A WOODY VEGETATION SURVEY OF HWANGE NATIONAL PARK

A Report Prepared for the

Department of National Parks and Wild Life Management Zimbabwe

by

Catherine M.L. Rogers

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The Department of National Parks and Wild Life Management
P.O. Box 8365
Causeway
Harare
Zimbabwe

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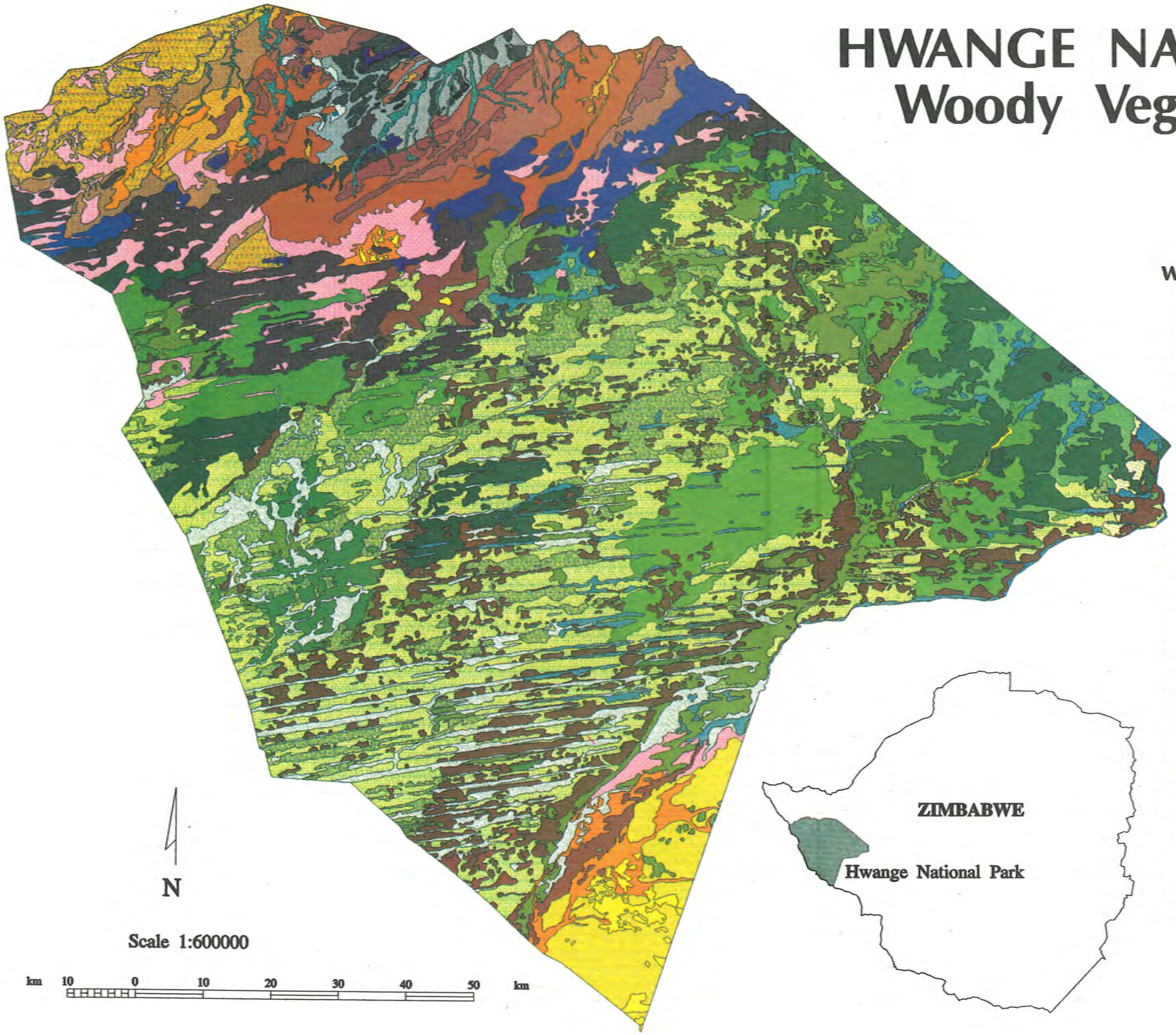
HWANGE NATIONAL PARK
Woody Vegetation Map



N

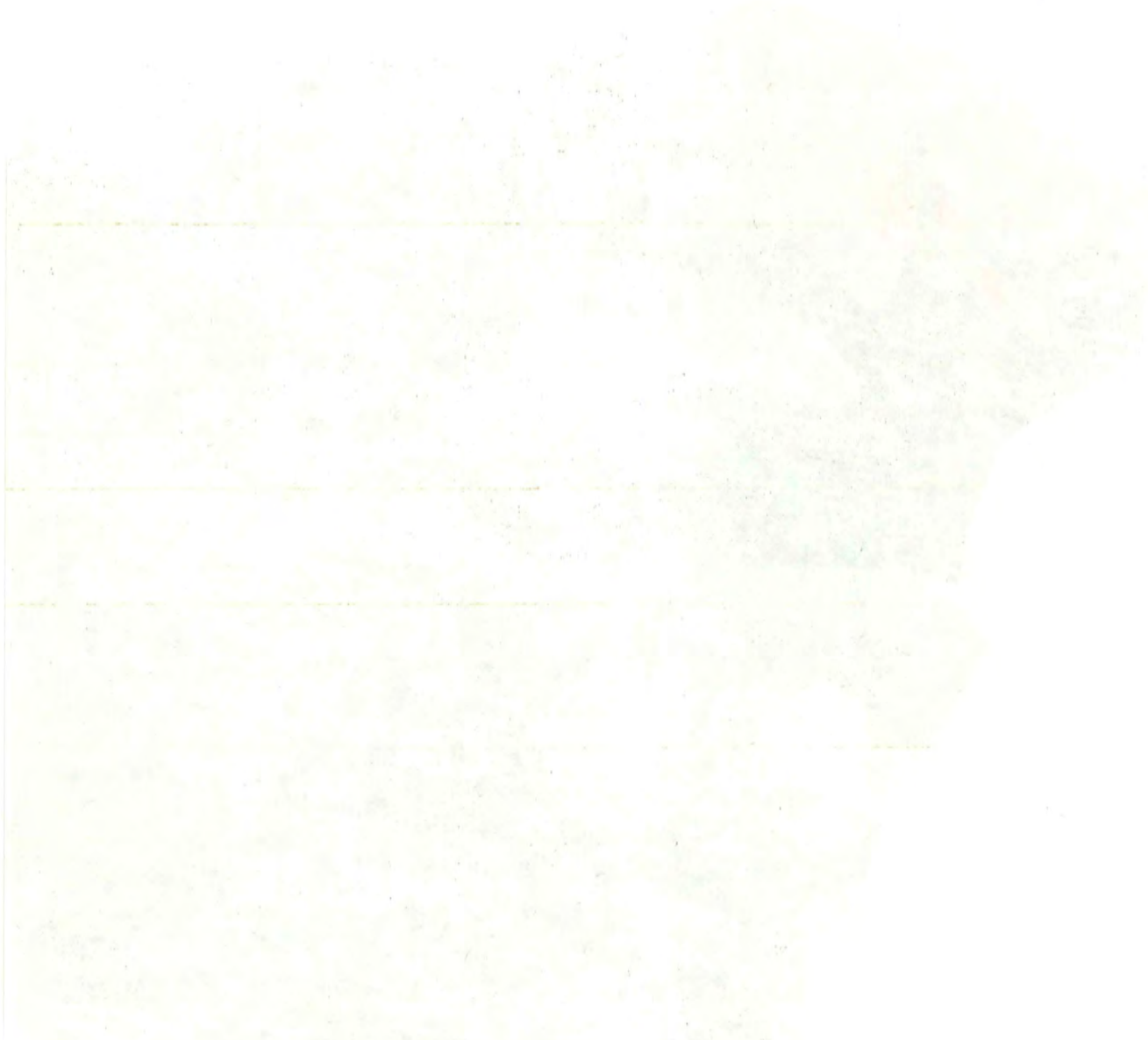
Scale 1:600000

km 10 0 10 20 30 40 50 km

LEGEND

Woody Vegetation Types

1 Combretum Boscia open scrub and thicket
2 Mopane Acacia woodland
3 Mixed woodland on scree slopes
4 Kopje woodland and thicket
5 Mopane wooded bushland
6 Combretum Baphia thicket
7 Mopane Combretum woodland
8 Mopane Terminalia prunioides woodland
9 Mopane Combretum thicket
10 Riverine woodland and thicket
11 Mopane grassland to woodland
12 Mopane bushed grassland to bushland
13 Mopane Combretum bushland
14 Mopane bushland
16 Stunted Mopane woodland
17 Mopane woodland bushland mosaic
18 Acacia bushed grassland
19 Combretum bushed grassland
20 Acacia Mundulea bushland
21 Terminalia Lonchocarpus bushland
22 Mopane Combretum wooded bushland
23 Baikiaea woodland thicket
24 Terminalia Acacia bushland
25 Terminalia Baikiaea bushland
26 Burkea bushland and woodland
27 Baikiaea Guibourtia woodland
28 Baikiaea Croton woodland
29 Baikiaea woodland and thicket
30 Burkea Terminalia bushland
31 Grassland
32 Mandavu Dam



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Thank you very much to GTZ (German Technical Co-operation) who funded a trip to Germany to visit the Environmental Systems Research Institute in Kranzberg, and to see the functional Geographic Information System (GIS) set up in Berchtesgaden National Park. Thanks to Michael Sittard of ESRI for all your help and hospitality.

Thank you very much Steve Hinde of Geographic Information Management Systems (GIMS) in Johannesburg, who facilitated the scanning of five out of six of the vegetation maps. Steve also kindly printed one of the versions of the colour vegetation map. Thanks to Jochim Doerfel, Dr. Kaufman and Michael Berger of the National Remote Sensing Facility (NRSF, Harare) for your help which came in many forms including the use of their facilities (the Zoom Transfer Scope, computer, digitizing tablet etc.). Thanks to Kingray Gowera (Systron and NRSF) for your technical advice. Thanks to Jonathan Timberlake who read the manuscript several times and provided valuable criticism and advice.

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Thank you Bob Drummond for amending and updating the woody species list.

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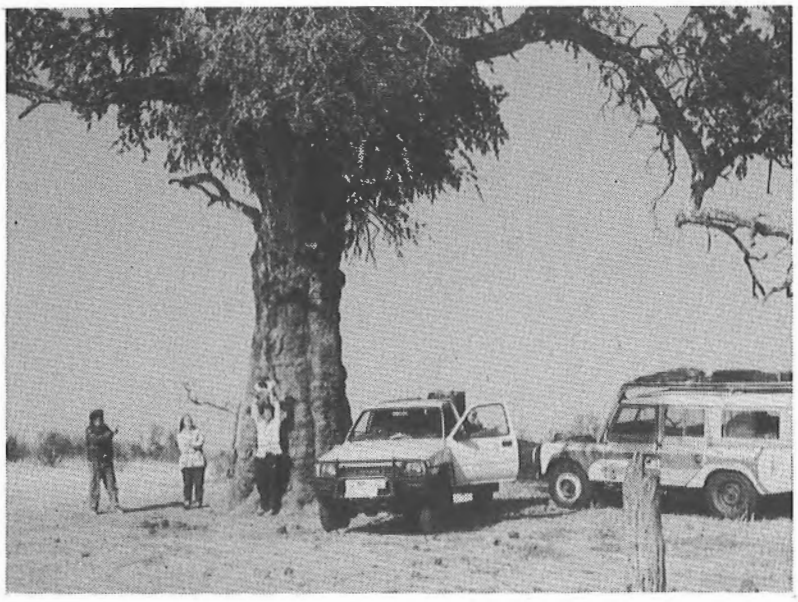
SUMMARY

The objective of the survey was to describe the distribution, structure and floristic composition of the woody communities in the Park. Panchromatic aerial photographs were used in the stratification of homogeneous vegetation units. Six hundred samples of the units were classified into thirty types of woody vegetation, in eleven groups of types. Five of the groups (sixteen types) of vegetation were associated with non-Kalahari sand (mostly shallow soil) environments on Basalt, Basement Complex and Karoo sediments. Six of the groups (fourteen types) of vegetation were located on the Kalahari sands. The groups and types were described in terms of their location, woody species composition and the range of environmental conditions (geology, soil texture and topography) under which they occurred. The inter-relationship of woody vegetation types, and the distribution of types in terms of environmental conditions, were described. The vegetation types of this survey were also briefly compared with woody vegetation types described in former surveys. There were close similarities, especially between the vegetation types described in this survey and those types described in the survey conducted by Childes and Walker (1987) on Kalahari sand communities. The vegetation map was digitized onto a computer using PC ARC/INFO for use in a Geographic Information System (GIS). Besides the vegetation type and group, information about physiognomy and associated geology was added to the map.



The largest Leadwood (*Combretum imberbe*) in Hwange National Park, at Dadada Pan.

