small trees

Baphia obovata	K	f - c	Canthium huillense	S	o
Bersama sp.	K	r	Chrysophyllum		
Brachystegia bakerana	S	1f	bangweolense	S	r - o
	K	1a		K	1o

Combretum psidioides		o - f
C. zeyheri	S	f - c
	K	f
Commiphora mossambicensis	S	lo
Cryptosepalum pseudotaxus	K	lo
Crossopteryx sp.	S	r
Croton gratissimus	S	lo
Dalbergia nitidula	S	r
	K	lo
Diospyros batocana		f - c
Diplorhynchus condylocarpon	S	f
	K	c
Hannoa chlorantha	S	lf
Hexalobus sp.	S	lc
Hymenocardia acida		f -lc
Lannea discolor		lo
Maprounea sp.	S	lo
	K	of
Monotes glaber		o
Ochna pulchra	S	o -lf
	K	f -lo
Olax obtusifolius		lo
Oldfieldia		lo
Piliostigma thoningii		
Protea petiolaris	S	lo
Pseudolachnostylis	S	o
	K	o - f
Rhus tenuinervis	S	o
	K	r
Rothmania englerana	S	lo
	K	r
Schrebera trichoclada		lo
Securidaca sp.		o
Steganotaenia sp.	S	lo
Strychnos cocculoides		o-lo
S. innocua	S	r- o
S. pungens	S	o
	K	o-lf
S. spinosa	S	o
	K	r
Swartzia sp.		o
Terminalia brachystemma		o- f
Uapaca kirkiana	S	o-lf
U. nitida	S	o-lf
Vangueriopsis sp.		o
Vernonia amygdalina	S	lo
V. colorata	S	lo
Xylopia odoratissima		o
Ziziphus abyssinica	S	r- o
Z. mucronata	S	lo

Shrubs

Acacia ataxacantha	K	lo
A. fleckii	K	r
Ancylanthos bainesii	K	lo-lf
Baphia obovata	S	o-lf
Bauhinia macrantha	S	lo
	K	f- c
B. urbaniana		f
Bridelia duvigneaudi	S	r- o
	K	r
Canthium huillense	K	lo
C. singueana	K	lo
C. venosum	S	r
Chrysophyllum megalismontanum	K	lo
Cissus cornifolia	S	r
Combretum celastroides	K	r
C. engleri	K	lo
Copaifera mopane	S	lf
	K	a
Dalbergia melanoxylon	S	lo
	K	r
Eriosema ellipticum	S	r
Erythrococca menyharthi	K	lo
Flacourtia sp.		o
Grewia falcistipula	S	o- f
	K	lo
G. flavescens	S	o- f
	K	o
G. monticola	S	lo
	K	r
G. retinervis	S	lf
	K	lo
Hannoa chlorantha	K	o
Heeria longipes	S	r
H. nitida	S	r
Holostylon sp.	S	r-lo
	K	r
Humularia megalophylla	K	r
Indigofera bauminiana	S	lo
I. microcalyx	S	lo
I. podocarpa	S	lo
I. sutherlandioides	S	lo
Jasminum stenolobum	S	r
Kotschya strobilantha	S	lf
	K	lo
Lepidagathis macrochila	S	lf
Maytenus senegalensis	K	o
Ochna cinnabarina	S	r
Ochthocosmas sp.	K	r
Paropsia sp.	S	f
	K	r
Pavetta assimilis		r
P. cataractarum	K	r
P. schumanniana		lo
Phoenix sp.	K	lf

Shrubs (contd.)

Popowia obovata	S	o	T. angolensis				lo
Protea angolensis	S	lo	Uvaria angolensis		K		r
P. gaguedi	S	o-1f	Vangueria tomentosa		S		o
Psorospermum baumi	S	lo	Vernonia glaberrima		S		o
P. febrifugum		o			K	o-	f
Rhus kirkii	K	r	V. shirensis		S	1-	o
Rytigynia orbicularis		lo			K		r
R. umbellulata	K	r	Vitex madiensis		S	o-	1f
Sapium cornutum	K	1f			K		r
Sida hoepfneri	S	1f	V. mombassae		K		lo
Sphedamnocarpus sp.	K	r	Xeromphis sp.		S		1f
Tapiphyllum velutinum	K	vr	Ximenia americana		K		r
Tricalysia allenii		lo- o	X. caffra				lo

Subshrubs

Abrus suffruticosus	S	lo	C. pseudotenuirama	IIb			
Acalypha senesis	S	o	C. rhodesia	IIb			
	K	lo	C. stenoptera	IIa,b			
Achyranthes sp.	S	o-1f	C. sp. aff.				
	K	lo-1f	tamboensis	IIb			
Aframomum			C. sp.	IIa,b			
biauriculatum	K	1f	Cassytha filiformis	IIa			
Aloe zebrina	S	r	Centemopsis		S		lo
	K	lo			K		r
Alvesia sp.	S	r-lo	Chamaeclitandra sp.				1f
	K	lo	Citrullus				
Ancylanthos			naudinianus	IIa	S		o
rubiginosus	S	lo	Clematopsis		K		lo
Annona stenophylla			scabissifolia		S		o
ssp. nana		1f	Clerodendron capitatum				lo
Aspilia africana	S	lo	C. lanceolatum		S		lo
	K	r			K		r
Baissea wolfhorstii IIa			C. uncinatum				lo
Barleria kirki	K	r	Clutea abyssinica		S		r
Blepharis			Coleus esculentus		S		r
maderaspatensis	K	1f			K		lo
Bolusia rhodesiana IIa			C. kapatensis		K		r
Brackenridgea sp.		1f	Crotolaria amoena				
Caloncoba sp.	K	lo	C. sericea				p
Cassia absus Ib			C. natalitia				
C. mimosoides Ib			Deinbolia sp.		K		r
C. obtusifolia Ib,IIb			Desmodium barbatum		S		lo
C. occidentalis Ib					K		r
Crotolaria Ib,IIb			D. velutinum				
C. baumii IIb			Dichapetalum rhodesicum				lo-1f
C. bequaertii IIb			Diospyros chaemanthus		S		1f
C. cephalotes IIb					K		r
C. goroensis IIb			D. virgata				o-f
C. gweloensis IIb			Diplolophium				lo
C. natalitia Ib,IIa,b			Dolichos africanus	Ib,IIb			
C. ochroleuca IIa,b			D. densiflorus		K		r
C. podocarpa IIa,b			D. trinervis	Ib			
			D. spp.	Ib,IIb			

Subshrubs (contd)

Ectadiopsis oblongifolium		S	o
Entada nana		S	r
Eriosema psoraleoides	IIb		
Erlangea sessilifolia	IIa		
Eugenia angolensis			1o
Fadogia fuchsioides		S	1o
F. giorgi		K	r
F. monticola			1o
F. spp.		K	r
Felicia sp.		S	r
Gardenia brachythamnus			o-1f
G. subacaulis			r
Gisekia pharnacioides	Ia,b		
Glycine javanica	Ib,IIb		
Helichrysum kirkii		S	o
Hemizygia sp.		S	o
Hermannia angolensis			o
H. glanduligera		K	f
Humularia lundaensis	IIb		
Hypoestes verticillaris		S	o
		K	f
Indigofera arenophila	Ib,IIa		
I. baumiana		K	1o
I. demissa	IIb		
I. filipes	IIa,b		
I. flavicans	IIb		
I. hirsuta	Ib,IIa		
I. griseoides			o
I. microcalyx		K	o-f
I. nummulariifolia	IIa		
I. spicata	Ib,IIa		
I. spp.	IIa,b		
Jasminum streptopus			1o
Justicia betonicoides			1f
Lablab niger	Ib		
Lannea ambacensis		S	1o
L. gossweileri		S	1o
		K	f-1c
Lepidagathis microchila	IIb		
Leptactina sp.			o-f
Magnistipula eglandulosa		K	1f
Mechowia sp.		S	r
Monechma fimbricatum		K	r
Napoleona sp.			f-c
Nidorella auriculata		S	1o
N. microcephala		K	1o
Ochna leptoclada			1f-f
O. pygmaea		S	1f
		K	r
Oldenlandia herbacea	IIb		
Parinari capensis			1c
Pavetta pygmaea		K	r
Phyllanthus maderaspatensis		S	o
		K	1o
P. welwitschianus		S	1o
		K	r
Pleiotaxis rogersi		K	r
Pollichia		S	o
Polycarpeae eriantha var. effusa	IIa,b		
Polygala nematophylla		K	r
Psychotria buzica		K	1o
P. kirkii			r
Rhus kirkii		S	o
Rothia hirsuta	Ib,IIb		
Rhynchosia holosericea	IIb		
R. minima	Ib,IIb		
Salacia erecta		S	1o
Sansevieria kirkii			1o
Sapium oblongifolium		S	o-1f
		K	r
Scoparia sp.		S	r
Smilax sp.		K	1f
Smithia strobilantha	IIb		
Sphenostylis sp.		S	o
Strobilanthopsis linifolia		S	o-f
		K	1o
Strychnos caespitosa		S	1f
		K	r
Sygium guineense spp. huillense		S	1o
Tapiphyllum discolor		S	r
Tephrosia cephalantha			o-f
Tephrosia rhodesica	IIb		
Thesium fastigiatum		S	r-o

Subshrubs (contd.)

T. lupinifolia	IIa			T. suffruticosa			r
T. purpurea var. pubescens	IIa,b			Triumfetta dekindti		S	1f
Tinnea vestita		S	o	Vigna dekindtiana	IIa,b		
		K	r	Waltheria sp.		S	1f
Tricalysia cacondensis			o-f	Zornia glochiciata	Ib,IIa		

Climbers

Abrus precatorius			r	Combretum mossambicense			o
Ampelocissus africana		S	1o	Dioscorea hirtiflora		K	1o
		K	r	Helinus integrifolius		K	r
A. obutusatus			1o	Ipomoea verbascoidea		K	r
Asparagus africanus		K	1o	Landolphia camptoloba		S	o-1f
A. plumosus		K	r			K	1c
A. racemosus		K	1o	Rhynchosia holosericea		S	o-1f
Baissea sp.		S	o-1f			K	r
		K	f	Secamone micrandra		K	r
Bauhinia fassoglensis		S	1o	Strophanthos welwitschi		S	r
		K	r			K	o-1f
Cardiospermum halicacabum		K	r	Thunbergia crispa		S	1o
				Vigna esculenta			o
Cassytha sp.		S	o				
Cissampelos mucronata		K	1o				

Grasses and Sedges

As noted in the introduction to Part 4, the grass cover under the various forms of woodland on the Barotse Sands and associated soils (principally Fanshawe's Kalahari sand woodland) is affected more by soil than by vegetation type. *Julbernardia paniculata - Brachystegia* woodland (Trapnell's K3 and P5) occurs on both Lake-dune Barotse Sands (IIa), Lake Basin Alluvial soils (IIb) and Upland Sedentary Soils (Ia) of the Plateau; the *Brachystegia spiciformis - Brachystegia bakerana* woodland (Trapnell's K5) also occurs on the Lake-dune Barotse Sands (IIa) and Lake Basin Alluvial Soils (IIb); *Burkea - Guibourtia -Baikiaea* woodland (Trapnell's K7) occurs on Upland Mixed Sedentary and Barotse Sand Soils (Ib), and Lake-dune Barotse Sands (IIa); while the *Burkea africana* woodland only occurs on the Lake-basin Alluvial Soils (IIb).