INTRODUCTION

Prior to this survey a comprehensive map of the woody vegetation types of Hwange National Park did not exist. The objective of the vegetation survey was to provide a description of the distribution, structure and floristic composition of the woody vegetation of Hwange National Park as a basis for Park management and research. This survey is part of an on-going exercise to map the vegetation of the Parks and Wild Life Estate in Zimbabwe (National Parks Research Branch Policy, 1992). Vegetation maps would be useful in Park planning, in research and as a background for management of fires and elephant, for example. The digital Hwange National Park vegetation map will be used in a Geographic Information System (GIS) for the monitoring of vegetation change, and for research into the relationship between various factors (such as elephant distribution and density, fire history patterns etc.) and vegetation changes.

The vegetation of the whole of the Hwange National Park has not, to date, been mapped at this scale (1: 100 000) and sampling intensity (4 samples per 25 km^2 or a 4% sample of the Park), being last mapped by Wiltshire (1964), who surveyed the harvestable timber of the Kalahari sand areas. Robinson (1974) described the vegetation of the Robins area using aerial photography and "ground checking where possible". Walker and Rushworth (1975) used classification and ordination techniques to describe the Kalahari sand communities in the Main Camp sub-region. Childes (1984) and Childes and Walker (1987) further studied the dynamics of some of the woody communities in the latter area. A vegetation survey of the Sinamatella area was carried out by Tafangenyasha (1988) and his 90 samples were included in the data set of this survey. The results of these surveys are compared with this survey in the Discussion section.

This survey examined only the woody vegetation. The species composition and structure of woody vegetation changes relatively slowly and can be easily viewed on medium altitude panchromatic aerial photographs. Aerial photographs, and not satellite imagery, was used in the stratification of types, as it is not possible to see physiognomy or structure on satellite imagery at present. Woody vegetation is more likely to reflect the long term environmental conditions than herbaceous vegetation, which is more sensitive to small oscillations in environmental factors, such as rainfall and temperature, determining growth.

Study Area

Hwange National Park is the largest national park in Zimbabwe, situated in the north-west of the country, with an area of about 14 600 square kilometres (Fig. 1).

It is situated between latitudes 18°30' and 19°50' south and longitudes 25°45' and 27°30' east. Hwange is bounded by Botswana to the west, Tjolotjo Communal Land to the south-east, Forestry Commission land to the east and Matetsi Safari Area to the north.

Geology

Four broad geological types are found in Hwange National Park (Fig. 2).

Kalahari sands

These aeolian sands cover a large percentage of the total area of the Park from Main Camp to the Botswana border (Fig. 2). In the central and south west of the Kalahari sands there are fossil sand dunes which were formed about 18 000 to 13 000 years ago (Thomas, 1983) by a wind blowing from the east and south east (Flint and Bond, 1968; Thomas, 1983). An ensuing wet period saw the formation of streams which eroded the sands in the north of the Park and in the Dzivanini area (Flint and Bond, 1968). The Park is on the eastern edge of Kalahari sand deposits which cover most of Botswana and extend into Zambia, Namibia, Angola and South Africa. Two-thirds of the Park is covered by these aeolian sands which average 60m in depth but may become 150m deep in the central part of the Park (Broderick, 1985). The existence of an impervious hard pan layer at varying depths in the soil is a significant edaphic factor.

Batoka basalt

Batoka basalts occur as horizontal lavas divided by a sandstone layer into a lower and upper part. They are of Jurassic age and outcrop on the Robins and Dzivanini areas. In the Dzivanini area Batoka basalt underlies the shallow Kalahari sands which vary in depth from 1.5m (Harrison, 1978) to 50m (Broderick, 1984).

Karoo sediments

The Madumabisa mudstones which are exposed in the Sinamatella area are overlain unconformably by Escarpment Grits. These grits form the hard caps of the steep sided escarpments so typical of the area. Below the Madumabisa mudstones lie the Upper and Lower carbonaceous mudstones and Hwange sandstones. The geology of this area is complex and has been described by Watson (1960).

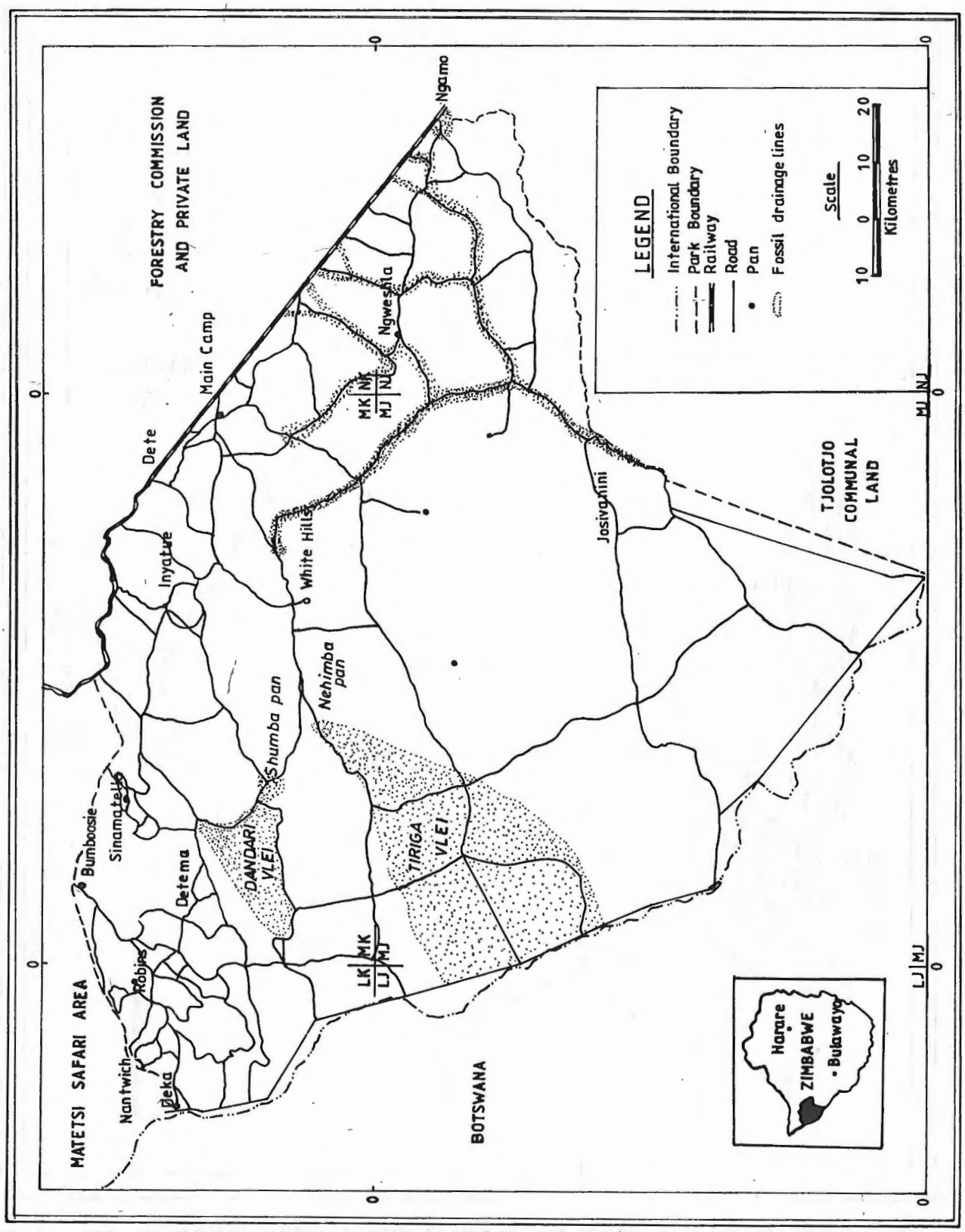


Fig.1. MAP OF HWANGE NATIONAL PARK SHOWING THE THREE MAIN CAMPS, ROADS, SOME OF THE PUMPED PANS AND FOSSIL DRAINAGE LINES

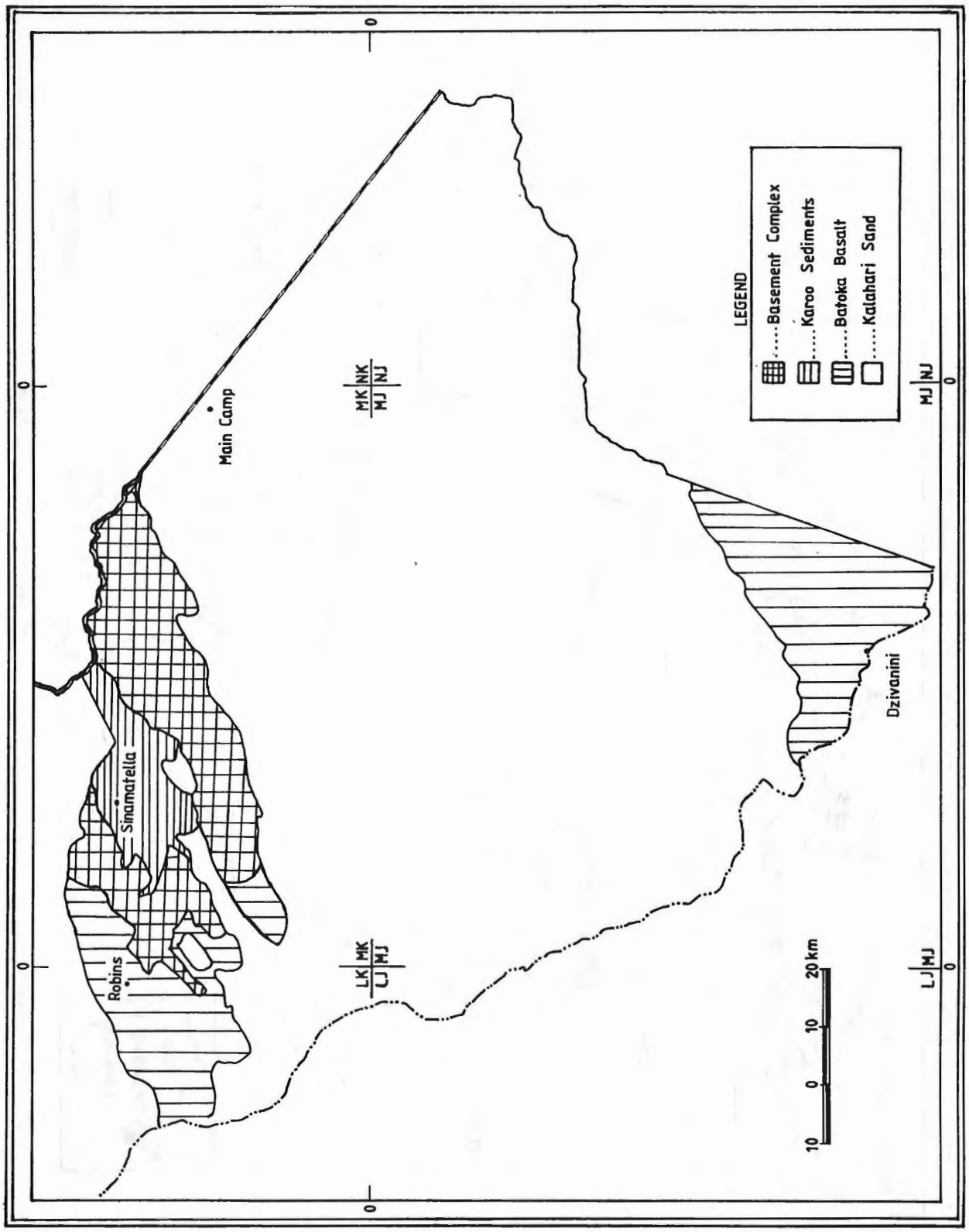


Fig.2. MAP SHOWING THE MAIN GEOLOGICAL TYPES IN HWANGE NATIONAL PARK

Pre-Cambrian rocks

The Pre-Cambrian rocks are "supra-chrystal belts separated by expanses of granitic gneiss" (Lockett, 1979). The "supra-chrystal belts" are the Malaputese, Inyantue and Tshontanda Formations. The two latter formations are composed of various schists, gneisses and quartzite, and the Malaputese Formation of quartzite and metapelites and pink paragneiss. Watson (1960) described the Sijarira Series which outcrops west of Sinamatella, as composed mainly of hard, flaggy red-brown quartzitic sandstones, overlying coarse white sandstones. In the Nantwich area there is an inlier of the Basement Complex which Bond (1953) described as 'flaggy micaceous schists' (Fig. 2).

Topography and Soils

Hwange is essentially flat, becoming more broken in the north, with an altitude of about 1000m. The Park lies astride the watershed which divides the Zambezi drainage basin to the north from the Makgadikgadi basin to the south. The northern facing slopes are drained by the Deka, Lukosi and some minor tributaries of the Gwaai River.

Drainage of the southern watershed is limited to fossil drainage lines with the exception of the Gwabazabuya and Dzivanini rivers which are seasonal streams flowing into the Nata River in the extreme south of the Park. Other features of the southern watershed include the remnants of long (up to 25km) east - west oriented sand dunes, and the extensive Dzivanini mud flats, which are seasonally inundated.

The soils reflect the underlying geology. In the Kalahari region soils are deep, unstructured fine grained regosols. Redistribution of the original aeolian deposits through the agents of wind and water have led to the accumulation of some clays and silts in the inter-dune troughs and drainage lines, and of calcrete in fossil lake basins. A variety of sandy and sandy clay soils of various depths occurs along the contact between the Kalahari sands and other geological types, but these have not been investigated in any detail. The topography here is essentially flat, to gently undulating where fossil dunes are found in the south central areas.

In basalt areas red clay lithosols predominate with limited areas of moderately deep to shallow self churning vertisols in drainage lines and some upland situations. These areas are undulating, rocky terrain dissected by many small streams. There are extensive flat areas of

deep, black self-churning clays derived from basalt in certain areas in the Robins sub-region, Dandari vlei and in the Dzivanini area (Fig. 2).

Soils on the Karoo sediments are usually shallow clays with limited areas of vertisols and alluvium along the major water courses. The topography is generally flat to undulating and dissected by streams and rivers. Escarpments, such as the one on which Sinamatella Camp is situated, arise from these flat areas and are capped by a layer of sandstone.

Soils derived from Basement Complex geology are predominantly sandy lithosols with some deeper pockets of siallitic soils. The terrain is rocky with outcrops of castle kopjes, and basins of sandy clay soils on the flat areas in between.

Climate

Average annual rainfall is 620 mm but varies across the Park from 570 mm at Sinamatella to 652 mm at Main Camp. There is an apparent decrease in rainfall toward the Botswana border and the south of the Park. Annual rainfall has varied from 335,6 mm to 1159,8 mm at Main Camp between 1918 and 1990. Mean monthly maximum temperatures recorded at Main Camp range from 24°C in June to 33°C in October. Frost may occur during the months May to August with ground minima of -5°C or lower. Black frosts (lower than -7° C) occur approximately once every five years.

Caution

Only the woody species of Hwange National Park were surveyed for the production of this map and report. Not every woody species was encountered during the survey and not all woody species encountered are presented in the phytosociological table (Table 2). There is a comprehensive herbarium at Main Camp and with it a complete species list of herbaceous, grass and woody species so far recorded from within the Park.

METHODS

The Braun-Blanquet approach to vegetation classification was used in this survey. According to Whittaker (1975), this approach is based on three assumptions:

i) that the classification and interpretation of communities can be based on floristic composition,

ii) that "some species in a community give a more sensitive expression of relationships than others", and

iii) that these "diagnostic (indicator) species will be used to organise communities into a hierarchical classification." (Whittaker, 1975).

The way in which communities (called types in this survey) are arranged hierarchically, is artificial and is not justified by theory but by its usefulness in allowing ecologists to conceptualise complex vegetation associations and patterns.

Stratification and Sampling

Medium altitude panchromatic aerial photography (scale 1:80 000, from 1983) was used in the stratification. Areas with homogeneous texture, tone and pattern, topography and geology were delimited with a chinagraph pencil on the aerial photographs. Woodland (with roughly over 20% canopy cover of trees) was separated from bushland, thicket, woodland thicket, bushed grassland and grassland. Thus the stratification of the aerial photographs was based partly on landscape (topography), and partly on woody cover (texture, tone and pattern).

Samples were placed in each of these homogeneous strata (or vegetation units) along the extensive road and firebreak network (Fig. 1). A minimum of 10 samples were sited in each stratum with more samples taken in geographically extensive strata.

The placement of the samples was subjective for a number of reasons. The amount of time was limited, and so sampling was concentrated along the roads and placement of samples in the field is more accurate close to a road in flat terrain. It was also considered more effective to spread the samples throughout the full extent of the strata and to try and cover as much of the variation as possible (Craig, Martin and Mhlangu, 1984).

Sampling was conducted through the months of January to May when the woody vegetation was still in leaf. From the aerial photographs the sample sites were located and an area of approximately one hectare was surveyed and a list of the woody species made. Instead of

estimating cover abundance for each species in each height stratum, a note was made as to whether the species occurred as a sub-shrub (<1m), a shrub (1-3m) or a tree (>3m) (Fig. 3). The dominant or important species were noted in the physiognomic description of the sample.

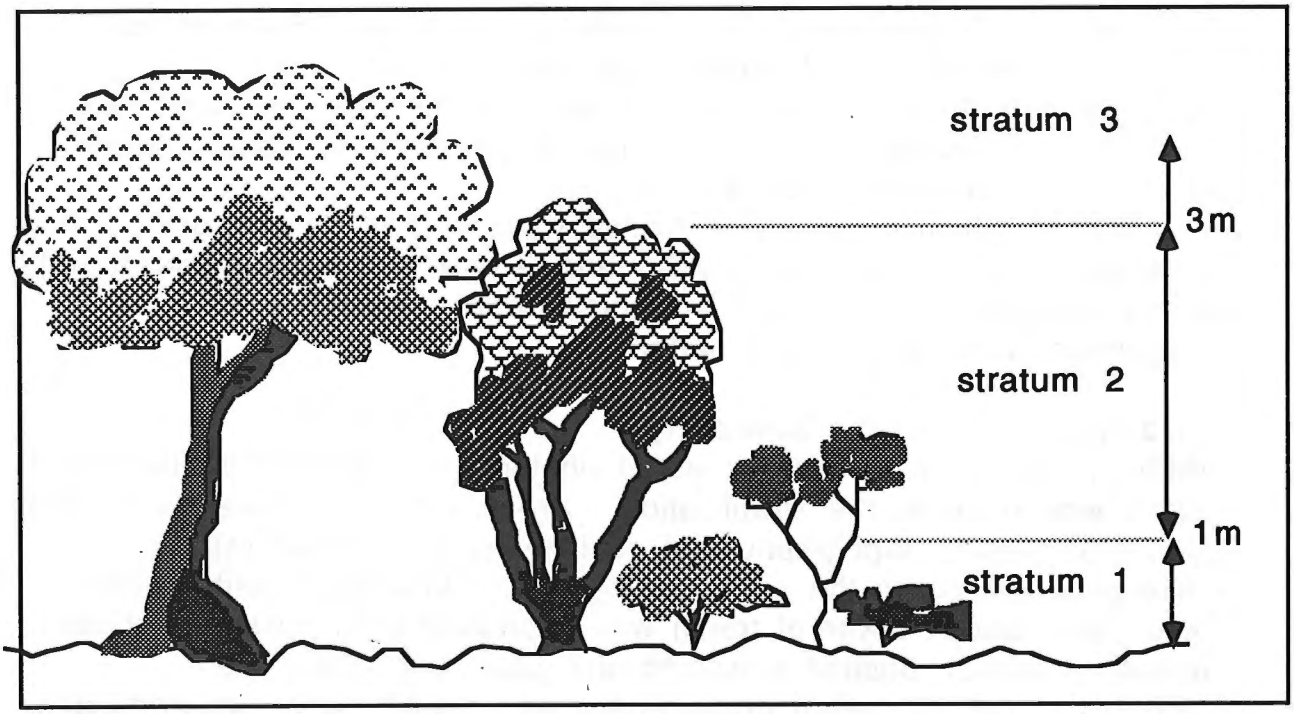


Fig. 3. The three height strata in which the presence or absence of woody species was noted during sampling.

Percent cover of the community in each height stratum (Fig. 3) was estimated and the dominant species were noted. A description of the physiognomic type, adapted from Pratt, Greenway and Gwynne (1966), was given (Table 1).

Environmental parameters including geological type, topography, rockiness, the surface soil texture, and colour, were described. Locations were described and a grid reference noted. Each sample took 15 minutes to half an hour to complete, with details recorded on the sample sheet (Appendix 1). The sample sheets (600) are filed at Hwange Main Camp.

Table 1. Physiognomic classification of the vegetation from field survey sheets (adapted from Pratt, Greenway and Gwynne, 1966)

Scrub scattered shrubs (< 50%) and trees (< 20%); no grazing value
Bushland shrubs < 3m; occasional emergents; bush canopy cover ≥ 20%; some grazing value
Thicket very closed; no grazing value
Woodland trees >3m in height; open or continuous but not thickly interlaced canopy; shrubs interspersed canopy cover > 20% (Grasses and herbs may or may not dominate ground cover)
Woodland thicket very closed bushland with tree canopy cover > 20%
Wooded bushland (own class) bushland as above with tree canopy cover ≤ 20%
Bushed grassland grassland and scattered/grouped shrubs and trees; canopy cover < 20%
Grassland dominated by grass and occasionally other herbs scattered trees and shrubs with canopy cover < 2%

Data Analysis and Map Production

These data were entered into a sample by species matrix and weighted (ie. as 1, 2 or 3) by size class for classification by the computer programme TWINSPAN (Hill, 1979). Thus trees (given a weighting of 3) were more heavily weighted than shrubs (given a weighting of 2 or 1). A classification of the data was also produced using only presence/absence of species (no weightings), but was found to be very similar to the classification in which species were weighted according to their physiognomy or size class. The similarity of these classifications can be assessed by comparing the classification of samples in Appendix 2 which are shown in the first two columns with headings 'old and 'new' - 'old' being the classification based on

presence/absence and new being the classification of stands in which species were weighted according to their size class.

TWINSPAN stands for Two-Way Indicator Species Analysis. It is a divisive hierarchical vegetation classification technique based on an ecological model (Gauss' response model) (Loth, 1990). It ordinates the samples first and divides them into two groups. The species which are associated with each side of the division are identified and an ordination constructed based on the differential species. Thus both samples and species are arranged according to their similarity to each other. TWINSPAN can be described as a "dichotomized ordination analysis" (Hill, 1979).

TWINSPAN compares the species composition of each sample with every other sample and places similar samples together in a sample by species matrix (phytosociological table). The programme is able to identify indicator species which are important in the differentiation of one group of samples (or vegetation type) from another.

A print-out of the phytosociological table and classification information was obtained from the TWINSPAN programme. The order of the species and samples in the table produced was a direct result of the TWINSPAN classification of the raw data (a sample by species matrix). In addition another table of environmental factors was printed out in the order of the TWINSPAN classification of the samples (Appendix 2). Thus, the environmental data (geology, soil texture and colour, percent woody plant cover at <1m, 1-3m and >3m, physiognomic description and the two most common or dominant species) were listed for each sample. In this way the groupings of environmental data according to vegetation type could easily be described.

Vegetation boundaries were transcribed from the 1:80 000 aerial photographs onto the 1:100 000 scale base maps using a Zoom Transfer Scope. The samples were located on the transcribed vegetation map. Each sample, which was classified within a vegetation type, was then used to name the stratum within which it occurred. Thus strata, which were sampled, were given a vegetation type name and number according to the sample which was placed within it. Strata without samples were labelled by inference according to their similarity to sampled strata in terms of tone, texture and pattern of the vegetation on the aerial photographs. If two blocks of vegetation, which were hypothesized to be two different types of vegetation, were found through sampling to be the same, then the line separating the two

blocks was erased. In a few instances what was thought to be one type of vegetation was classified as two vegetation types, and a boundary was drawn separating the two on the aerial photographs and transferred to the vegetation map.

Vegetation boundaries were then checked with false colour Thematic Mapper satellite image transparencies projected onto the map. The broad spectrum of colours and the large areas which could be registered with the satellite image were useful especially in strata which were identified by inference. Some boundaries were thus redrawn or realigned accordingly.

Five of the six mylar sheets on which the vegetation map was drawn in black ink, were scanned into digital format in Johannesburg, and the sixth was digitized by hand into the Hwange National Park computer using PC ARC/INFO. Much time was spent editing these digital maps, making sure lines were correct, removing kinks which were incorporated during the scanning process, and making sure the intersections of lines were good. 'Slivers' or very small polygons had to be removed (also a result of scanning). Each polygon was then labelled and given a unique number. The map was transformed and projected into Universal Transverse Mercator (UTM) coordinates from digitizer centimetres.

The vegetation type labels were then applied to each polygon of the map (ie. vegetation type numbers 1 to 30, type 31 which was grassland and type 32 which was the Mandavu Dam polygon). The map was then checked again for polygon errors and label errors. Each time edit changes were made, the coverage had to be CLEANed or BUILDed to restore polygon topology (which is the term used to describe the spatial relationship of one polygon to another). This was a very time consuming part of the exercise as to CLEAN can take up to 5 or 6 hours to complete on the computer, if all goes well.

The completed digital map was then taken to the USAID FEWS office where a colour print of the map at a scale of about 1:250 000 was produced. This was done using ARCVIEW and a special A3 colour printer.

Information on the structure and geology associated with each type has also been entered as items into the PAT (polygon attribute table), so that a map of the physiognomic or geologic types can be derived from the vegetation map. The area of each polygon is given as an item in the

PAT so that it is easy to work out the extent of each vegetation type, structural or geological type in the Park.

Once a map is digitized and topology built, all polygons are automatically measured and the areas displayed under an item called AREA in the polygon attribute (PAT) file. The PAT is automatically created for maps displaying polygons.

In order to get the total area for each vegetation type, the areas of each polygon of each type were added together. This was done in the TABLES module by using the STATISTICS function to tabulate the total areas, numbers of polygons and means of areas. In order to get these statistics for different physiognomic types of vegetation, DISSOLVE was performed in ARC on the item STRUCT which contains the number corresponding to physiognomy of each vegetation type. From the new coverage (ARC/INFO term for map) the STATISTICS function could be run in TABLES, and the areas of each physiognomic type obtained.

Photographs of vegetation types

All the woody vegetation types were photographed to aid in their description. There is considerable variability within each vegetation type, and the relatively small number of photographs obtained cannot show the total species composition and structural variation within each type.

RESULTS

The results obtained in the survey are listed below. They are in the form of:

a vegetation map,
descriptions of vegetation types and groups,
a phytosociological table,
dendrograms,
profiles of topography and vegetation types,
photographs, and
summary tables.