The above soil notation, which conforms with the soil section of the report, is used in the following lists, from which the grass and sedge cover for the different soil units and therefore for the different vegetation communities can be worked out.

Grasses

Andropogon amplectens	Ia,Ib,IIb	Apochaete hispida	IIb
A. brazzae	Ia,Ib	Aristida atroviolacea	IIb
A. eucomus	IIb	A. graciliflora	IIb
A. gayanus	Ia,Ib	A. meridionalis	IIb
A. huillensis	IIb	A. sp.	IIb
A. schirensis	Ia,Ib,IIb	Brachiaria brizantha	Ia,Ib
A. sp.	IIa,b	B. distichophylla	IIa
Anthephora acuminata	IIb	B. dura	IIa,b

Grasses (contd.)

B. humidicola	IIb
B. nigropedata	IIb
B. xantholeuca	IIb
B. sp. aff. distichophylla	IIb
Cenchrus biflorus	IIa
Chloris pycnothrix	Ia, Ib, IIa
C. virgata	Ia, Ib, IIa
Craspedorhachis rhodesiana	IIa, b
Cymbopogon citratus	Ia
C. densiflorus	Ia, Ib
Cynodon dactylon	
Dactyloctenium aegyptium	Ia, Ib
Danthoniopsis viridis	IIb
Diandrochloa namaguensis	IIb
Digitaria brazzae	IIa, b
D. milanjuana	Ia, Ib, IIa, b
D. monodactyla	IIb
D. perrottetii	IIb
D. sp.	Ia, Ib, IIa, b
Dolichochaete nodiglumis	IIa, b
Eleusine coracana	Ia, Ib, IIa
E. indica	Ia, Ib, IIb
Eragrostis arenicola	IIa, b
E. chapelieri	Ia, Ib
E. gangetica	IIb
E. patens	Ib, IIa
E. rigidior	IIa, b
E. tenuifolia	Ia, IIa, b
E. tremula	IIa, b
E. viscosa	Ia, Ib, IIa
E. sp. aff, pallens	IIa, b
E. sp.	Ia, Ib, IIa, b
Heteropogon melanocarpus	Ia, Ib, IIa, b
H. contortus	Ia, Ib
Homozeugos eylesii	Ia, Ib
Hyparrhenia diplandra	Ia, Ib
H. dissoluta	Ia, Ib, IIa, b
H. filipendula	Ia, Ib
H. grallata	Ia, Ib
H. newtonii	Ia, Ib
H. poecilotricha	Ia, Ib
H. rudis	Ia, Ib
H. rufa	Ia, Ib
H. variabilis	Ia, Ib
H. sp.	Ia, Ib
Leptocarydion vulpiastrum	IIa
Loudetia lanata	IIa, b
L. simplex	IIa, b
Megastachya mucronata	IIb
Melinis macrochaeta	Ia, Ib, IIb
Microchloa indica	IIa, b
Miscanthidium teretifolium	IIb
Monocymbium ceresiifolium	IIb
Oryza perennis	IIb
Panicum maximum (hairy form)	Ia, Ib, IIa, b
Paratristachya superba	IbIIb
Pennisetum polystachion	Ia, Ib
P. typhoides	Ia, Ib, IIa
Perotis leptopus	IIa, b
P. vaginata	IIa
Pogonarthria squarrosa	Ia, Ib, IIa, b
Rhynchelytrum nyassanum	Ia, Ib, IIa, b
R. subglabrum	IIa
Rottboellia exaltata	Ia, Ib, IIb
Rytachne robusta	Ia, Ib
Schizachyrium jeffreysii	IIa
S. ursulus	Ia
S. sp. aff. jeffreysii	IIa
Setaria anceps	IIb
S. homonyma	IIa, IIb
S. pallidifusca	Ia, Ib, IIa
Sorghum sp. cf. roxburgii	IIa, b
Sporobolus molleri	Ia, Ib, IIa, b
S. pyramidalis	Ia, Ib, IIa, b
S. sanguineus	IIb
S. subtilis	IIb
Trachypogon spicatus	IIb
Tricholaena monachne	IIa, b
Trichoneura grandiglumis	Ib, IIb
Tristachya eylesii	IIb
T. heillensis	Ia, Ib
Urelytrum squarrosum	IIa, b
Vetiveria nigritana	IIb

Sedges

Ascolepsis elata	IIb
Bulbostylis sp.	IIb
Cyperus amabilis	IIa, b
C. sylvestris	IIb
C. tenax	IIa, b
Mariscus deciduus	IIb
M. laxiflorus	IIa
M. ochrocephalus	IIb
Scleria bambarensis	IIb
S. induta	Ia, IIb

Colophospermum mopane Woodlands (Trappnell's S1 and L1)

This formation occurs on the Brown Mopane Alluvium (III e) - Trapnell's Brown Lower Valley Soils - examined during this survey, and on Trapnell's Grey Alluvial Clays which were not investigated during the present survey. The following list refers to Senanga district.

Canopy trees

Acacia nigrescens	o - 1f	Euphorbia candelabrum	o - f
A. sieberiana	o	Lannea stuhlmannii	1o
Adansonia sp.	r - o	Lonchocarpus capassa	o
Afzelia sp.	r	Manilkara mochisia	o
Albizia amara	f	Sclerocarya sp.	r - o
A. harveyi	o - f	Strychnos stuhlmannii	o - 1f
Colophospermum mopane	a	Terminalia sericea	o
Combretum imberbe	1o	Ziziphus abyssinica	o
Diospyros mespiliformis	o		

Small trees and shrubs

Acacia erubescens	o	Diospyros lycioides	o - f
Albizia anthelmintica	f	Erythroxylum sp.	r - o
Boscia mossambicensis	f - c	Euclea divinorum	o
Canthium frangula	r	Euphorbia espinosa	r
Capparis tomentosa	o	Gardenia resinifera	o
Combretum elaeagnoides	o - 1f	G. spatulifolia	r
C. ghasalense	o	Grewia flavescens	o
Commiphora madagascariensis	o	G. monticola	o
C. mossambicensis	o	Hyphaene sp.	1o
Cordia pilosissima	o	Markhamia acuminata	o
Crossopteryx sp.	o	Popowia obovata	o
Croton gratissimus	o	Steganotaenia sp.	o
Dalbergia melanoxylon	o	Ximenia americana	o - f
Dichrostachys sp.	1o	X. caffra	o

Suffrutices

Aloe chabaudii	1c	Dyschoriste verticillaris	1c
A. zebrina	1f	Sansevieria deserti	1c
Blumea gariepina	1f		

Climbers

Asparagus africanus	O - 1f	Hippocratea buchanani	o
Cissus quadrangularis	o - 1f	Pergularia sp.	o
Dregea macrantha	o	Strophanthus nicholsoni	o
Fockea sp.	f - c	Turbina shirensis	o - f

Grasses

Enteropogon macrostachyus	Sporobolus passicoides
Schmidtia bulbosa	

3. OTHER DECIDUOUS WOODLANDS AND FORESTS

Baikiae plurijuga forests (Trapnell's K6 on Transitional Kalahari Sands)

This community occurs on the following soils distinguished during this survey: Upland Mixed Sedentary and Barotse Sand Soils (Ib) (Trapnell's Kalahari Contact Soils), and the Lake-dune Barotse Sands (IIa) (Trapnell's Undifferentiated and Transitional Kalahari Sands). Some of the species listed occur mainly on either one or the other of these soils, as shown on the species lists below.

Canopy trees

Acacia giraffae	IIa	f - c	Entandrophragma caudatum		r - lo
A. nigrescens		r	Erythrophleum africanum		r
A. sieberiana	Ib		Ficus fischeri		r - o
Adansonia digitata		r	Guibourtia coleosperma		r
Afzelia quanzensis		1 - o	Hyphaene sp.		r
Albizia harveyi		r	Kigelia sp.		r
A. versicolor		r	Lannea stuhlmannii		lo
Amblygonocarpus andongensis	IIa	r	Lonchocarpus nelsi		f
Baikiaea plurijuga		a	Parinari curatellifolia		
Berchemia sp.		r - o	Peltophorum sp.		lo
Boscia albitrunca		o	Pterocarpus angolensis		r
Brachystegia spiciformis		r	P. antunesi		lf
Combretum imberbe		r	Ricinodendron rautanenii		lo
C. mechowianum		f - c	Sapium bussei		lo
Commiphora angolensis		lf	Sclerocarya caffra		r
Croton gratissimus		f	Strychnos innocua		lo
Dialium engleranum		o	S. stuhlmannii		lo
Diospyros mespiliformis		r	Swartzia madagascariensis		
Diplorhynchus condylocarpon			Terminalia sericea		o - lf

Small trees

Albizia anthelmintica		r	Phyllanthus discoideus		r
Cassipourea sp.		lo	P. engleri		r
Combretum celastroides		f - c	Rhus tenuinervis		o
C. engleri		o	Schrebera trichoclada		lo
Markhamia acuminata		o - lf	Vangueriopsis sp.		r
Ochna pulchra		o			

Shrubs and scramblers

Acacia ataxacantha		f - lc	Citrullus naudinianus	IIa	
A. fleckii		lf	Combretum elaeagnoides		f - c
Baissea wolfhorstii	IIa		Croton pseudopulchellus		lf
Baphia obovata		c	Dalbergia martini		o - lf
Bauhinia macrantha		f - c	D. melanoxylon		r
Bridelia duvigneaudi		r	Dichrostachys sp.		lf
Byrsocarpus sp.		r - o	Erlangea sessilifolia	IIa	
Canthium huillense		lo	Erythrococca menyharthi		o
Cassytha filiformis	IIa		Euclea divinorum		lo
Citropsis sp.		lo	Fagara trijuga		r - o

Shrubs and scramblers (contd.)

Gisekia pharnaceoides	IIa	Phyllanthus reticulatus	lo
Grewia avellana	f	Polycarpea eriantha var.	
G. falcistipula	r - o	effusa	
G. flavescens	f	Popowia obovata	f
G. retinervis	lo	Strobilanthopsis	
Maerua juncea	r	linifolia	
Markhamia obtusifolia	lf	Tarenna luteola	o - f
Maytenus senegalensis	r - o	Tricalysia allenii	o - f
Ochna cinnabarina	o	Vangueria tomentosa	r
Paropsea sp.	r	Vitex amboniensis	o
		Ximenia americana	o

Subshrubs

Achyranthes sp.	lf	H. physaloides	r - o
Aspilia africana	r - o	Hypoestes verticillaris	lf
Clerodendrum capitatum	lo	Jasminum streptopus	o
C. uncinatum	lo	Justicia betonicoides	o - f
Coleus esculentus	r	Peristrophe sp.	r
Crotalaria		Phyllanthus capillaris	o
flavicarinata	o	P. pentandrus	f
Euphorbia benthami	lo	Plumbago sp.	o
E. transvaalensis	lo	Pollichia sp.	r
Gardenia brachythamnus	lo	Pupalia lappacea	o - f
Hemizygia sp.	lf	Solanum panduriforme	lo
Hibiscus calyphyllus	r - o	Triumfetta annua	o - f
H. lobatus	lo		
H. mastersianus	lf		

Climbers

Asparagus africanus	r - o	Hippocratea indica	
Baissea sp.	f - lo	var. parviflora	f
Bonamia minor	lo	Ipomoea verbascoidea	o
Clematis brachiata	r	Rhynchosia caribea	lo
Cocculus sp.	r	Strophanthus kombe	r - o
Combretum mossambicense	o - f	Vigna vexillata	o

Herbs

Bolusia rhodesiana	IIa	I. baumiana	IIa
Cassia mimosoides	Ib	I. filipes	IIa
C. obtusifolia	Ib	I. griscoides	IIa
C. occidentalis	Ib	I. hirsuta	Ib, IIa
Crolotaria amoena	Ib	I. microcalyx	IIa
C. natalitia	Ib, IIa	I. nummulariifolia	IIa
C. ochroleuca		I. spicata	Ib, IIa
C. podocarpa	IIa	I. subulata	Ib
C. sphaerocarpa	IIa	I. sp.	IIa
C. stenoptera	IIa	Lablab niger	Ib
C. sp.	IIa	Rothia hirsuta	Ib
Desmodium velutinum	Ib	Rhynchosia	Ib
Dolichos africanus	Ib	holosericea	
D. trinervis	Ib	R. minima	Ib
D. sp.	Ib	Tephrosia cephalantha	IIa
Glycine javanica	Ib	T. lupinfolia	IIa
Indigofera arenophila	Ib, IIa	T. purpurea var.	
		pubescens	IIa

Herbs (contd.)

T. purpurea var. pubescens	
Vigna dekindtiana	IIa
Zornia glochidiata	Ib, IIa

Grasses

Andropogon amplectens	
A. brazzae	Ib
A. eucomus	IIa
A. gayanus	Ib
A. huillensis	IIa
A. schirensis	
A. sp.	IIa
Anthephora acuminata	IIa
Apochaete hispida	IIa
Aristida atroviolacea	IIa
A. graciliflora	IIa
A. meridionalis	IIa
A. sp.	IIa
Brachiaria brizantha	Ib
B. dura	IIa
B. humidicola	IIa
B. nigropedata	IIa
B. xantholeuca	IIa
B. sp. aff. distichophylla	IIa
Chloris pycnothrix	Ib
C. virgata	Ib
Craspedorhachis rhodesiana	IIa
Cymbopogon densiflorus	Ib
Cynodon dactylon	IIa
Dactyloctenium aegyptium	Ib
Danthoniopsis viridis	IIa
Diandrochloa namaquensis	IIa
Diheteropogon grandiflorus	IIa
Digitaria brazzae	IIa
D. milanjiana	
D. monodactyla	IIa
D. perrottetii	IIa
D. sp.	
Dolichochaete nodiglumis	IIa
Eleusine coracana	Ib
E. indica	
Eragrostis arenicola	IIa
E. chapelieri	Ib
E. gangetica	IIa
E. patens	Ib
E. rigidior	IIa
E. tenuifolia	
E. tremula	IIa
E. viscosa	Ib
E. sp. aff. pallens	IIa
E. sp.	
Heteropogon melanocarpus	
H. contortus	Ib
Homozeugos eylesii	Ib
Hyparrhenia diplandra	Ib
H. dissoluta	
H. filipendula	Ib
H. grallata	Ib
H. newtonii	Ib
H. poecilotricha	Ib
H. rudis	Ib
H. rufa	Ib
H. variablilis	Ib
H. sp.	Ib
Loudetia lanata	IIa
L. simplex	IIa
Megastachya mucronata	IIa
Melinis macrochaeta	
Microchloa indica	IIa
Miscanthidium teretifolium	IIa
Monocymbium ceresiiforme	IIa
Oryza perennis	
Panicum maximum (hairy form)	IIa
Paratristachya superba	
Pennisetum polystachion	
P. typhoides	Ib
Perotis leptopus	IIa
Pogonarthria squarrosa	
Rhynchelytrum nyassanum	
Rottboellia exaltata	
Rhytachne robusta	Ib
Schizachyrium sp. aff. jeffreysii	IIa
S. jeffreysii	IIa
Setaria anceps	IIa
S. homonyma	IIa
S. pallidifusca	Ib
Sorghum cf. S. roxburgii	IIa
Sporobolus molleri	
S. pyramidalis	
S. sanguineus	IIa
S. subtilis	IIa

Grasses (contd.)

Trachypogon spicatus	IIa	Tristachya eylesii	IIa
Tricholaena monachne	IIa	T. huillensis	Ib
Trichoneura grandiglumis		Urelytrum squarrosum	IIa
		Vetiveria nigritana	IIa

Sedges: were only collected on the Lake Dune Barotse Sands.

Cyperus amabilis	Mariscus laxiflorus
C. tenax	

4. DECIDUOUS THICKET TYPES

Commiphora - Combretum - Pterocarpus Thicket or Forest (Trapnell's K10)

Details are not available of this community which occurs in Mongu district.

Combretum apiculatum	C. ugogensis
C. elaeagnoides	Kirkia acuminata
Commiphora chlorocarpa	Pteleopsis anisoptera
C. fischeri	Pterocarpus antunesii

5. HIGH-GRASS - WOODLAND OR 'CHIPYA' TYPES

Erythrophleum - Pterocarpus and 'Chipya' Vegetation (Trapnell's K 11)

Details of this vegetation type are not available.

Canopy trees

Baikiaea plurijuga	Pterocarpus angolensis
Erythrophleum africanum	Syzygium guineense ssp. afromontanum
Parinari mobola	

Small trees

Canthium captum	Diplorhynchus sp.
C. venosum	Hymenocardia acida
Chrysophyllum megalismontanum	Landolphia camptoloba
Clerodendrum tanganyikense	L. parvifolia
Combretum sp.	Terminalia sp.

Acacia - Combretum and allied vegetation (Trapnell's K12)

This association was recorded on Lake-dune Barotse Sands (IIa) (Trapnell's Transitional Kalahari Sands) during the present survey.

Canopy trees

Acacia clavigera	f - lc	A. nigrescens	f - c
A. galpini	o	A. polyacantha	lo
A. giraffae	f - o	A. sieberiana	o - f

Canopy trees (contd.)

Adansonia sp.	r	Guibourtia coleosperma	r
Afzelia quanzensis	r	Hyphaene ventricosa	o - 1f
Albizia amara	o - 1f	Kigelia sp.	1o
A. harveyi	o - 1f	Lannea stuhlmannii	1o
A. versicolor	o	Lonchocarpus capassa	o - f
Amblygonocarpus andongensis	1o	Manilkara mochisia	r
Baikiaea plurijuga		Ostryoderris sp.	o - 1f
Berchemia sp.	r	Parinari curatellifolia	r
Combretum imberbe	c	Peltophorum sp.	1o
Erythrophleum africanum	1o	Pterocarpus angolensis	
Ficus capensis	r	Ricinodendron rautanenii	
F. fischeri	r	Sclerocarya sp.	1o
		Strychnos stuhlmannii	o - 1f
		Swartzia madagascariensis	
		Terminalia sericea	f - 1c

Small trees

Acacia hebeclada	o - f	Rhus tenuinervis	o
A. mellifera	1f	Strychnos cocculoides	r
Albizia anthelmintica	o	S. spinosa	o
Combretum hereroense	f - c	Ziziphus abyssinica	o
C. zeyheri	o	Z. mucronata	o
Piliostigma sp.	o		

Shrubs

Baissea wolfhorstii		Grewia flavescens	1o
Bridelia cathartion	r	Hoslundia sp.	1o
Byrsocarpus sp.	o	Maytenus senegalensis	o - f
Carissa edulis	1o	Phyllanthus reticulatus	1o
Cassytha filiformis		Polycarpeae eriantha var. effusa	
Citrillus naudinianus		Securinega sp.	o
Commiphora pyracanthoides	1o	Strobilanthopsis linifolia	
Dalbergia melanoxylon	1f	Tarenna luteola	1o
Dichrostachys sp.	f - c	Urena sp.	o - 1f
Diospyros lycioides	f	Vernonia glabra	o - f
Erlangea sessilifolia		Wissadula sp.	1o
Euclea divinorum	o - f	Withania sp.	r
Gisekia pharnaceoides		Ximenia americana	o

Subshrubs

Achyranthes sp.	1f	H. mechowi	1o
Aerva lanata	f	Ipomoea vernalis	1o
Aloe chabaudii	1o	Lantana rhodesiensis	r - o
Barleria mackeni	1f	Leonotis rugosa	1f
Blepharis buchneri	o - 1f	Pavonia hirsuta	o - f
Blumea sp.	1f	Peristrophe sp.	1o
Cleome hirta	r	Sesamum capense	1c
Clerodendrum uncinatum	1o	Sida alba	o
Corchorus tridens	1o	Solanum incanum	1o
C. trilocularis	r	Sutera elegantissima	1f
Heliotropium ovalifolium	1f	Triumfetta annua	1o
Hermannia glanduligera	1f	Walafrida sp.	1o
Hibiscus cannabinus	1o		

Climbers

Abrus precatorius	o	Combretum mossambicense	o
Ampelocissus africana	r - o	Dioscorea quartiniana	lo
Asparagus racemosus	o	D. sylvatica	r
Cardiospermum halicacabum	o - lf	Dolichos africanus	o
Cissampelos mucronata	o	Merremia tridentata	o - f
Cissus integrifolius	r - o	Momordica cardiospermoides	r
Cocculus sp.	o - f	Pergularia sp.	r - o