These maps, tables, photographs and profile figures etc. are referred to in the descriptions of each vegetation type which follow under two main sub-headings:

Non-Kalahari sand vegetation types and
Kalahari sand vegetation types.

It should be remembered that this is a descriptive survey and not a quantitative assessment of the vegetation. All of the numerical data in the results are descriptive (category) data, and not quantitative (integer) data.

Vegetation Map

The vegetation map shows the distribution of the 30 types described below. The colour scheme of the vegetation groups on the map broadly represents the geology upon which they are found such that :

red and light brown - Basement Complex
yellow ochre - Basalt
dark brown and purple - ecotone areas
grey - Karoo sediments
greens - Kalahari sand

The most representative geology of a vegetation type or group was taken and each stratum coloured accordingly. The significance of the colours is that red and light brown are warm colours symbolising the origin of the Basement Complex formed under conditions of heat and pressure . The grey colours represent the grey clays of the Madumabisa mudstones. The yellow ochre for basalt represents the colour of the grasses widespread in basalt areas. The greens to dark brown indicate the dense woodland and bushland typical of the Kalahari sands.

The map is an integration of the landscape and woody cover interpretation of the aerial photographs, and of the floristic classification of woody species for 600 samples representing each of the units delimited during the stratification.

Descriptions of vegetation groups and types

Each vegetation group (A to K) and type (1 to 30) is described according to the order in which they appeared in the TWINSPAN phytosociological table (Table 2). There are some advantages to this: it is easy to follow the transition in species composition, and the hierarchical structure in which the types and groups have been classified as they are both given according to the phytosociological table. A disadvantage may be that the classification is not an ecological one. However, although the TWINSPAN programme does not take environmental factors into account, the species themselves are 'indicators' of environmental conditions (see discussion and Appendix 2), such that species' assemblages tend to be associated with specific geological strata, soil conditions and moisture regimes, etc.

The names of each group and type may seem long in some cases. This is often so in order to achieve consistency in the nomenclature, which is described below.

In the description of the types, the distribution and range in physiognomy are given. If the type is associated with a specific topography then this is described with reference to the profile figures. The dominant or most common species are then given, followed by the indicator and differential species. A brief description of the surface soil texture and sometimes colour is also given.

There is a short description of each of the groups A to K, giving the general location and association of each type within the group to geology. The main species which are common and which differentiate the group from other groups are given. The species diversity and any other features of interest are given.

Photographs of vegetation types

There are photographs of each woody vegetation type with the type descriptions. Each vegetation type is variable, making it difficult to represent the structure and species composition of any type with only one photograph. However, the photographs were taken of areas which were considered to be most typical and are intended only as an aid to the visualisation of each vegetation type. It would be more useful to concentrate on the general structure of the type in the photograph rather than be able to identify woody species.

Phytosociological table

The phytosociological table (Table 2) is greatly condensed and shows only the presence of most of the common and differential species which occur in each of the 30 types. The table is a summary of the TWINSPAN output with less common species (those species with less than four occurrences throughout) omitted. Thus out of about three hundred species only 106 species are given in the phytosociological table presented in this report. Abbreviations of the species names are used in the table. Their full names are given in Appendix 2.

The vegetation type numbers are represented by 1 to 30 across the top of the table and the number of samples representing each type are given immediately below. The total number of species are also given for each type. The numbers given for species/type in the body of the table are the average of the percent presence (and not weighted according to the physiognomy) of the species in all samples representing the type. For example, *Julbernardia globiflora* was present in 15 of the 24 samples in type 5, and was thus present in 62% of the total number of samples (Table 2).

In the table the species occurring in over 50% of the samples within a type are given in bold lettering, to give an initial impression of the main trend in the change in species composition with vegetation type and group.

Dendrograms

TWINSPAN is a divisive hierarchical classification technique. Thus a dendrogram can show clearly how the samples of vegetation are divided up during classification. Figs. 4, 5, 8, 9 and 13 show how the vegetation groups and types were progressively separated from each other.

Fig. 4 is an overview of the whole classification to group level. The main geological type associated with each group is given. Figs. 5 and 8 give a detailed break down of the classification of the non-Kalahari sand vegetation while Figs. 9 and 13 show the classification of Kalahari sand vegetation types. The indicator species used by TWINSPAN are listed next to each division, which is represented by a circled number. Vegetation groups are identified by the letters A to K and vegetation types by the numbers 1 to 30.

Table 2. Phytosociological table of vegetation types and selected species.

Type Nos.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
No. Stands	14	5	7	19	24	15	20	14	15	13	30	35	39	23	7	14	9	38	30	25	31	8	22	12	33	24	16	12	24	22
Species	80	60	81	156	109	130	119	99	104	124	94	134	97	91	53	26	76	84	107	74	66	74	57	53	60	55	56	59	99	71
Julb glob				10	**62**	29						9	7																4	
Afze quan			14	**67**	43	4						6	6	4															8	
Brid moll			28	**51**	6				12	14																				
Schr tric	21		14	**73**	49	**55**	25	14	25	14	3	3										13							16	
Stry mada	**63**		28	**77**	**74**	**60**	5	14	32	7	3	9	4						3										12	
Cant glau	35	**60**	**85**	**52**	12	34	25	35	**52**	30		9		4															4	
Comb elae	**64**	40	**85**	31	47	**80**	**64**	**92**	22	16	14		8			22		3			3	25								
Dios quil	**99**	**99**	**84**	**89**	**93**	**56**	**90**	**85**	**99**	**76**	10	6	7	34	16														8	
Ster afri		20	71	**52**	6	4	10	7	33		3		5	4																
Stry pota		40	14	**52**	24	30	35	7	33	**60**	3		4																	
Xero stuh	21	20		**57**	37	**55**	**65**	7	**52**	14	7	3	4						3	4		13						8		
Abru schi	**64**			10	6	8	5		6																					
Bosc an.co.	**77**		42	25			10	7	6													13								
Cant pseu	**92**		28	35	6	12	10	7	12																				4	
Comm kari	7		**70**	**61**		4	20	**56**	6	7	3	6	9	12																
Comm marl			**57**	26			5																							
Lonc erio	**63**			15			5																							
Pter luce	**63**	20	42	10		4	10	7	6		3																			
Comb moss	49	**80**	**56**	36		30	**50**	28	**52**	**91**	41	9	5	4	16		22	2	6	4	6							8	4	
Term prun	7	**80**	28	5	6		10	**85**	37	16	10	9	4	**66**			4		8	8										4
Gard resi	14	40	**56**	20		17	15	**56**	12		3	11		8	16		11	7	6			13	4							
Mark zanz	49	20	**98**	**62**	30	47	**55**	**56**	**73**	15	10	6		4	16		22	2				25	18		3			8	28	
Brac boeh				20	42	17						20	5																12	
Carp pube		20	14	**78**	**93**	47	**65**	**63**	**72**	14	3	9	**66**	**64**	32				3										8	
Comm moll			42	**51**	**62**	**51**	45	7	32	7	3	26	26	38	16												6		24	
Elep goet		20	42	**56**	18		30	35				3	20	29		6	11													
Eryt zamb		**80**		**83**	**93**	**58**	**80**	**92**	**92**	43	17	**54**	**57**	**68**	16				3		3	25						8	31	
Kirk acum	7		**56**	**62**	**50**	**77**	**50**	28	6			29	**50**	21								13							33	4
Lann disc	7			41	**55**	43	25	14		7		40	33	8						4		13							33	4
Cass abbr	35			**67**	**67**	42	**80**	49	32	30	28	46	**72**	47	16		11		13			13							37	4
Ciss corn		20	28	**68**	**68**	**65**	**80**	**77**	6	22	14	**60**	**63**	**64**	33		11					25							32	
Scle birr				**51**	**55**	30	**55**	7	13	14	7	37	**63**	17	16		22				3	13							8	
Vite pete			28	20		13	10	49	32	15	3		17	**56**	16															
Acac robu	7	**80**		15	24	21	40	21	45	37	24	17	9	17	32	12			3			13								
Berc disc			14	10			5		**59**	30	14	9		4	16		11		3			13								
Vepr zamb				5			5	**50**			3			4	**66**	6														

Type Nos.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Comb aden				10		12	10			15		43	35	8				2	3											
Term rand				5			5	28		15	7	20	**73**	**56**					3											
Term stuh			14	5				**56**				9	35	**51**	49															
Acac nigr		20	28	**66**	**61**	29	**65**	**63**	46	45	**62**	43	**78**	**73**	16	26	**55**	2	16			13						4	4
Pter rotu				**78**	**87**	**90**	**55**	28	6	7	7	**69**	**94**	**56**			33		12			13					6		33	
Comm moss	7		28	**93**	**99**	**85**	**75**	**63**	32	7	7	**66**	**83**	**60**	33		33	2	13	8	6	25	4		3	12	6	33	**86**	4
Term sten				36	**55**	29		14		7	1	46	38	8					9							12	12	8	4	4
Allo afri		20	14	36	24	**52**	40	21	39	**60**	24	37	32	16				5	13	8		25			3	4		8	20	4
Colo mopa	**56**	**99**	**99**	**99**	**93**	**64**	**99**	**99**	**78**	**83**	**83**	**97**	**99**	**95**	**99**	**99**	**88**	**72**	38	44	10	**88**	4						16	9
Comb apic	**56**	20	14	**94**	**86**	**99**	**90**	**56**	**59**	45	24	**77**	**93**	**85**		12	**66**	31	49	16	10	**50**		8				8	**66**	40
Cross febr	21			25	49	21			6	7	3	**63**	7		16			2	10						3				12	22
Dalb mela			28	**68**	**50**	**64**	**70**	**64**	46	37	34	**89**	**93**	**73**	**83**	46	**66**	49	49	32	19	**99**							49	9
Eucl divi	7	40	14	36	12	43	40	28	39	**53**	38	**71**	38	21	16		33	2	36	8	13	25			3				24	44
Catu spin	14			**68**	**93**	**64**	15	14		23	3	**74**	35	13	16		11	7	13								6		**74**	9
Acac tort				5		8		7	13	**53**	21	11	5				22	2	9		3									
Albi harv					6	21	20	14	6	23	21	29	2	13	16		22	7	20	4									9	
Bolu spec											21	46	22	8				2	13										4	
Lonc capa	7	40		15	6	33	25	14	39	**99**	**90**	40	12	21			**88**	15	**56**			13			3			4	35	
Flue viro	7	20		10		34	20		33	**99**	41	40	7	25	32		33	2	19	4	6						6	8	4	4
Comb imbe		20		5		8	10	7	46	**91**	**86**	**69**	**55**	**52**			44	38	**89**	4	6			8						**67**
Dios mesp	7	40		20	12		5			**91**	14	20	17	12			11		39									8	8	30
Comb cela	**70**	**60**	**56**	10		4		14	19										3	4	3	38	**77**		3			8		
Comm afri		40	14	21	12	25	**60**	**92**	12		10	**54**	**68**	**60**	**99**	32	**99**	**86**	20	**88**	**58**	**63**	26	41	15	8		8	20	4
Comm pyra		40	14	36	49	**56**	**65**	**96**	32	23	21	49	**76**	**77**	49	32	**66**	**59**	36	**80**	29	**50**	22	8			6	8	49	13
Grew mont	7	40	**56**	**57**	**81**	**86**	**90**	**71**	46	45	34	**71**	**76**	**69**	49	46	**66**	**60**	**59**	**60**	23	**63**	13	25	30	24	25	**57**	**95**	49
Dipl cond	21			**67**	**74**	**60**	5	14			3	**71**	**56**	4			22		36		10	38		33	6	**66**	**74**	24	**95**	**95**
Comb here		20	—	15	24	20	10	7	6	**99**	**72**	**89**	**65**	**59**		6	**66**	**93**	**92**	**60**	48	**63**	18	25		4	6		12	**53**
Hyph pete										7	38	9	2				11	2	16											40
Mayt sene		20				4				7	41	31	7	13			11	27	**69**	4	13								4	26
Term brac				31	24	12	5			7	3	40	7					2	12								25		16	**76**
Acac erub											3					46		20		8	10									
Dich cine	14	**99**	28	**57**	**68**	**68**	**80**	**63**	**86**	**83**	**69**	51	27	**56**	**99**	**59**	**99**	**89**	**89**	**96**	**97**	**88**	**94**	**58**	**84**	49	**74**	**66**	32	49
Pelt afri				20	6	34	5		6	46	28	**63**	43	4			44	41	**58**	24	45	**50**		41	6	16	6		33	40
Zizi mucr		20	14	5	6	21		7		**75**	**59**	34	19	12			11	**74**	**65**	28	48		4	16	9	4				13
Vang infa	21			25	37	**64**	15	14	13	14	3	14	2				**66**	17	13	**60**	13	**50**	**71**	16	6		12	**75**	**62**	9
Acac atax	42	**80**	42	5		8	5	21	32	22	3			4			11	18	9	**60**	**90**	**50**	**90**	**50**	**75**	33	6	33	4	
Comm ango	7			15	12	4	25	7	6			26	15	21			11	47	13	**88**	**71**	38	**80**	16	**54**	8		41	8	
Crot grat	14	20	14	21		4		28	6	15			12	33	32		22	15	16	36	35	25	**90**		18	16	12	**91**	**57**	
Hipp indi	42		14	10	6	21	20		26	7	3			4			22	2	6	**84**	**65**	**75**	**58**	33	30			8		
Comb albo			14			4	5	42	6		8	3		8		6	22	28	3	**60**	10	13	26							
Grew fl.fl.	42	20	**84**	25	6	42	20	**85**	**66**	30	31	20	9	25	16	13	**99**	**93**	**63**	**96**	**99**	**50**	**99**	**66**	**75**	49	**55**	**58**	20	31
Mund seri	49	40		10	6		5	42		14		6	5	26	16		33	**57**	3	**96**	26	25	22		3			8		
Acac lued						4	5		26	7	24	6					11	**56**	19	**88**	32		13		3					
Dios lyci				5		4				30	21	6					33	44	**53**	16	29	13	8	8		4				17
Acac erio												3		4			**66**	**86**	**78**	**86**	**81**	25	**62**	**99**	36	32	**68**	33	4	**80**
Acac flec						8						6					33	**65**	48	**64**	**94**	**50**	**72**	**90**	**78**	16	6	24	8	8
Rhus tenu				5		8	10		12		3	14	32	13			**66**	**67**	**63**	**92**	**90**	**63**	**86**	**57**	**57**	37	37	**58**	**62**	26
Lonc nels						12	5				7	3		8			**88**	**75**	22	**92**	**94**	**88**	**76**	41	**63**	20	6	8	12	8
Ochn cinn						4											11	13	6	**92**	**71**	**63**	**94**	41	42	4				
Bosc albi	7						5				3	6		4			22	**78**	3	**68**	29	38	16	16	9					
Grew flava						17	15					14					**55**	**59**	19	**52**	**52**	38	8				12	8	4	4
Pave lasi				5	6		5				7	6					22	41	36	**56**	48	**50**	8	8					4	
Bauh pete				20	**56**	**60**	5		12	30		32	27				11	2	10	44	**74**	**63**	17	**83**	**99**	**87**	**62**	**91**	**91**	36
Comb coll	**84**			25	18	**69**	25		19	7	3	20		8			**55**	15	16	**88**	**84**	**88**	**53**	**66**	**96**	**78**	18	**75**	**78**	22
Comb zeyh	49			**51**	**74**	46	10		40	7	7	23	12	4	33	10	19	**52**	**79**	35	**81**	**75**	35	**83**	**93**	**91**	**99**	**91**	**74**	**59**
Term seri				15	**55**	**56**	10	7	6	22	14	**60**	9				**99**	**54**	**90**	**88**	**94**	**63**	40	**99**	**99**	**95**	**99**	**82**	**87**	**90**
Pseu mapr	14			31	43	42		14	13	14		11	13						3							29	**93**	41	**53**	**80**
Stry spin				15	18	8				7		3							16		6	13	4	41	12	**50**	**68**	16	25	**58**
Vite payo	21			15	36	43	10	7	12			14								4	3	13	4	33	6	**83**	**80**	**74**	**66**	13
Baph mass						**51**			12			6					33	20	19	**92**	**90**	**63**	**95**	**99**	**96**	**91**	**62**	**99**	**86**	26
Crot pseu																				20	23	38	**76**	16	**84**	**65**	43	**91**	8	4
Grew avel						8						3						2			23		**81**	8	27	20	37	**74**	16	18
Baik plur					17															8	6	25	**99**		**60**	**57**	**99**	**99**	**91**	
Ochn pulc					8							6						4	36		**81**	25	13	**99**	**96**	**98**	**99**	**82**	**87**	**94**
Comb psid																		2	12	8	45		4	**83**	**81**	**87**	**80**	**75**	**66**	**67**
Dich rhod					8							3							3	16	19	25	18	**57**	**87**	**79**	49	**75**	**54**	9
Burk afri					12	8						26						2	**59**	8	45	13	9	**99**	**75**	**99**	**86**	**58**	**83**	**99**
Eryt afri	14				6	20						6						2	26	12	23		4	**74**	**60**	**81**	**99**	44	**78**	**80**
Guib cole																		2	10				4	16	9	**74**	**99**	**82**	20	**58**
Pter ango				5		12						9									3	38		16	**52**	**94**	**86**	33	**70**	35