Herbs

Bolusia rhodesiana
Crotalaria natalitia
C. ochroleuca
C. podocarpa
C. sphaerocarpa
C. stenoptera
C. sp.
Indigofera arenophila
I. baumiana
I. filipes
I. griscoides
I. hirsuta
I. microcalyx
I. nummulariifolia
I. spicata
I. sp.
Tephrosia cephalantha
T. lupinifolia
T. purpurea var. pubescens
Vigna dekindtiana
Zornia glochidiata

Grasses

Andropogon sp.
Anthephora acuminata
Aristida graciliflora
A. meridionalis
A. sp.
Brachiaria dura
B. xantholeuca
B. distichophylla
Cenchrus biflorus
Chloris pycnothrix
C. virgata
Craspedorhachis rhodesiana
Digitaria brazzae
D. milanjiana
D. perrottetii
D. sp.
Dolichochaete nodiglumis
Eleusine coracana
Eragrostis arenicola
E. patens
E. rigidior
E. tenuifolia
E. tremula
E. viscosa
E. sp. aff. pallens
E. sp.
Heteropogon melanocarpus
Hyparrhenia dissoluta
Leptocarydion vulpiastrum
Loudetia lanata
L. simplex
Microchloa indica
Panicum maximum (hairy form)
Pennisetum typhoides
Perotia leptopus
P. vaginata
Pogonarthria squarrosa
Rhynchelytrum nyassanum
R. subglabrum
Schizachyrium jeffreysii
S. sp. aff. jeffreysii
Setaria homonyma
S. pallidifusca
Sorghum S. cf.S. roxburgii
Sporobolus molleri
S. pyramidalis
Tricholaena monachne
Urelytrum squarrosum

Sedges

Cyperus amabilis
C. tenax
Mariscus laxiflorus

6. BUSH-GROUP, TREE-GRASSLAND AND SCRUB-GRASSLAND TYPES

Hyphaene Palm Association (Trapnell's SK 1)

This association was recorded by Trapnell as occurring on the margins of his Transitional Sands (Lake Dune Barotse Sands). It was noted on Recent Alluvium in Abandoned Watercourses (IId) during the present survey, and consists of belts or groups of trees in grassland.

Trees

Acacia giraffae
Burkea africana
Combretum sp.
Hyphaene ventricosa
Terminalia sericea

Grasses

Acroceras macrum
Andropogon eucomus
A. huillensis
A. tumidulus
Brachiaria humidicola
B. nigropedata
B. platytaenia
Cynodon dactylon
Diandrochloa namaquensis
Diheteropogon
Digitaria abyssinica
Echinochloa pyramidalis
Eragrostis capensis
E. lappula
E. mildbraedii
E. sp. aff. denudata
Hemarthria altissima
Leersia hexandra
Loudetia phragmitoides
L. simplex
Miscanthidium teretifolium
Monocymbium ceresiiforme
Panicum dregeanum
P. glabrescens
P. ianthum
P. juncifolium
P. repens
Paratristachya superba
Paspalum commersonii
Pennisetum polystachion
Phragmites mauritianus
Rhytachne rottboellioides
Sacciolepis cinereo-vestitum
S. gracilis
S. typhura
S. scirpiodes
Setaria anceps
S. sphacelata
Sporobolus subtilis
Themeda triandra
Trachypogon spicatus
Vetiveria nigritana

Sedges

Ascolepsis elata
Bulbostylis laniceps
B. sp.
Cyperus denudatus
C. esculentus
C. longus
C. margarotaceus
C. mwinilungensis
C. nudicaulis
C. spaerospermus
C. sylvestris
C. tenax
C. sp.
C. sp. aff. angolensis
Fimbristylis longiculmis
F. squarrosa
F. triflora
Fuirena glomerata
F. pubescens
F. stricta
F. umbellata
Kyllinga erecta var. intricata
Lipocarpha albiceps
Mariscus deciduus
M. umbellatus
Pycreus lanceolatus
P. lanceus
P. polystachyus
Rhynchospora candida
R. corymbosa
R. holoschoinoides
R. rugosa
R. glauca
Scirpus corymbosus
Scleria veseyfitzgeraldii
Typha sp.? australis

Legumes

Aeschynomene indica

Bush-Group Types of Vegetation (Trapnell's SK 2, SK 3 and SK 4)

These bush groups are composed of species of the *Cryptosepalum*, *Burkea* and *Acacia - Combretum* vegetation types, occurring in Trapnell's Kalahari Sand Plain and Watershed grasslands. They occur on the Recent Alluvial Soils of Abandoned Watercourses (IId) and on River Levee Soils (IIIc) of the present survey. Fanshawe (1961b, 1963b) has listed the woody vegetation of the Bush-groups in Senanga (S) and Kalabo (K) districts. This notation is used below.

Canopy trees

Acacia albida				Ficus fischeri		r
A. clavigera	S		lo	F. sycomorus	K	r
A. giraffae	S		o	Garcinyia livingstonei	S	o
	K		lo	Guibourtia coleosperma	K	f
A. nigrescens	S		f	Lannea stuhlmannii	S	o
	K		lo	Lonchocarpus capassa		o
A. sieberiana			r	Manilkara mochisia	S	o
Afzelia quanzensis	S		r	Parinari curatellifolia	K	f
	K	o -	lf	Peltophorum sp.	S	r - o
Albizia amara	K		r		K	lo
A. antunesiana	K		o	Piliostigma thonningii	K	lo
A. harveyi	S	o -	f	Pseudocassine sp.	S	o - lf
A. versicolor	K	r -	o	Pterocarpus angolensis	K	f
Amblygonocarpus sp.	K		o	Sclerocarya caffra	K	r
Baikiaea plurijuga	K	f -	lc	Stercospermum sp.	K	r
Berchemia sp.			r	Strychnos stuhlmannii	S	o
Brachystegia spiciformis	K		a		K	lo
Burkea africana	K		c	Syzygium guineense ssp.		
Combretum hereoense	S	o -	f	barotsense	K	r
C. imberbe	S		f	S. huillense	K	o - lf
	K		r	Terminalia mollis	K	lf
Dialium engleranum	K	o -	lf	T. sericea	S	o
Diospyros mespiliformis	K		r		K	lo
Erythrophleum africanum	K			Ziziphus mucronata	S	o
Euphorbia candelabrum	S	r -	o		K	lo

Small trees

Acacia mellifera	S		lo	Lannea discolor	K	o
A. nilotica	S		lo	Maerua angolensis	K	r
	K		r	Maprounea sp.	K	o - f
Albizia anthelmintica	S		o	Markhamia accuminata	S	o
Baphia obovata	K	f -	c	M. obtusifolia		o - f
Bersamia sp.	K		r	Monotes glaber	K	o
Canthium burtii	S		r	Ochna pulchra	K	f - lc
Combretum hereroense	K		r	Olax obtusifolia	K	lo
C. psidioides	K	o -	f	Oldfieldia sp.	K	lo
C. zeyheri	K		f	Pseudolachnostylis sp.	K	o - f
Croton gratissimus	S		o	Rhus tenuinervis	S	o
Dalbergia nitidula	K		lo		K	r
Diospyros batocana	K	f -	c	Rothmannia englerana	K	r
D. kirkii	K		r	Sapium bussei	S	r
Diplorhynchus sp.	K		c	Schrebera trichoclada	K	lo
Hymenocardia acida	K	f -	lc	Securidaca sp.	K	o

Small trees (contd.)

Strychnos cocculoides	K	lo		Terminalia brachystemma	K	o - f
S. pungens	K	o - 1f		Vangueriopsis sp.	K	o
S. spinosa	K	r		Xylopia odoratissima	K	o
Swartzia sp.	K	o				

Shrubs

Acalypha ornata	S	o - 1f		Kotschya strobilantha	K	lo
Allophylus cataractarum	S	o		Ludwigia leptocarpa		
	K	lo		Maytenus senegalensis	S	lo
Ancylanthos bainesii	K	lo - 1f			K	lo
Antidesma venosum	K	lo - 1f		Mimosa pigra		
Baphia obovata	S	o		Moringa oleifera		
Bauhinia macrantha	S	o		Paropsia sp.	K	o - f
	K	fc		Pavetta assimilis	K	r
B. urbaniana	K	f		P. cataractarum	K	r
Bridelia duvigneaudi	K	r		P. schumanniana	K	lo
Byrsocarpus sp.	S	o - 1f		Phoenix sp.	K	1f
	K	lo		Phyllanthus mulleranus	K	lo
Canthium huillense	K	lo		P. reticulatus	S	o
Capparis tomentosa	K	lo			K	1f
Carissa edulis	S	lo		Popowia obovata	S	o - 1f
	K	r			K	lo
Cassia occidentalis				Psorospermum febrifugum	K	o
C. singueana	K	lo		Rhus kirkii	K	r
Chrysophyllum				Rytigynia orbicularis	K	lo
megalismontanum	K	lo		Securinega sp.	K	lo
Citropsis sp.	S	r		Sesamum angustifolium		
Commiphora				Sesbania sesban		
pyracanthoides	S	r - o		S. sesban var.		
Copaifera mopane	K	a		zambesiaca		
Dalbergia melanoxylon	K	r		Sida hoepfneri	S	lo
Dichrostachys sp.	K	lo		Sphedamnocarpus	K	r
Diospyros lycioides	S	f		Striga gesnerioides		
	K	lo		Tarenna luteola	S	lo
Erythrococca menyharthi		lo		Tephrosia linearis		
Euclea divinorum	S	f		Tricalysia allenii		lo
	K	lo - 1f		T. angolensis	K	lo
Feretia sp.	S	lo		Vangueria tomentosa	S	r
Flacourtia sp.	K	o		Vernonia amygdalina	K	lo
Grewia falcistipula	K	lo		V. glaberrima	K	o - f
G. flavescens		lo		V. shirensis	K	r
G. monticola	K	r		Vitex madiensis	K	r
G. rectinervis	K	lo		V. mombassae	K	lo
G. schinzi	S	o		Wissadula sp.	S	f
Hannoa chlorantha	K	o		Withania sp.	S	lo
Heeria nitida	K	lo		Ximenia americana	S	o
Humularia megalophylla	K	r			K	r
Hyphaene sp.	K	lc		X. caffra	S	o
Indigofera arrecta					K	lo
I. ormocarpoides	S	r				

Subshrubs

Abrus fruticulosus	IIIc			Acalypha senensis	IId	K o - 1f
A. indica	IIIc			Achyranthes sp.		K lo - 1f
Abutilon angulatum		S o - 1f				

Subshrubs (contd.)

Aeschynomene indica	IId		
Aframomum biauriculatum		K	1f
Aloe zebrina		K	lo
Alvesia sp.		K	lo
Annona stenophylla spp. nana		K	1f
Aspilia africana		K	r
Barleria mackeni		S	1f
Blepharis maderaspatensis		K	1f
Brackenridgea sp.		K	1f
Cassia absus	IIIc		
C. mimosoides	IIIc		
C. goreensis	IIIc		
C. mucronata	IIIc		
C. ochroleuca	IIIc		
C. rhodesia	IIIc		
C. shamvaensis	IIIc		
C. spinosa	IIIc		
Chamaeclitandra sp.		K	1f
Clematopsis scabiosifolia		K	lo
Clerodendrum capitatum		S/K	lo
Coleus esculentus		K	lo
Combretum platypetalum		K	lo
Dichapetalum rhodesicum		K	lo-1f
Dicliptera verticillata		K	1f
Diospyros virgata		K	o- f
Diplolophium sp.		K	lo
Disperma sp.		S	f-lc
Dolichos densiflorus		K	r
Eriosema paucijugum		K	r
E. psoraleoides		K	1f
Eugenia angolensis		K	lo
Fadogia monticolia		K	lo
Glycine javanica	IIIc		
Gnidia kraussiana		K	lo
Hermannia glanduligera		S/K	lo
Hibiscus calyphyllus		S	r
H. cannabinus		K	lo
Hypoestes verticillaris		S/K	o- f
Indigofera baumiana		K	o
I. demissa	IIIc		
I. gairdnerae	IIIc		
Jasminum fluminense		K	
J. streptopus		K	lo
J. betonicoides		K	1f
		S	f
Lablab niger	IIIc		
Lantana rhodesiensis		S	r
Lannea gossweileri		K	f -lc
Leptactina sp.		K	o - f
Magnistipula eglandulosa		K	1f
Napoleona sp.		K	f - c
Nidorella microcephala		K	lo
Ochna leptoclada		K	f
Parinari capensis		K	lc
Pavonia hirsuta		S	lo
Peristrophe sp.		S/K	r
Phyllanthus maderaspatensis		K	lo
Psychotria buzica		K	lo
P. kirkii		K	r
Pupalia lappacea		S	o
Pygmaeothamnus zeyheri		K	1f
Rothia hirsuta	IIIc		
Ruspolia decurrens		S	lo
Rhynchosia minima	IIIc		
R. sublobata	IIIc		
R. venulosa	IIIc		
Sansevieria deserti		S	f -lc
S. kirkii		K	lo
Sapium oblongifolium		K	r
Smilax sp.		K	1f
Sida alba		K	r
Strobilanthopsis sp.		K	lo
Tephrosia cephalantha		K	o -1f
Tinnea vestita		K	r
Tricalysia cacondensis		K	o - f
T. suffruticosa		K	r
Triumfetta dekindtiana		K	1f
Vernonia glabra		K	1f

Climbers

Abrus precatorius	S	o	Cyclantheropsis sp.	S	r -	o
	K	r	Dioscorea hirtflora	K		lo
Ampelocissus africanus	K	r	Gongronema angolense	S		lo
A. obtusatus	K	lo	Gymnema sp.	S	r -	o
Asparagus africanus	K	lo	Helinus integrifolius	S		lo
A. racemosus	S	o		K		r
	K	lo	Hippocratea africana	S/K		lf
Bauhinia fassoglensis	K	r	H. indica var.			
Cardiospermum halicacabum	S	o	parrifolia	S		lo
	K	r	Landolphia camptoloba	K		lc
Cissampelos mucronata	S	o -f	Pergularia sp.	S		r
	K	lo	Rhoicissus tridentatus	K		r
Cocculus sp.	S	o -f	Strophanthos welwitschi	K	o -	lf
	K	lo	Tragia benthami	S	r -	o
Combretum mossambicense	S/K	o	Vernonia aurantiaca	S	r -	lo

Grasses

Acroceras macrum	IId	Loudetia phrasmitoides	IId
Andropogon eucomus	IId	L. simplex	IId
A. huillensis	IId	Miscanthidium	
A. tumidulus	IId	teretifolium	IId
Aristida eriophora	IIIc	Monocymbium	
A. pilgeri	IIIc	ceresiifolie	IId
A. sp.	IIIc	Panicum dregeanum	IId
Brachiaria humidicola	IId	P. glabrescens	IId
B. nigropedata	IId, IIIc	P. lanthum	IId
B. platytaenia	IId, IIIc	P. juncifolium	IId
Chloris gayana	IIIc	P. maximum (hairy form)	IIIc
Chasmopodium		P. repens	IId, IIIc
caudatum	IIIc	Paratristachya superba	IId
Cymbopogon citratus	IIIc	Paspalum commersonii	IId
Cynodon dactylon	IId, IIIc	Pennisetum glaucocladum	IIIc
Diandrochloa		P. polystachion	IId
namaquensis	IId	Phragmites mauritianus	IId
Digitaria abyssinica	IId, IIIc	Rendlia pseudoharpochloa	IIIc
D. brazzae	IIIc	Rhytachne	IId
Diheteropogon		rottboellioides	
grandiflorus	IId	Saccharum officinarum	IId
Dolichochaete		Sacciolepis	
nodiglumis	IIIc	cinereovestitum	IId
Echinochloa		S. gracilis	IId
pyramidalis	IId	S. typhura	IId
Eleusine indica	IIIc	S. scirpiodes	IId
Elyonurus brazzae	IIIc	Setaria anceps	IId, IIIc
Eragrostis atrovirens	IIIc	S. sphacelata	IId, IIIc
E. capensis	IId	S. verticillata	IIIc
E. lappula	IId, IIIc	S. sp.	IIIc
E. mildbraedii	IId	Sporobolus	
E. rigidior	IIIc	pyramidalis	IIIc
E. sp. aff. denudata	IId	S. spicatus	IIIc
Hemarthria altissima	IId	S. subtilis	IId, IIIc
Hyparrhenia dissoluta	IIIc	Themeda triandra	IId
Leersia hexandra	IId	Trachypogon spicatus	IId
		Vetiveria nigritana	IId

Sedges

Ascolepis elata	IId	C. denudatus	IId
Bulbostylis laniceps	IId	C. esculentus	IId
B. sp.	IId	C. longus	IId
Cyperus auricomus	IIIc	C. margaritaceus	IId

Sedges (contd.)

C. mwinilungensis	IId	Kyllinga erecta var. intricata	IId
C. nudicaulis	IId	Lipocarpha albiceps	IId
C. spaerospermus	IId	Mariscus deciduus	
C. sylvestris	IId	M. umbellatus	
C. tenax	IId	Pycreus lanceolatus	
C. sp. aff. angolensis	IId	P. lanceus	IId
C. sp.	IId	P. polystachyus	IId
Fimbristylis exilis	IIIc	Rhynchospora candida	IId
F. longiculmis	IId	R. corymbosa	IId
F. squarrosa	IId	R. holoschoinoides	IId
F. triflora	IId	R. rugosa	IId
Fuirena glomerata	IId	R. glauca	IId
F. pubescens	IId	Scirpus corymbosus	IId
F. stricta	IId	Scleria veseyfitzgeraldii	IId
F. umbellata	IId	Typha sp. (?australis)	IId

Diplorrhynchus and other scrub grasslands (Trapnell's SK 5)

This community occurs on the Flood Plain Sandy Alluvium(IIIb) distinguished during the present survey, locally called the Plains Litongo and termed Kalahari Sand Plains by Trapnell.

Small trees and shrubs

Acacia giraffae	Magnistipula eglandulosa
Burkea africana	Parinari capensis
Cassia occidentalis	Polygala nambalensis
Combretum sp.	Protea sp.
Diplorhynchus condylocarpon	Sesamum angustifolium
Hymenocardia acida	Striga gesnerioides
Indigofera microcalyx	Uapaca sp.

Herbs

Crotolaria pseudotenuirama	Vigna sp.
Indigofera daleoides	Zornia milneana
Rhynchosia venulosa	

Grasses

Alloteropsis semialata	Eleusine indica
Andropogon eucomus	Elyonurus brazzae
A. huillensis	Eragrostis atrovirens
A. schirensis	E. capensis
Apochaete hispida	E. lappula
Aristida atroviolacea	E. mildbraedii
A. graciliflora	E. tremula
A. meridionalis	Loudetia lanata
A. pilgeri	L. simplex
Brachiaria dura	Miscanthidium teretifolium
B. humidicola	Monocymbium ceresiiforme
B. nigropedata	Panicum juncifolium
Chasmopodium caudatum	Paratristachya superba
Cynodon dactylon	Rendlia pseudoharpochloa
Diandrochloa namaquensis	Rhytachne rottboellioides
Diheteropogon grandiflorus	Schizachyrium jeffreysii
Digitaria milanjiana	Setaria anceps
D. perrottetii	S. sphacelata

Grasses (contd.)

Sporobolus macotrix
S. marginatus
S. molleri
S. pyramidalis
Themeda triandra
Trachypogon spicatus
Vetiveria nigritana

Sedges

Cyperus amabilis
C. tenax
Fimbristylis dichotoma
F. exilis
Fuirena glomerata
F. pubescens
F. stricta
F. umbellata
Kyllinga erecta var. intricata
Lipocarpha albiceps
Mariscus deciduus
M. umbellatus
Kyllinga erecta
P. lanceus
P. polystachyus
Rhynchospora candida
R. corymbosa
R. holoschoinoides
R. rugosa
Scirpus corymbosus
Scleria veseyfitzgeraldii
Typha sp. ? australis

7. GRASSLAND TYPES

(Readers are referred to the previously described communities for grasslands associated with woodland, bush and scrub.)

Kalahari Sand Plain and Watershed Grasslands (Trapnell's SK 6 and S4)

This community occurs on the following soils distinguished during this survey: Flood Plain Sandy Alluvium - Plains Litongo - (IIIb) and Recent Alluvium in Abandoned Watercourses on the Mongu Kalabo Terrace (IId). Some of the species listed occur mainly on either one or the other of these soils, as shown below. Those species occurring on both soil types have no indication of soil type in the lists.

Fanshawe (1961b) renamed this type suffrutex savanna, on account of the large number of suffrutices present, and described it as 'Kalahari Woodland in its ultimate debased form'. Certain species were noted as occurring only in Senanga district (S) or Kalabo district (K); these abbreviations are used below.

Shrubs

Acacia giraffae			Protea madiensis	K	
Ancylanthos bainesii	K	1f	Protea welwitschi	K	1o
Diplorhynchus condylocarpon	K	r			

Subshrubs or suffrutices

Aeschynomene indica			Crotolaria pseudotenuirama		
Annona stenophylla ssp. nana	K	f - c	Diospyros chamaethamnus	S	1c
Becium angustifolium	K	1o		K	r
B. obovatum	K	1o	Dolichos densiflorus	S	o
Brackenridgea sp.		f -1c	Ectadiopsis producta	S	r -o
Cassia occidentalis					

Subshrubs or suffrutices (contd.)