A key to the abbreviations of species' names can be found in Appendix 2. The numbers are % presence of each species in each type.

Table of soil texture

The field data concerning soil texture of each vegetation type were collated and summarised in Table 3. These data were derived from the first summary of samples and environmental data according to the sequence of samples as classified by TWINSPAN (Appendix 2). There is a general trend from bedrock, to rock and gravel, to clay, sandy clay and shallow sand to deep sand within the vegetation types 1 to 30 (Table 3). The percentage figures in the table represent the percent number of samples of the total in which the soil texture was recorded.

Table 3. Broad trends in soil texture associated with each vegetation type.

Vege. Type	Grp. No.	No. Stds	bedrock	rock	gravel	clay	sandy clay	shall. sand	deep sand
1		14		21%			14%	64%	
2	A	5				80%	20%		
3		7		71%				29%	
4		19	21%	47%			5%	21%	
5	B	24	33%	17%			8%	4%	
6		15		13%			53%	27%	7%
7		20	11%	26%	11%		32%	21%	
8	C	14		14%	21%	43%	21%		
9		15		33%	20%	7%	13%		
10		13				23%	8%		
11	D	30	3%	3%	10%	52%	14%	10%	
12		35		3%	3%	29%	46%	14%	
13		39		46%	5%	23%	3%	3%	
14	E	23		39%	9%	30%	17%		
15		7			14%	71%	14%		
16		14				93%	7%		
17		9				22%	78%		
18	F	38				32%	58%	11%	
19		30				20%	53%	13%	3%
20		25				4%	68%	24%	
21	G	31				6%	42%	42%	10%
22		8				13%	75%	13%	
23		22				5%		9%	86%
24	H	12					50%	33%	8%
25		33					8%	8%	43%
26		24					8%	17%	75%
27	I	16							94%
28		12						17%	67%
29	J	24				4%	25%	25%	46%
30	K	22					9%	18%	73%

The figures in the body of the table are the percentage of the total number of samples constituting a vegetation type which have a particular range of soil textures.

Summaries of vegetation types and their characteristics
Summaries of the characteristics of vegetation types of each group are given in tables in Appendix 3. These data were derived from the first summary of samples and environmental data according to the sequence of samples as classified by TWINSPAN. The types of each of 11 groups are listed, the number of samples, the indicator species (in bold type) and sometimes common species, the number of species, the topography and soil texture class as a percent of the total number of samples, are also given.

Summary of the woody species found within each physiognomic stratum in each vegetation type
There is a table for each type summarising the woody species of each physiognomic stratum in each vegetation type (Appendix 4). Only those species which occurred in over 25% of the total number of representative samples were listed in the <1m and 1-3m strata. In the tree stratum (>3m) woody species which occurred in over 20% of the total number of samples were listed.

The figures of percent presence are relative. They are frequency indices for each species within the samples representing each type, given as an aid to the description of each vegetation type. Thus for example, in type 1 *Abrus schimperi* was found to occur in 64% of the total number of 14 samples representing the type. It is the most frequently encountered species in the <1m stratum.

Definitions and naming of groups and types
A vegetation **group** is an assemblage of vegetation types which are similar to each other according to the TWINSPAN classification (Fig. 4).
A vegetation **type** is defined as a group of samples with similar species compositions which were hierarchically classified by the TWINSPAN programme (Figs. 5, 8, 9 and 13).
A **differential** species is one which separates one similar vegetation type from another vegetation type when the two types or groups are compared (Whittaker, 1975).
An **indicator** species (given by TWINSPAN) is the most strongly differential species.
A **common** species, in this survey, is one which is found in over 50% of the samples representing the type or group.
A **character species** is one whose distribution centres in a particular

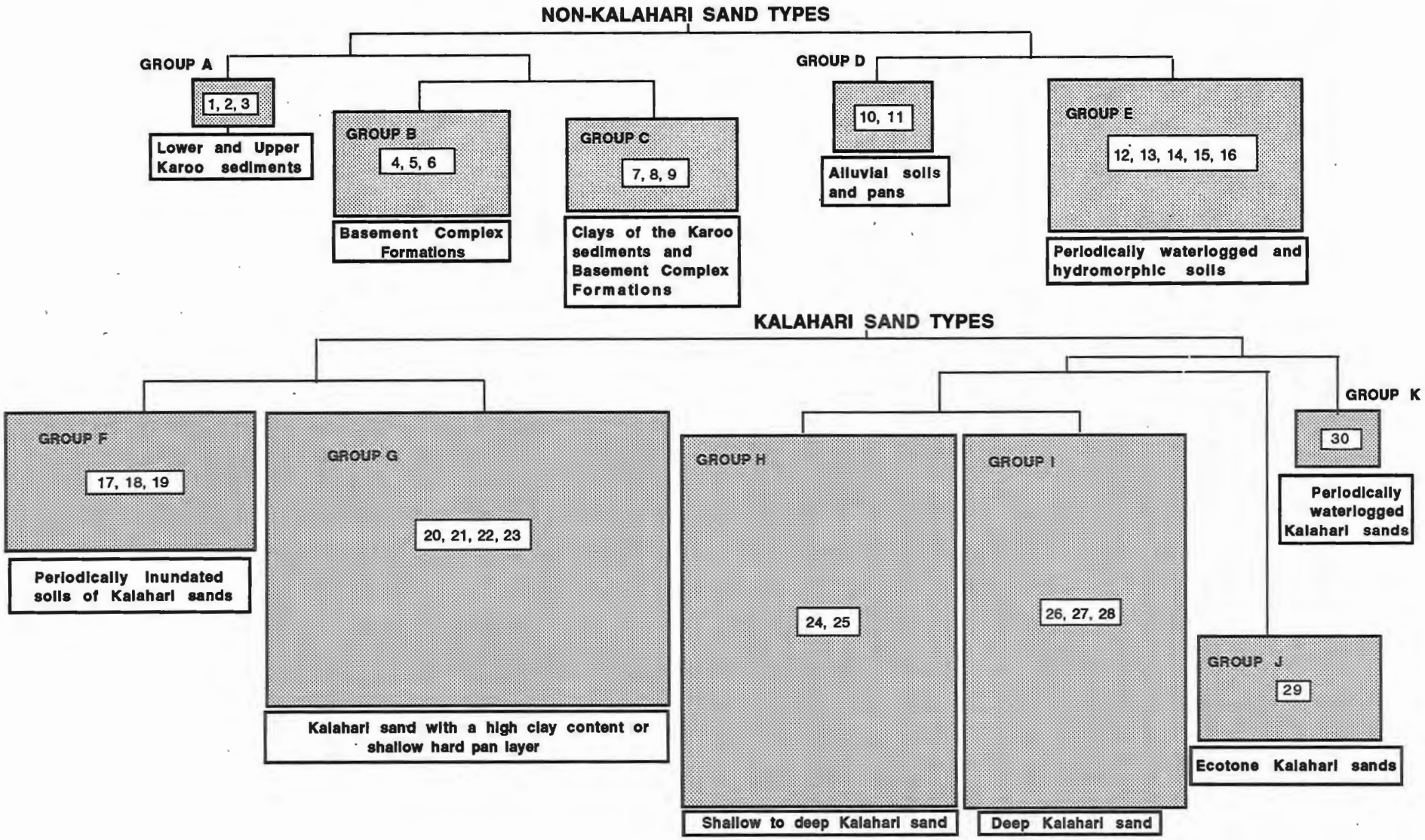


Fig. 4. Vegetation groups and types and their associated geology, according to the TWINSPAN classification.

Note that the areas of the boxes around the type numbers are representative of the areas covered by each vegetation group.

vegetation type or community (Whittaker, 1975).

The groups are named according to their physiognomy and the geological type or types on which they occur. Each type is named according to the following criteria: the most common or dominant species are used, sometimes with the differential species; then the physiognomy of the type; and if pertinent the geological type or topographical feature upon which it may be found. For example, "*Colophospermum mopane* - *Acacia* woodland adjacent to watercourses." *Colophospermum mopane* is common in this group and there are several common *Acacia* species; the physiognomy is woodland and the topography with which the type is associated is that adjacent to watercourses.

The areas of vegetation types, groups and physiognomic types

The vegetation map is now stored on a computer, to be incorporated into a Geographic Information System (GIS). From the digital or computer vegetation map one can easily determine the areas of each vegetation type, group and structural type. This has been done, and the figures are shown in Tables 4a and 4b.

Three-quarters of the Park is covered by Kalahari sand vegetation types, and a quarter by non-Kalahari vegetation types (Tables 4a and 4b). Eighty two percent of the non-Kalahari sand vegetation types are Mopane types, and nearly half of these are Mopane woodland types (Table 4a); or 10% altogether. Only 0.65% of the total area of the Park supports riverine vegetation , which occurs only in the Sinamatella - Robins area. Only 3.4% of the non-Kalahari sand areas are covered by thicket. The predominant species in the non-Kalahari sand areas is *Colophospermum mopane*, associated with different species.

About 30% of the vegetation of the whole Park is woodland ie. woodland plus woodland thicket, excluding wooded bushland and woodland-bushland-grassland mosaic (Table 5). Twenty two percent of Hwange National Park is covered by *Baikiaea* woodland types (Table 4b). This excludes the woodlands of *Burkea* - *Pterocarpus*, type 26. Thus there is double the area of *Baikiaea* woodland than there is of Mopane woodland.