Entada nana	S	lo	O. pygmaea	S	lf
Eugenia angolensis	K	lo		K	lo
Gnidia kraussiana	K	o- f	Parinari capensis		a
Hibiscus rhodanthus	K	lo	Polygala nambalensis		
Indigofera daleoides: I microcalyx			Pygmaeothamnus zeyheri		c
Lannea edulis	S	o	Rhynchosia venulosa		
L. gossweileri	K	c	Scoparia dulcis	K	lf
Magnistipula eglandulosa	K	f- c	Sesamum angustifolium		
Napoleona sp.		lf	Striga gesnerioides		
Ochna leptoclada	S	lf	Strychnos caespitosa	S	lf
O. manikensis	K	lo	Syzygium huillense	K	c
			Vigna sp.		
			Zornia milneana		

Grasses

Acroceras macrum	IId	Leersia hexandra	IId
Alloteropsis semialata	IIIb	Loudetia lanata	IIIb
Andropogon eucomus		L. phragmitoides	IId
A. huillensis		L. simplex	
A. schirensis	IIIb	Miscanthidium teretifolium	
A. tumidulus	IId	Monocymbium ceresiiforma	
Apochaete hispida	IIIb	Panicum dregeanum	IId
Aristida atroviolacea	IIIb	P. glabrescens	IId
A. graciliflora	IIIb	P. ianthum	IId
A. meridionalis	IIIb	P. juncifolium	
A. pilgeri	IIIb	P. repens	IId
Brachiara dura	IIIb	Paratristachya superba	
B. humidicola		Paspalum commersonii	IId
B. nigripedata		Pennisetum polystachion	IId
B. platytaenia	IId	Phragmites mauritianus	IId
Chasmopodium caudatum	IIIb	Rendlia pseudoharpochloa	IIIb
Cynodon dactylon		Saccharum officinarum	IId
Diandrochloa namaquensis		Sacciolepis cinereo-vestitum	IId
Diheteropogon grandiflorus		S. gracilis	IId
Digitaria abyssinica	IId	S. typhura	IId
D. milanjiana	IIIb	S. scirpiodes	IId
D. perrottetii	IIIb	Schizachryrium jeffreysii	IIIb
Echinochloa pyramidalis	IId	Setaria anceps	
Eleusine indica	IIIb	S. sphacelata	
Elyonurus brazzae	IIIb	Sporobolus macrotrix	IIIb
Eragrostis atrovirens	IIIb	S. marginatus	IIIb
E. capensis		S. molleri	IIIb
E. lappula		S. pyramidalis	IIIb
E. mildbraedii		S. subtilis	IId
E. tremula	IIIb	Themeda triandra	
E. sp.aff denudata	IId	Trachypogon spicatus	
Hemarthria altissima	IId	Vetiveria nigritana	

Sedges

Ascolepis elata	IId	C. longus	IId
Bulbostylis laniceps	IId	C. margaritaceus	IId
B. sp.	IId	C. mwinilungensis	IId
Cyperus amabilis	IIIb	C. nudicaulis	IId
C. denudatus	IId	C. spaerospermus	IId
C. esculentus	IId	C. sylvestris	IId

Sedges (contd.)

C. tenax	IId	Lipocarpha albiceps	
C. sp.	IId	Mariscus deciduus	
C. sp. aff. angolensis	IId	M. umbellatus	
Fimbristylis dichotoma	IIIb	Pycreus lanceolatus	
F. exilis	IIIb	P. lanceus	
F. longiculmis	IId	P. polystachyus	
F. squarrosa	IId	Rhynchospora candida	
F. triflora	IId	R. corymbosa	
Fuirena glomerata		R. holoschoinoides	
F. pubescens		R. rugosa	
F. stricta		Scirpus corymbosus	
F. umbellata		Scleria veseyfitzgeraldii	
Kyllinga erecta var. intricata		Typha sp. (australis?)	

Valley and Floodplain Grasslands (Trapnell's S 5)

This unit of Trapnell's includes a number of landform units with different soils and vegetation which were distinguished during the present survey: Valley Alluvium (dambos) (Id); Humic Soils of the Flood Plains on both the Mongu and Bulozi Terraces (IIc, IIIa): Flood Plain Sandy Alluvium (IIIa); River Levee Alluvium (IIIc)*; and Recent Alluvium in Abandoned Watercourses on the Volozi Terrace (IIId). Some of the species listed are restricted to certain of these units as shown by the lists below. Fanshawe (1961b, 1963b) noted certain of the woody species as only occurring in Senanga district (S) or Kalabo district (K) and these abbreviations are used below.

Trees

Acacia albida		K	o	Diplorhynchus condylocarpon	IIIb		f
A. giraffae	IIIb			Rhus quartiniana		K	o f
Combretum imberbe		K					

Shrubs and subshrubs

Acrocephalus gairdnerae		S	lo	Entada nana		S	r
Aeschynomene cristata	IIId			Epaltes sp.		K	lf
A. fluitans	IIId			Eriosema pauciflorum		S	lo
A. indica	Id, IIId	K	r	E. psoraleoides	IIc	S	lf
A. nilotica	IIId					K	o f
Alvesia sp.		S	lo	Ficus pygmaea		K	c
Alcylanthos rubiginosus		S	lo	F. verruculosa		K	lo
Ascocarydion mirabile	Id	K		Floscopa glomerata	IIId		
	IIc, IIa		a	Gnidia buchanani		S	lo
Asparagus asiaticus	IIIb	K	lo-lf	G. chrysantha		S	lo
				G. kraussiana		S	f
Aspilia sp.		K	lo	Gomphocarpus rostratus		K	r
Bauhinia fassoglensis		S	lo	Hermannia quartiniana		S	r
Cassia occidentalis	IIIb			Hibiscus rhodanthus		S	lo
Cissampelos mucronata	IIIc	K	lf	Hypericum lalandi		S	r
Combretum platypetalum		S	o-lf	Indigofera daleoides	IIIb		
Commelina purpurea	IIId			I. microcalyx	IIIa, b		
Crotolaria pseudotenuirama	IIIb			Ipomea aquatica	IIId		
				I. vernalis		S	lo
Desmodium salicifolium	Id, IIc, IIIa	K	r	Lannea edulis		S	f
				L. gossweileri		S	f- c
Dissotis princeps		K	c	Ludwigia sp.		K	c
Ectadiopsis producta		S	r	Magnistipula eglandulosa	IIIb		
				Maytenus senegalensis		K	f- c
				Napoleona sp.		S	lf

* some species; see also the Bush-group types of vegetation

Shrubs and subshrubs (contd.)

Neorautanenia sp.		S	r
Nidorella welwitschi		K	lf
Ochna leptoclada		S	lf
Parineri capensis	IIIb		
Phyllanthus reticulatus		K	lf
Polygala nambalensis	IIIb		
Polygonum salicifolium	IIId		
Pygmaeothamnus zeyheri		S	f
Rhynchosia venulosa	IIIb		
Sesamum angustifolium	IIIb	S	f
Sesbania caerulescens	Id		
S. microphylla	IIId		
S. sesban	Id,IIId		
S. sesban var. zambesiaca	IIId		
Sopubia ramosa		S	lf
Striga gesneroides	IIIb		
Sutera elegantissima	IIIc	K	lo
Syzygium huillense		S	lc
Tacazzea apiculata		K	c
Thalia welwitschi	IIId		
Thesium fastigiatum		S	r
Triumfetta cordifolia		K	lo
Urena sp.	IIIc	K	lf
Vigna sp.	IIIb		
Walafrida	IIIc	K	
Zornia milneana	IIIb		

Grasses

Acroceras macrum	IIId
Alloteropsis semialata	Id,IIc,IIIa,b
Andropogon eucomus	Id,IIc,IIIa,b
A. huillensis	Id,IIc,IIIa,b
A. schirensis	IIIb
Apochaete hispida	Id,IIIb
Aristida atroviolacea	IIIc
A. graciliflora	IIIb
A. meridionalis	IIIb
A. pilgeri	IIIb
Brachiaria dura	IIIb
B. humidicola	IIc,III,a,b
B. mutica	IIc
B. nigropedata	IIIb
Chasmopodium caudatum	IIIb
Cynodon dactylon	IIIb
Diandrochloa namaquensis	Id,IIIb
Digitaria abyssinica	IIId
D. horizontalis	IIId
D. milanjiana	IIIb
D. perrottetii	IIIb
Diheteropogon grandiflorus	IIIb
Diplachne fusca	IIId
Echinochloa holubii	IIId
E. pyramidalis	IIId
E. stagnina	IIId
Eleusine indica	IIIb
Elyonurus brazzae	IIIb
Eragrostis atrovirens	IIIb,d
E. capensis	Id,IIc,IIIa,b
E. lappula	IIIb,d
E. mildbraedii	IIIb
E. rigidior	IIId
E. tremula	IIIb
E. sp.aff.denudata	IIc,IIIa
Eriochrysis brachypogon	IIc,IIIa
E. pallida	IIc,IIIa
Hemarthria altissima	Id,IIId
Hyparrhenia bracteata	Id,IIc,IIIa
Imperata cylindrica	IIc,IIIa
Ischaemum arcuatum	IIcIIIa
Leersia hexandra	IIc,IIIa,d
L. sp.	IIId
Loudetia lanata	IIIb
L. simplex	Id,IIIc,b
L. sp.	IIId
Miscanthidium teretifolium	IIc,IIIa,b,d
Monocymbium ceresiiforme	Id,IIIb
Odyssea paucinervis	IIId
Oryza perennis	IIId
O. sativa	IIId
Panicum dregeanum	IIId
P. glabrescens	IIId
P. lanthum	IIId
P. inaequilatum	IIc,IIId
P. juncifolium	IIIa,b
P. maximum (hairy form)	IIId
P. parvifolium	IIc,IIIa

Grasses (contd.)