Table 4a. The areas, in square kilometres, of each **non- Kalahari sand vegetation type** according to the current vegetation map.

Type	(abbreviated name)	Area square km	% of total area	No. polygons each type
Type 1	Combretum - Boscia angustifolia open scrub and thicket	14.98	0.10	7
Type 2	Mopane - Acacia woodland	163.70	1.15	12
Type 3	Mopane - Commiphora marlothii	8.67	0.06	18
	Total area of Group A	187.35	1.31	37
Type 4	Castle kopje mixed woodland	179.07	1.25	28
Type 5	Mopane-Julbernardia wooded bushland	308.24	2.16	22
Type 6	Combretum-Baphia thicket	366.82	2.57	28
	Total area of Group B	854.13	5.98	78
Type 7	Mopane-Combretum woodland	469.14	3.29	13
Type 8	Mopane-T.prunioides woodland	120.35	0.84	28
Type 9	Mopane-C.elaeagnoides thicket	102.82	0.72	14
	Total area of Group C	692.31	4.85	55
Type 10	Riverine vegetation	92.82	0.65	8
Type 11	Mopane-Acacia-Combretum grassland to woodland	216.73	1.52	9
	Total area of Group D	309.55	2.17	17
Type 12	Mopane-C.hereroense bushed grassland to bushland	592.36	4.15	79
Type 13	Mopane-Combretum bushland	322.92	2.26	34
Type 14	Mopane bushland	188.60	1.32	23
Type 15	Mopane-Vepris zambesiaca woodland	(mapped with Type 8)		
Type 16	Mopane-Acacia-Grewia bicolor stunted woodland	371.52	2.60	8
	Total area of Group E	1475.40	10.34	144
Total area of non-Kalahari sand vegetation		3518.74	24.65	331

Table 4b. The areas, in square kilometres, of each **Kalahari sand vegetation type** according to the current vegetation map.

Type	(abbreviated name)	Area square km	% of total area	No. polygons each type
Type 17	Mopane woodland-Combretum bushed grassland mosaic	185.83	1.30	20
Type 18	Acacia-Boscia albitrunca-Mopane bushed grassland	781.81	5.48	134
Type 19	C.hereroense-Hyphaene bushed grassland	334.33	2.34	135
	Total area of Group F	1301.97	9.12	289
Type 20	Acacia-Mundulea sericea bushland	967.21	6.78	132
Type 21	T.sericea-L.nelsii bushland	781.98	5.48	109
Type 22	Mopane-C.apiculatum wooded bushland	28.32	0.20	11
Type 23	Baikiaea-Combretum woodland	1329.07	9.31	668
	Total area of Group G	3106.58	21.76	920
Type 24	T.sericea-A.erioloba bushland	258.28	1.81	29
Type 25	T.sericea-Baikiaea bushland	2572.44	18.03	196
	Total area of Group H	2830.72	19.83	225
Type 26	Burkea africana-Pterocarpus angolensis bushland and woodland	1336.77	9.37	46
Type 27	Baikiaea-Guibourtia woodland	603.96	4.23	16
Type 28	Baikiaea-Croton gratissimus woodland	411.43	2.88	15
	Total area of Group I	2352.16	16.48	77
Type 29	Ecotone Baikiaea-Commiphora mossambicensis woodland and thicket	855.42	5.99	43
	Total area of Group J	855.42	5.99	43
Type 30	Burkea africana-T.brachystemma bushland	221.82	1.55	21
	Total area of Group K	221.82	1.55	21
Total area of Kalahari sand vegetation		10668.67	74.75	1575
Total area of all woody vegetation types		14187.41		
Grassland		84.92	0.59	40
Mandavu Dam		0.43	0.00	1
Total area of Hwange National Park		14272.76*		

* This is the area of Hwange National Park up to the road which runs north - south along the inside edge of the Zimbabwe - Botswana border.

Thirty four percent of the whole Park, or 45% of the Kalahari sand area, is covered by Kalahari sand bushland types. Just over 9% of the whole Park is covered by Kalahari sand grassland and bushed grassland types. On the Kalahari sands, bushed grassland comprises 12% of all vegetation types. This figure would increase to a maximum of 15.5% if the bushed grasslands of types 11 and 12 were included. The latter two types are classified physiognomically as mosaics of grassland, bushed grassland, bushland and woodland (Appendix 5). Only about 0.6% of the whole Park is covered by pure grasslands.

Table 5. The areas, in square kilometres, of each **physiognomic class** according to the current vegetation map.

Physiognomic Class	Area km²	(% of total)	No. polygons of each type
Grassland	84,92	(0,6%)	40
Bushed grassland	1116,14	(7,8%)	269
Scrub	14,98	(0,1%)	7
Bushland	5462,96	(38,5%)	541
Thicket	469,64	(3,3%)	42
Woodland	2049,14	(14,4%)	138
Wooded bushland	1645,01	(11,5%)	68
Woodland-bushland-grassland mosaic	1216,73	(8,5%)	129
Woodland thicket	2184,49	(15,3%)	689

The physiognomy of each vegetation type is variable, but usually with one predominant structure. The most representative physiognomy was assigned to each type and the areas of the vegetation types combined to give estimates of the areas of physiognomic types. The estimates of the areas of each type are thus only approximate.

The most extensive physiognomic type is bushland which covers 38.5% of the Park ie. over 5400 square kilometres (Table 5). The next most extensive physiognomic type is woodland thicket (covering 15% of the Park) and woodland (14 %). Thus woodland thicket and woodland cover just under a third of the Park area.

The least extensive physiognomic type is scrub which is the structure of vegetation type 1 (*Combretum - Boscia angustifolia* open scrub and thicket).

Non-Kalahari Sand Vegetation Types

There are five groups of types (A to E) described below. They are floristic groups, with structural similarities, derived directly from the TWINSPAN classification.

These five groups are found in the north and extreme south of Hwange National Park, and are often dominated by *Colophospermum mopane* trees, across three geological types - Batoka Basalt, Karoo sediments and Basement Complex. *Colophospermum mopane* and *Erythroxylum zambesiacum* are the indicator species for the non-Kalahari sand vegetation groups (Fig. 4). Species listed in the phytosociological table (Table 2) which are found only in non-Kalahari sand areas are *Bridelia mollis*, *Sterculia africana*, *Strychnos potatorum*, *Abrus schimperi*, *Commiphora karibensis*, *C. marlothii*, *Lonchocarpus eriocalyx*, *Pterocarpus lucens* and *Terminalia stuhlmannii*.

The terrain in which these groups are found varies from flat grassy plains, with few woody species, such as those in the Dzivanini area, Dandari and south of Salt Pans, to the extensive mopane woodlands on Karoo sediments and Basement Complex, and the rocky, hilly country around Bumboosie Hill, west of Sinamatella where woody species diversity is high. The only riverine vegetation in Hwange is found along the seasonal and perennial rivers in these areas.

When reading the descriptions of types it is important to keep referring to the colour vegetation map. The colours on the map which represent the non-Kalahari sand vegetation types are red, brown, grey, yellow, ochre and purple.

Group A. Woodland thicket types on Lower to Upper Karoo sediments.

The three communities within this group are confined to small areas in the Sinamatella region, occurring on both sandstones and mudstones of the Karoo Series (Fig. 5). They cover an area of 187,35 square kilometres (Table 4a).

Colophospermum mopane and *Diospyros quiloensis*, although rarely dominant, are most often represented in the group. *Canthium glaucum* (formerly *Canthium frangula*), *Combretum elaeagnoides*, *C. mossambicense*, *Markhamia zanzibarica* (formerly *M. acuminata*) and *Acacia ataxacantha* are common. *Combretum celastroides* differentiates this group from other non-Kalahari sand groups (Fig. 5).

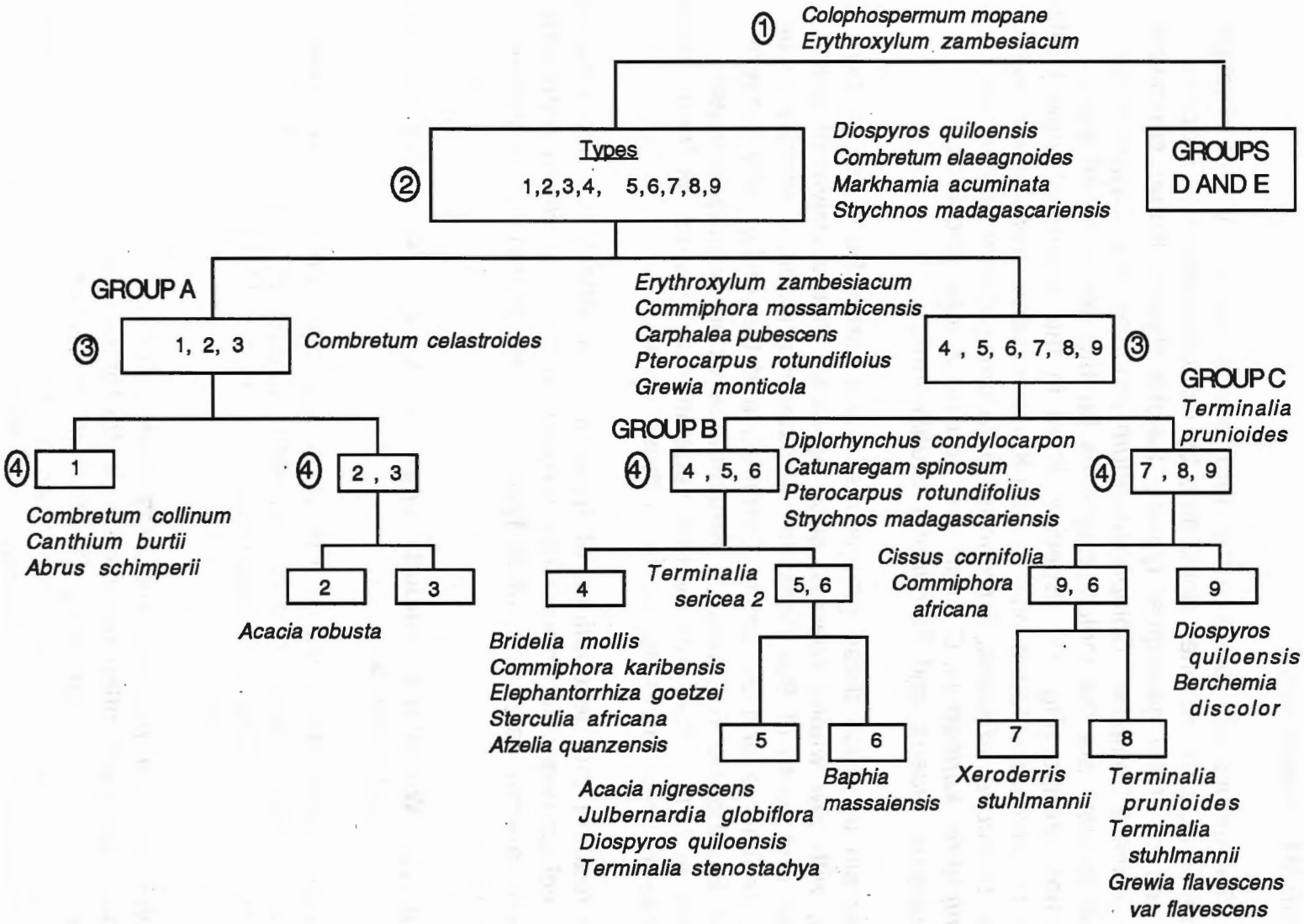


Fig. 5. Dendrogram showing the TWINSPAN classification of types 1 to 9 in groups A, B and C.

The numbers in circles denote the level of division in the classification. The species listed below or adjacent to each type number are the TWINSPAN indicator species.

The numbers which sometimes follow the name of a species refers to the height class of the indicator species.