P. repens	IIId
P. sp. aff. coloratum	IIc,IIIa
P. sp. aff porphyrrhisos	IIId
P. sp. aff. subrepandum	Id
Paratristachya superba	IIIb
Paspalidium sp. aff. platyrrhachis	IIId
Paspalum commersonii	Id,IIId
Pennisetum glaucocladum	IIId
P. purpureum	Id,IIIa
Phragmites mauritianus	Id,IIId
Phyllorachis sagittata	Id
Rendlia pseudoharpochloa	IIId
Robynsochloa purpurascens	IIId
Rhytachne rottboellioides	IIIb,d
Saccharum officinarum	IIc,IIIa,d
Sacciolepsis africana	IIId
S. gracilis	Id,IIId
S. typhura	IIId
S. sp. aff. typhura	IIId
Schizachyrium jeffreysii	IIc
Seteria anceps	IIIb,d
S. sphacelata	IIIb,d
Sorghum macrochaeta	IIId
Sporobolus acinifolius	IIId
S. macotrix	Id,IIIb,d
S. molleri	IIIb
S. pyramidalis	IIIb
S. spicatus	IIId
Themeda triandra	IIIb
Trachypogon spicatus	Id,IIIb
Trichopteryx dregeana	IIc,IIIa
Vetiveria nigritana	IIIb
Vossia cuspidata	IIId
Willkomia sarmentosa	IIId

Sedges

Ascolepis capensis	Id,IIc,IIId
Bulbostylis aphyllanthoides	IIId
B. schoenoides	IIId
Cyperus amabilis	IIIb
C. aureo-brunneus	Id
C. auricomus	IIId
C. compactus	IIId
C. denudatus	IIId
C. difformis	IIId
C. esculentus	IIId
C. longus	IIId
C. margaritaceus	Id,IIId
C. mwinilungensis	IIId
C. nudicaulis	IIId
C. papyrus	IIId
C. radiatus	IIId
C. spaerospermus	IIId
C. sylvestris	Id
C. tenax	Id,IIIb
Eleocharis sp.	IIId
E. dulcis	IIId
Fimbristylis complanaya	IIId
F. dichotoma	Id,IIIb,d
F. exilis	Id,IIIb
F. longiculmis	IIc,IIIa
F. squarrosa	IIId
Fuirena glomerata	IIc,IIIa,b,d
F. pubescens	IIIa,b,d
F. sticta	Id,IIIbmd
F. umbellata	IIc,IIIa,b,d
Juncus sp.	IIId
Kyllinga erecta var. intricata	IIIb,d
Lipocarpha albiceps	IIIb,d
L. chinensis	Id,IIc,IIId
Mariscus deciduus	IIIbmd
M. ochrocephalus	Id
M. umbellatus	IIIb
Pycreus aethiops	IIId
P. flavescens	IIId
P. lanceus	IIIb,d
P. mundtii	IIId
P. polystachyus	IIIb,d
Rhynchospora candida	IIb,IIId
R. corymbosa	IIIb,d
R. holoschoinoides	IIc,IIIa,b,d
R. rugosa	IIIb
Scirpus corymbosus	IIIb,d
S. cubensis	IIId
S. ap.	IIId
Scleria bambarensis	IIc
S. melanompha	IIId
S. veseyfitzgeraldii	IIc,IIIa,b
Typha sp. (?australis)	Id,IIIb,d

Swamp and Papyrus Sudd (Trapnell's SW)

This community occurs on the soil type Recent Alluvium in Abandoned Watercourses (IId, IIId) distinguished during the present survey.

Shrubs

Commelina purpurea
Floscopa glomerata
Ipomea aquatica
Polygonum salicifolium
Thalia welwitschii

Grasses

Acroceras macrum
Brachiaria humidicola
Digitaria abyssinica
D. horizontalis
Digitariella remotigluma
Diplachne fusca
Echinochloa holubii
E. pyramidalis
E. stagnina
Eragrostis atrovirens
E. lappula
E. rigidior
Hemarthria altissima
Leersia hexandra
L. sp.
Loudetia sp.
Miscanthidium teretifolium
Odyssea paucinervis
Oryza perennis
O. sativa
Panicum dregeanum
P. glabrescens
P. ianthum
P. maximum (hairy form)
P. repens
P. sp. aff. porphyrrhisos
Paspalidium sp. aff. platyrrhachis
Paspalum commersonii
Pennisetum glaucocladum
Phragmites mauritianus
Robynsochloa purpurascens
Rhytachne rottboellioides
Saccarum officinarum
Sacciolepis africana
S. gracilis
S. typhura
S. sp., aff. S. typhura
Setaria anceps
S. sphacelata
Sorghum macrochaeta
Sporobolus acinifolius
S. macotrix
S. spicatus
Vossia cuspidata
Willkomia sarmentosa

Sedges

Cyperus spp.
Scirpus corymbosus
S. cubensis
S. sp.
Scleria melanomphala
Typha sp.

Legumes

Aeschynomene cristata
A. fluitans
A. indica
A. nilotica
Sesbania microphylla
S. sesban
S. sesban var. zambesiaca

APPENDIX 3. CHEMICAL ANALYSIS OF FODDER SAMPLES, AND THE INTERPRETATION OF RESULTS, BY A. BLAIR RAINS

In Volume 2, Part 4 of this report the value of the chemical analysis of fodder was discussed, and the care needed in the interpretation of the resultant data (see Table 30) noted. In view of its probable importance during the ensuing development of the Western Province cattle industry, the subject is discussed in greater detail here.

DIGESTIBILITY

The digestibility of the individual constituents of fodder can vary considerably, and it may be reduced in a number of ways. The digestibility of protein in most tropical grasses for example is lower than the digestibility of the organic matter; while the digestibility of the fodder and its constituents will usually be reduced by an inadequate supply of protein (nitrogen) which depresses the activity of the micro-organisms in the rumen. In particular as fodder matures the level of protein increasingly declines, with a consequent reduction in digestibility.

With regard to crude fibre, tropical grasses are more fibrous at an early stage of development than temperate grasses, and they are less easily digested, but the rate of the subsequent decline in digestibility with increasing maturity is slower in tropical grasses.

The digestibility of tropical herbage is further reduced by the accumulation of the woody material lignin into the structural elements of the plant, which occurs at the same time as the decline in the level of crude protein already mentioned. Lignin which is resistant to fermentation reduces the digestibility of both the structural elements and the cell contents of herbage. The deposition of lignin may occur as a result of temporary wilting, and it is particularly rapid in many tall-growing perennial grasses at flowering, when this coincides with the end of the rains. However neither flowering nor leafiness provide a reliable indication of digestibility.

Under certain conditions including low rainfall, and an abrupt cessation of the rains, the gradual deterioration in the composition and digestibility of the grass described above does not take place; instead the grass 'cures' on the ground, retaining its nutritive value throughout the dry season. Unfortunately prolonged wet season or dry season showers result in the loss of nutrients through leaching and reduce the feeding value of this 'standing hay' fodder.

FRESH HERBAGE

The sample of herbage collected for analysis should be representative of the grassland under investigation. To achieve this it is usually desirable to take a number of small samples in a way which avoids subjective bias, several random

areas of definite size being cut and weighed. An estimation of yield per acre is often made at this stage. A sample for analysis is then removed from the bulked samples, the fresh weight of the sample being recorded at the time of removal.

DRY MATTER

The sample of the herbage should be dried quickly without losing leaf which after drying shatters easily. Drying in controlled temperature ovens prevents the loss of nutrients due to continuing respiration or to fermentation, but these facilities are not always available. Air drying is most difficult when the humidity remains high, and the development of moulds must be prevented by spreading samples out, and by ensuring an adequate circulation of air around them, while they are drying. The dried sample is weighed and the yield of dry matter can then be calculated. The digestibility of the dry matter may be determined, or this value may be expressed in terms of total digestible nutrients.

ASH

The ash fraction, which may contain soil particles contaminating the sample, includes most but not all of the mineral constituents of the dry matter.

In many tropical grasses silica is the principal constituent of the ash so that the amount of acid soluble ash is a better indication of the available mineral content. However it is the determination of the level of individual chemical elements which is of greatest value. Elements of importance in animal nutrition, which are frequently determined include phosphorus, calcium, magnesium, potassium and sodium and in samples from certain areas copper, cobalt, manganese, molybdenum, iodine and selenium are also important.

Throughout the tropics the most commonly deficient mineral in the herbage is phosphorus, a reflection of the widespread deficiency of phosphorus in tropical soils (Naik, 1965). Phosphorus is closely linked with calcium in animal nutrition, but in most tropical herbage samples calcium is more than adequate to meet the needs of the animal, and may in some cases be so abundant that it creates an unfavourable imbalance with phosphorus (Hennaux and Compère 1955). Other elements may also be inadequate for healthy animal development, but in relatively few areas are trace elements likely to be the primary cause of low animal production.

The actual requirement of an animal for a particular mineral will vary according to the class of stock. In some areas trees and shrubs which are browsed, are a useful source of minerals in poor supply in the herbage. Relatively little is known about the absorption of minerals by the animal, although this is relevant to any attempt to relate the animal's requirements for minerals to their levels in the herbage, and browsed shrubs.

An attempt to indicate deficiency levels of some minerals is shown in Table A1 (see also du Toit *et al*, 1934, 1940).

TABLE A1 Tentative deficiency levels of minerals in herbage, expressed as percentages or parts per million of the dry matter

Element	Deficient	Uncertain	Theoretically adequate for production	Remarks
Phosphorus	<0.10%	0.10-0.20%	0.14%	A ratio Ca:P of 1.2 to 1.5:1 is desirable. Wider variations of this ratio are tolerated if levels of the elements and of Vitamin D are adequate
Calcium	<0.15%	0.15-0.30%	0.20%	
Potassium			0.34%	Rarely deficient in tropical herbage
Magnesium			0.10%	
Sodium	<0.01		0.02	Although salt will be eaten in excess of requirements 28 g (1oz) head/day should be provided since a deficiency results in unthriftiness
Chlorine			0.07	
Copper	<5 ppm	5 - 8 ppm	7.5 ppm	A combined deficiency may sometimes occur on calcareous and alkaline sands
Cobalt	<0.06 ppm	0.06 - 0.10 ppm	0.07 ppm	

ORGANIC COMPOUNDS

The commonest deficiency in extensively reared cattle such as those found in Western Province is probably a lack of sufficient total food, but this is usually complicated by shortages of certain constituents, particularly phosphorus found in the ash component, and protein found in the nitrogenous component of the organic compounds.

In fact the *major* nutrients required by the animal are found in the organic matter, and in order to calculate the amount of *digestible* organic matter, the digestibility of the organic matter is often determined. When interpreting the results a digestibility coefficient of 55-60% for organic matter or 50-55% for digestible organic matter may be regarded as satisfactory.

The organic matter may be conveniently divided into subsistances containing nitrogenous and non-nitrogenous constituents which are considered below.

NITROGENOUS CONSTITUENTS

The level of nitrogenous constituents is shown in most analyses as crude protein. It is obtained by determining the total nitrogen in the sample and multiplying this by the factor 6.25 as protein contains 16% nitrogen. The presence of non-protein constituents in the crude protein is relatively

unimportant because ruminants can usually utilise non-protein nitrogen. A number of formulae have been devised for calculating the digestibility of the crude protein or the amount of digestible crude protein in a sample, based on the level of crude protein; these estimations have been compared to the results obtained in feeding trials and have proved satisfactory.