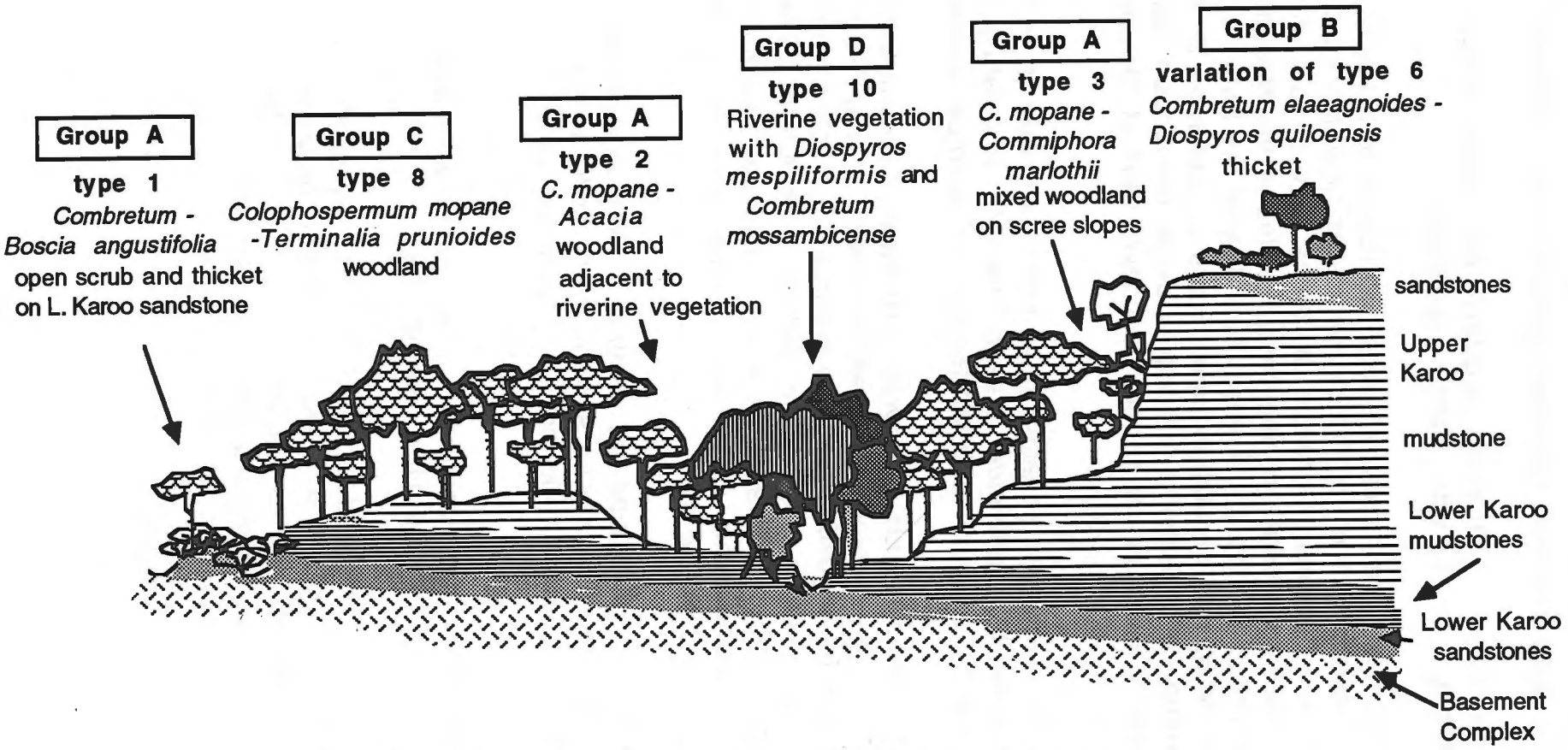


Fig. 6. The relationship of vegetation types to the topography derived from Karoo sediments in the Sinamatella area.

This is the least diverse of the non-Kalahari sand groups (137 species). It was also the least sampled and least geographically extensive group.

Type 1 ***Combretum - Boscia angustifolia*** **open scrub and thicket on Lower Karoo sandstone.**

This scrub or thicket type occurs as small islands of vegetation, mostly in the western half of the Karoo sediments near the contact between Karoo and Basement Complex. It can be seen on low, elongated, dome-shaped, sandstone ridges on the eastern sides of the Masuma and Mandavu Dam (Plate 1). On the northern boundary of the Park, north-west of Sinamatella, this vegetation type occurs on outcrops of Karoo sediments surrounded by Basement Complex below Bumboosie Hill and near the Mambane River on the northern boundary west of Sinamatella Camp.

This type can be recognised as either open scrub or thicket (2 to 4m tall) often dominated by *Combretum elaeagnoides*, *C. apiculatum*, *C. celastroides* and *C. collinum* with scattered *Lonchocarpus eriocalyx*.

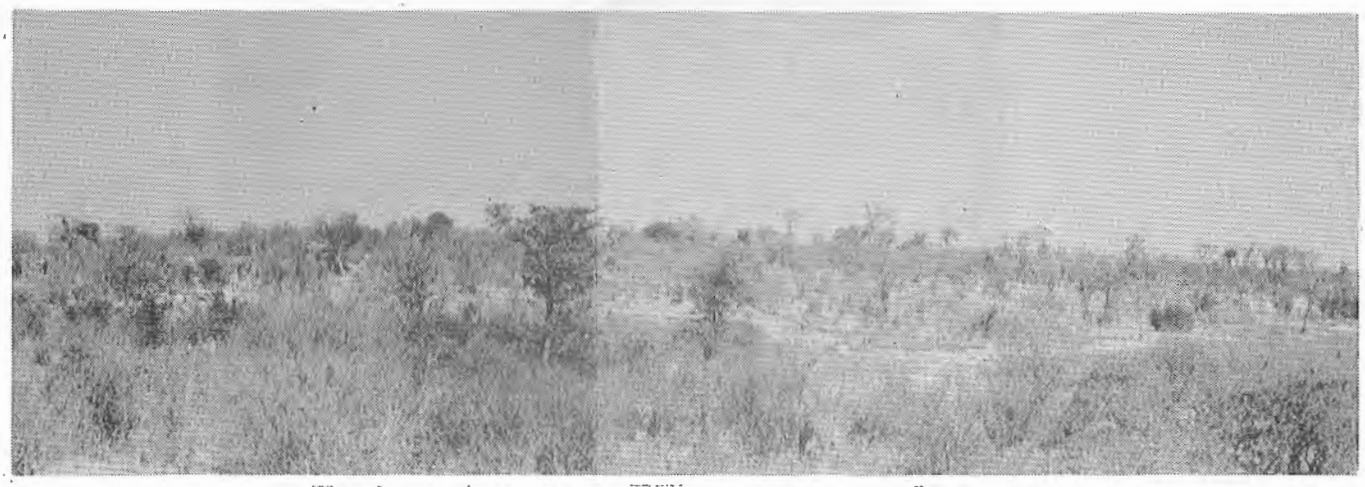
Other common species include *Diospyros quiloensis* , *Colophospermum mopane*, *Canthium pseudorandii* (formerly *C. burtii*) , *Combretum collinum* and *Boscia angustifolia* var.*corymbosa* . Indicator species are *Canthium pseudorandii, Combretum collinum* and *Abrus schimperi* (Table 2). *Lonchocarpus eriocalyx* is a differential and character species, with its distributional centre in this type, and only rarely found in types 4 and 7 (Table 2).

The soils of this vegetation type are shallow to very shallow sandy soils. Most of the samples are on shallow sandy soils, with a proportion of the samples on rocky soils and some on sandy clay soil (Table 3).

Type 2 ***Colophospermum mopane -Acacia*** **woodland adjacent to riverine vegetation.**

This mopane woodland (Plate 2) is found in the low lying Madumabisa mudstone areas adjacent to the riverine vegetation of watercourses such as the Lukosi River and its tributaries (Fig. 2). It is lower on the catena than *C. mopane - Terminalia prunioides* woodland (type 8), also on Madumabisa mudstones (Fig. 6). More samples of this type are required to confirm it as only 5 samples represent this relatively

Plate 1. **Type 1 *Combretum - Boscia angustifolia* open scrub and thicket on Lower Karoo sandstone.** The location of these photographs is near Mandavu Dam. Note the low, elongated, dome-shaped ridge, and the rocky terrain in the first photo-composite. Note the *Combretum* species, and *Pteleopsis myrtifolia* in the right foreground in the bottom photograph.



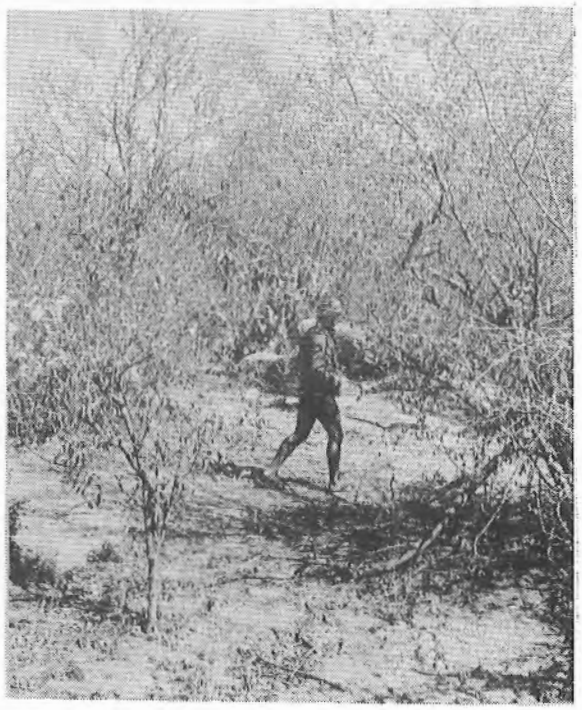


Plate 2. **Type 2 *Colophospermum mopane - Acacia* woodland adjacent to riverine vegetation.** The photograph was taken just below Sinamatella Hill looking towards the Mandavu River.

Type 3 *Colophospermum mopane - Commiphora marlothii* mixed woodland on scree slopes. This is the scree slope below the staff houses at Sinamatella Camp. Note the steep slope and rocky terrain.

extensive vegetation type (163,7 square kilometres) in the Sinamatella area.

This type is less diverse than other types in this group, and commonly includes *Diospyros quiloensis*, *Dichrostachys cinerea*, *Combretum mossambicense*, *Terminalia prunioides*, *Erythroxylum zambesiacum*, *Acacia robusta* and *Acacia ataxacantha* in the well developed understorey. The indicator species *Acacia robusta* is generally associated with seasonally moist habitats in Hwange National Park. Other differential species which separate this type from type 3 include *Terminalia prunioides*, *Erythroxylum zambesiacum*, *Dichrostachys cinerea* and *Acacia ataxacantha*.

Most of the samples are on grey clays, and the rest on brown sandy clays.

Type 2 at first seems to be out of place in group A since it is a mopane woodland type and perhaps should be grouped with the mopane woodland types in group C. However, type 2 has a greater representation of riverine species than type 8 of group C, next to which it usually occurs in the Sinamatella area.

Type 3 *Colophospermum mopane - Commiphora marlothii* mixed woodland on scree slopes.

This community or vegetation type is easily identified since it occurs only on steep scree slopes of escarpments of Karoo formations in the Sinamatella area (Figs. 2 and 8).

This species rich community (81 species) is a thicket or woodland thicket type, with no one species dominant. Almost always present are *Colophospermum mopane*, *Markhamia zanzibarica*, *Canthium glaucum*, *Combretum elaeagnoides*, *Grewia flavescens* var. *flavescens* and *Diospyros quiloensis*. The differential species separating this from type 2, include *Commiphora karibensis*, *Commiphora marlothii*, *Markhamia zanzibarica*, *Kirkia acuminata*, *Sterculia africana* and *Grewia flavescens* var. *flavescens*. The former species and *Afzelia quanzensis* and *Elephantorrhiza goetzei* are indicative of the rocky habitat.

This type occurs on lithosols of the steep scree slopes of escarpments in the Sinamatella area. Most samples in this type occurred on rocky soils and the rest on shallow sandy soils (Table 3).

The species of woody plants found in this habitat are those which are thicket forming on rocky soils. The most common trees are usually found on rocky outcrops or in rocky areas, such as *Commiphora marlothii* and *Sterculia africana* .

Group B. Mixed bushland, thicket and woodland on Basement Complex formations.

This group of vegetation types is found in the Sinamatella and Robins sub-regions and in the north western area of the Main Camp sub-region, mainly on the Basement Complex (Fig. 2). It covers an area of 854,13 square kilometres or nearly 6% of the park (Table 4a).

The group is the most species rich in the Park (185 species). Most of the species present are generally found in rocky habitats or can be found in the middle to highveld where conditions are more moist. For example *Afzelia quanzensis*, *Strychnos madagascariensis*, *Lannea discolor*, and *Catunaregam spinosa* (*Xeromphis obovata*) are typically found in rocky areas, and *Diplorhynchus condylocarpon*, *Brachystegia boehmii*, *Euclea divinorum* and *Terminalia sericea* are frequently present in areas of higher rainfall. The large surface area of boulders which allow for increased run-off of rainfall thus increasing the effective rainfall to adjacent pockets of soil may account for the presence of the latter group of species.

The types in this group are part of a large scale catena on Basement Complex, from rocky kopjes (type 4) to flatter rocky ground (type 5) to shallow sand overlying rock (type 6) at the edge of the Kalahari sand area.

Type 4 Castle kopje mixed woodland and thicket.

This type is widespread in distribution in the Sinamatella area, occurring in the Mambanje area north west of Dete and on 2 km wide north-east, south-westerly oriented series of rocky kopjes. It is also found west of Sinamatella Camp on and around Bumboosie Hill on Basement Complex (Fig. 2). This is the least extensive type in this group covering an area of 179 square kilometres (Table 4a).