Tropical grasslands have a low level of crude protein compared to temperate grasslands. These low levels can be attributed to an absence of legumes comparable to the clovers found in temperate grasslands, and to the lack of nitrogen in tropical soils. In many tropical soils there is a short period at the beginning of the rains when nitrogen is available, and the first flush of grass is consequently relatively rich in nitrogen; but then with an increase in dry matter as the result of growth, the percentage protein declines rapidly. At a medium stage of growth the crude protein content of many tropical grasslands is between 5 and 7% of the dry weight, but this falls to less than 3% later in the season. Frequent grazing or cutting will help to maintain a higher percentage of protein in a smaller total dry weight of herbage; while applications of nitrogenous fertilisers increase the yields of both the dry matter and crude protein. However they have less effect on the level of crude protein, apart from an initial improvement of short duration, than frequent grazing or cutting.

Although it has been shown by Elliot and Topps (1963) that indigenous African livestock are physiologically adapted to conserve nitrogen and to have a lower protein requirement for maintenance than temperate breeds, adequate levels of protein are required if stock are to be productive and are essential for young stock and for lactating animals.

The following formula devised by Milford and Minson (1965)

$$\text{Digestible crude protein} = 0.899 \text{ crude protein} - 3.25 \pm 0.84$$

expresses the relationship between crude protein and digestible crude protein, and is shown in Figure A1.

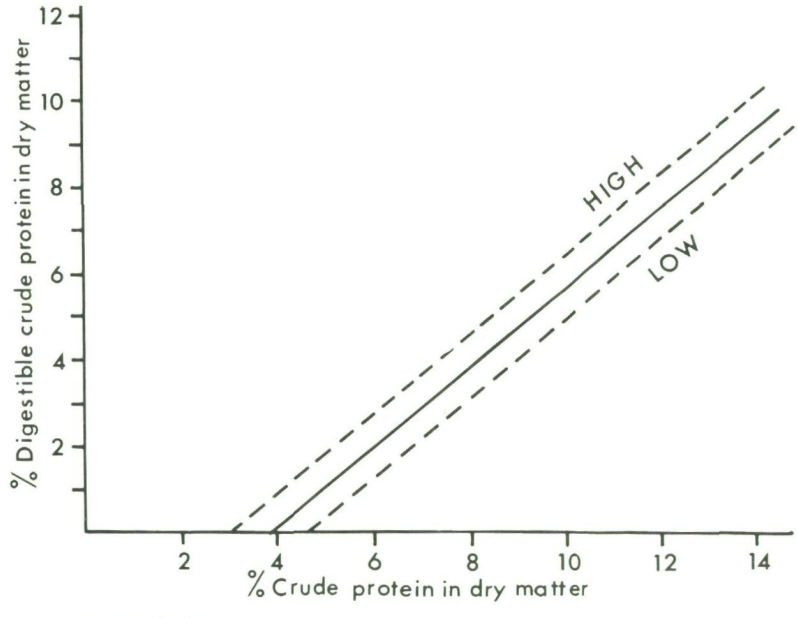

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FIGURE A1 The relationship between crude protein and digestible crude protein

It will be seen that the variation in digestible crude protein at any level of crude protein is 1.68% between the best and worst herbage samples, and at the low levels of crude protein common in the tropics this difference can be critical.

The lack of protein results in reduced ruminal activity and a slower movement of food through the gut; this in turn results in a lower intake of food, and combined with reduced ruminal activity this reduces the energy available to the animal, with a corresponding reduction in performance.

The ability of indigenous African cattle to utilise low protein diets depends on the adequacy of the diet as a source of energy and the energy value of a feeding stuff is indicated by the digestible organic matter or by the total digestible nutrients. Provided that energy is adequate, mature and semi-mature cattle will maintain weight on fodder with 2% digestible crude protein, and will gain weight on fodder containing 3% digestible crude protein.

To obtain 2% and 3% digestible crude protein the herbage must contain not less than 4.9% and 6.0% crude protein respectively.

Relatively few natural tropical herbage samples, apart from samples taken at the beginning of the rains will contain 6% or more crude protein; fortunately selective grazing enables the animal to obtain a more nutritious diet. Not only are the leafier and younger shoots of grass chosen, but the animal may also obtain protein from the leaves and fruits of trees.

Selective grazing is not possible when there is a scarcity of fodder, and it must always involve the animal in a greater expenditure of energy in obtaining its food. Where selective grazing is possible the composition of the animal's food may be 20-100% better than the results of herbage analysis suggest. Without elaborate trials it is not possible to assess this factor, although with careful observation the herdsman can produce a sample which approximates to what the animal has eaten. For example in Northern Nigeria when the crude protein content of the standing dry season herbage was 2-3%, the cattle secured a diet, a hand collected sample of which contained 5.7% crude protein. However this included pods and seeds of shrubs, and some of these may not have been digested by the animal (Blair Rains 1963). See also Dougall (1958).

NON-NITROGENOUS CONSTITUENTS

Although a very large number of distinct chemical substances are included in this category it may be broadly divided, although not on a chemical basis, into structural components: substances which form the cell walls and the strengthening elements within the plant, and non-structural components which are found within the cells.

STRUCTURAL COMPONENTS

The principal chemical substances of the structural components are cellulose and lignin, which together are normally described as crude fibre. Because the nature of these two substances is very different the crude fibre determination is one of the less satisfactory determinations in conventional analysis, but it probably has to be retained because of technical difficulties.

A large proportion of the cellulose is fermented in the rumen by micro-organisms and is utilised by the animal; the lignin is not only resistent to fermentation and enzyme decomposition, but its presence reduces the digestibility of both the cellulose and the cell contents.

NON-STRUCTURAL COMPONENTS

Among the large number of substances making up the non-structural components are fats, pigments, vitamins and a variety of carbohydrates.

FATS

The level of fat and similar substances determined in the traditional analysis of herbage samples is shown as ether extract. Although fat contributes to the digestible organic matter and energy, it is generally a minor constituent of tropical herbage.

The fat fraction includes carotene, the precursor of vitamin A and vitamin D. These substances are both essential for animal health. Vitamin D is necessary for the absorption of calcium and phosphate, and for the formation of bones, but a deficiency of vitamin D is unlikely to occur, where the animals eat sun-cured herbage. Carotene however may be deficient in the bleached dry-season herbage. The symptoms of a deficiency are night blindness, susceptibility to infections, and a variety of physiological disorders including long calving intervals, abortion and weak calves. Green herbage is a good source of carotene.

The animals' needs for carotene and vitamin A are very small when they are on a low plane of general nutrition and they are also able to store large amounts of these substances in the liver. Consequently no dietary carotene or vitamin A supplements will be needed, so long as the animals have sufficient reserves to meet their physiological needs. Serious deficiencies may be rectified by a dietary supplement, or by an injection of the vitamin and because of the animals' storage ability treatment may be on a monthly basis.

The carotene requirements of the animal are shown in Table A2.

TABLE A2 The carotene requirements of cattle

Class of animal	Daily requirements of carotene in mg per 100 lb* liveweight	
	Minimum	Optimum
Non-breeding stock	1.5	5
Breeding stock during the last 3 months of the gestation period, and lactating animals	20 20	30 30

*100 lb = 45.36 kg

If the carotene content of the herbage falls below 0.17 mg per 100 gm dry matter the minimum requirement of non-breeding stock will not be satisfied and the body reserves will be depleted. See Myburgh (1941) and Miller (1961a) for more details.

CARBOHYDRATES

Carbohydrates provide the animal with its energy, and a surplus is converted and stored in the body fat. The level of carbohydrates in a herbage sample is obtained by subtracting the total of the other constituents from one hundred. It may be shown as the nitrogen free extract, but it is both more usual and accurate to describe it as the residual carbohydrate due to the method of determination. Soluble carbohydrate refers to a small part of the total carbohydrate which is soluble in a mixture of alcohol and water.

The carbohydrates are an important part of the digestible organic matter, but cannot usefully be considered separately.

PUBLICATIONS OF THE LAND RESOURCES DIVISION

These publications have a restricted distribution and are not available to booksellers. The Division makes a report on each completed project. The report is published as a *Land Resource Study* or *Technical Bulletin* only with the consent of the government concerned. The abbreviated titles of the reports in the style of the 'World List of Scientific Periodicals' are *Land Resour. Stud.* and *Tech. Bull. Land Resour. Div. Dir. Overseas Surv.*

BAWDEN, M. G. and LANGDALE-BROWN, I.	1961	An aerial photographic reconnaissance of the present and possible land use in the Bamenda Area, Southern Cameroons.*
BAWDEN, M. G. and STOBBS, A. R.	1963	The land resources of Eastern Bechuanaland.
LANGDALE-BROWN, I. and SPOONER, R. J.	1963	The land use prospects of Northern Bechuanaland.
BAWDEN, M. G. (Ed.)	1965	Some soils of Northern Bechuanaland with a description of the main vegetation zones.

LAND RESOURCE STUDIES

SPOONER, R. J. and JENKIN, R. N.	1966	The development of the Lower Mgeta River Area of the United Republic of Tanzania. *Land Resource Study* No. 1.
BAWDEN, M. G. and TULEY, P.	1966	The land resources of Southern Sardauna and Southern Adamawa Provinces, Northern Nigeria. *Land Resource Study* No. 2.
BAWDEN, M. G. and CARROLL, D. M.	1968	The land resources of Lesotho. *Land Resource Study* No. 3.
JENKIN, R. N. and FOALE, M. A.	1968	An investigation of the coconut-growing potential of Christmas Island. Volume 1, The environment and the plantations. Volume 2, Appendixes. *Land Resource Study* No. 4.
BLAIR RAINS, A. and McKAY, A. D.	1968	The Northern State Lands, Botswana. *Land Resource Study* No. 5.
HILL, I. D.	1969	An assessment of the possibilities of oil palm cultivation in Western Division, The Gambia. *Land Resource Study* No. 6.
VERBOOM, W. C. and BRUNT, M. A.	1970	An ecological survey of Western Province, Zambia, with special reference to the fodder resources. Volume 1, The environment. Volume 2, The grasslands and their development. *Land Resource Study* No. 8.**

TECHNICAL BULLETINS

CARROLL, D. M. and BASCOMB, C. L.	1967	Notes on the soils of Lesotho. *Technical Bulletin* No. 1.
PIGGOTT, C. J.	1968	A soil survey of Seychelles. *Technical Bulletin* No. 2.

* Out of print.
**Land Resource Study No. 7 has not yet been published.

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