This is the most diverse of all the vegetation types in the Park (156 species). The community is generally mixed woodland and thicket with

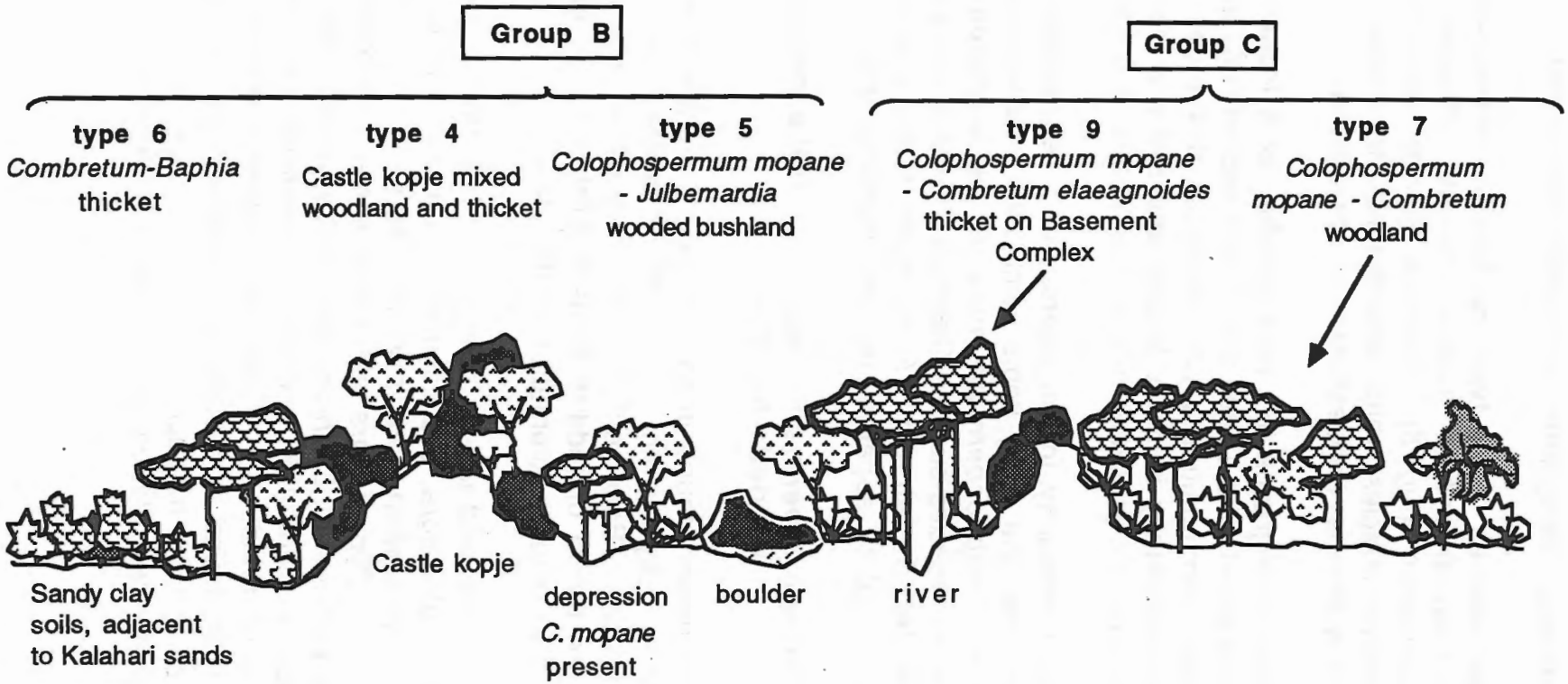


Fig. 7. The relationship of the vegetation types to the topography in Basement Complex areas.

Colophospermum mopane, *Combretum apiculatum*, *Commiphora mossambicensis*, *Diospyros quiloensis*, *Erythroxylum zambesiacum*, *Kirkia acuminata* being most commonly represented.

The indicator species of the type are *Bridelia mollis*, *Commiphora karibensis*, *Elephantorrhiza goetzei*, *Sterculia africana* (1-3m) and *Afzelia quanzensis* (Fig. 5). They are species typically found in rocky areas. Another species which differentiates this type from the others in the group is *Boscia angustifolia* var. *corymbosa* .

On the aerial photographs this type appears as a mosaic of castle kopjes interspersed with flatter areas and depressions (Fig. 7). Thus there are two communities which constitute this broad type:

i) the community in rocky kopjes and rocky areas with species such as *Bridelia mollis*, *Commiphora karibensis* and *Elephantorrhiza goetzei*.

ii) the community in the interspersed depressions which often has species from the rocky kopje community present, but may be dominated by *Colophospermum mopane*, with scattered *Afzelia quanzensis* and species such as *Carphalea pubescens* and *Catunaregam spinosa* in the <1m stratum. At the scale of the photography used it was not practical to separate the two communities.

Type 5 ***Colophospermum mopane -Julbernardia-Combretum*** **wooded bushland.**

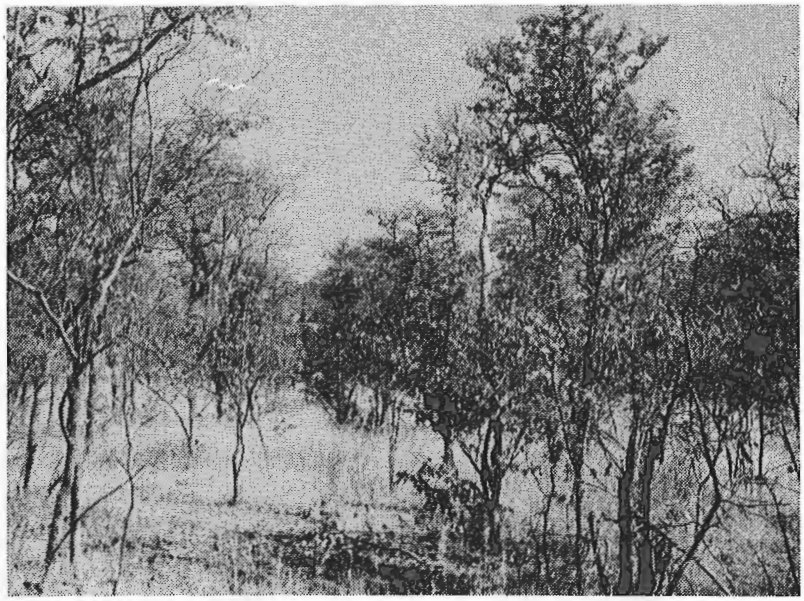
This type is usually found in sites adjacent to type 4, where the topography is rocky but not dominated by castle kopjes and is generally flat to undulating. Basement Complex geology is underlying (Fig. 2). The soils are brown or reddish lithosols (Table 3). It extends over an area of 308,24 square kilometres (Table 4a).

In this mixed bushland to woodland, *Colophospermum mopane* and *Julbernardia globiflora,* are commonly co-dominants with *Combretum zeyheri*, *C. apiculatum* and *Terminalia sericea* . *Diplorhynchus condylocarpon*, *Commiphora mossambicensis, Diospyros quiloensis*, *Carphalea pubescens*, *Erythroxylum zambesiacum*, *Catunaregam spinosa*, *Pterocarpus rotundifolius* and *Grewia monticola* are found in the understorey (Appendix 4). There are numerous species occurring in this type which are found in miombo or *Brachystegia* woodland, for example, *Strychnos madagascariensis*, *Brachystegia boehmii*, *Lannea discolor* and *Pseudolachnostylis maprouneifolia*.

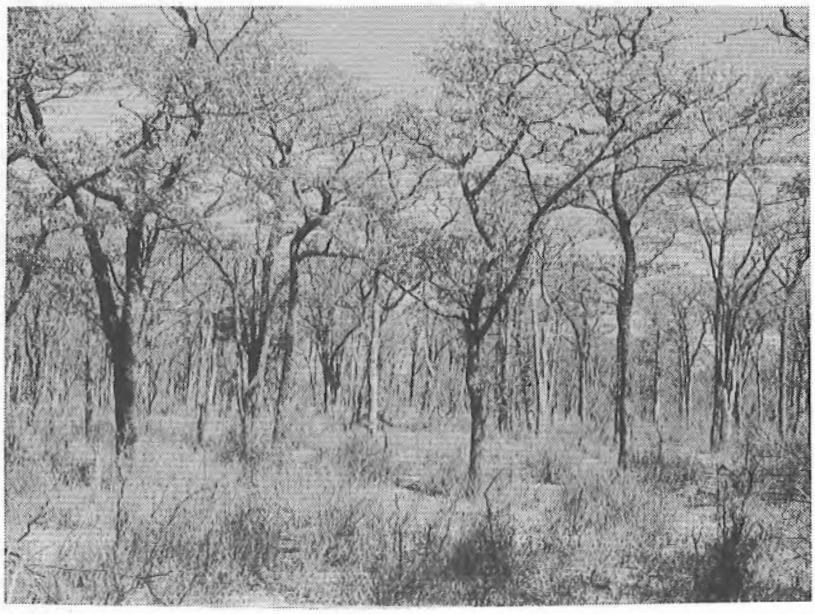
Plate 3. **Type 4 Castle kopje mixed woodland and thicket.** This is an outcrop which can be seen on the main road between Shumba and the turn-off to Robins Camp. Note the *Commiphora marlothii*, *Sterculia africana* and *Afzelia quanzensis* trees and the large boulders of the kopje.

Type 6 *Combretum* - *Baphia* thicket. Photograph taken just south of Manzimbomvu Pan, on the edge of the Kalahari sands. Note the *Combretum apiculatum* and *Commiphora mossambicensis* in the centre, mid-ground of the photograph.

Plate 4. **Type 7 *C. mopane - Combretum* woodland on Basement Complex.** The photograph was taken just north of Shumba Pans before the turn-off to Robins Camp. Note *Combretum apiculatum* in the right foreground and *Sterculia africana* just right of centre.



Type 8 *Colophospermum mopane - Terminalia prunioides* woodland on Madumabisa mudstones. This photograph was taken 500 m past the turn-off to Robins Camp, on the way to Mandavu Dam. This uniform woodland is about 8 m tall. The understorey of this type is not always as poorly developed as is seen in this photograph.



The indicator species are *Julbernardia globiflora*, *Acacia nigrescens*, *Diospyros quiloensis* and *Terminalia stenostachya* (Fig. 5). Other species which differentiate this type from the similar type 6, are *Brachystegia boehmii*, *Euclea divinorum*, *Crossopteryx febrifuga* and *Combretum zeyheri*.

Type 6 *Combretum - Baphia* thicket.

Combretum - Baphia thicket covers an extensive area (366,8 square kilometres) from Dete to Shumba, along the watershed, on the ecotone between the Kalahari sands and other geological types. The reddish sandy clay soils on which it occurs are Kalahari sands overlying Basement Complex or Basalt (Fig. 2). The topography is usually flat to sloping (Fig. 7). Samples from the top of Sinamatella and Bumboosie Hills, which are part of the Basement Complex, were included in this type but may possibly, with further sampling, result in a separate vegetation type.

In this diverse thicket to bushland type (130 species), the species most frequently occurring in samples include *Combretum apiculatum* (sometimes dominant) with *C. celastroides, C. elaeagnoides, Colophospermum mopane, Erythroxylum zambesiacum, Baikiaea plurijuga, Diospyros quiloensis*, *Pterocarpus rotundifolius*, *Grewia monticola* and *Commiphora mossambicensis* (Table 2). The indicator species is *Baphia massaiensis* (Fig. 5). Other species which differentiate this type from type 4 and 5 are *Combretum elaeagnoides*, *Allophyllus africanus*, *Commiphora pyracanthoides*, *Vangueria infausta*, *Grewia flavescens* var. *flavescens* and *Combretum collinum*. This type is often found on the catena between type 5 (*C. mopane - Julbernardia* wooded bushland) and type 29 ecotone *Baikiaea plurijuga - Commiphora mossambicensis* woodland and thicket (Fig. 7).

There are two communities in this type. The majority of samples on ecotone Kalahari sand vegetation represent the first community (Fig. 7) and fewer samples situated on top of escarpments such as the Sinamatella Camp escarpment represent the second (Fig. 6).

There is little difference in the species composition between the two communities of this vegetation type, and more sampling would be required to differentiate them. In the few samples representing the community on top of escarpments *Combretum elaeagnoides* and *Diospyros quiloensis* were frequently the dominant species.

Group C. *Colophospermum mopane* woodland and thicket on Granitic Gneiss and Madumabisa mudstones.

This mopane woodland group (types 7, 8 and 9) covers an extensive area in the Sinamatella region (692,3 square kilometres).

In these woodlands dominated by *Colophospermum mopane*, species such as *Diospyros quiloensis* and *Erythroxylum zambesiacum* are almost always present.

Although mopane woodland is often thought of as species poor, this is the third most diverse group with 156 woody species. Many of the thicket species are common, including *Combretum elaeagnoides*, *Markhamia zanzibarica*, *Carphalea pubescens*, *Cassia abbreviata*, *Cissus cornifolia*, *Acacia nigrescens*, *Commiphora mossambicensis*, *Combretum apiculatum*, *Dalbergia melanoxylon*, *Commiphora africana*, *C. pyracanthoides*, *Grewia monticola*, *Dichrostachys cinerea* and *Grewia flavescens* var.*flavescens* (Table 2). The indicator species for the group is *Terminalia prunioides* (Fig. 5).

Type 7 *Colophospermum mopane* - *Combretum* woodland on Basement Complex.

This is the most extensive of the mopane woodland types covering 469 square kilometres (Table 4a). It can be found on the rocky ground of the Basement Complex from the northern boundary of the Park around Inyantue siding stretching in a belt 1 km to 15 km wide, in a south west, north east orientation, to the edge of the Dandari Vlei (Fig. 1). This mopane woodland is also found on the outcrop of the Basement Complex on the western edge of the Karoo mudstones in the Deteema and Chingahobe areas of the Robins sub-region.

It varies from woodland to bushland and thicket dominated by *C. mopane* with thicket species such as *Combretum apiculatum*, *C. elaeagnoides*, *Xeroderris stuhlmannii*, *Commiphora mollis*, *Terminalia randii*, *T. stuhlmannii*, *Diospyros quiloensis*, *Erythroxylum zambesiacum*, *Cissus cornifolia*, *Dichrostachys cinerea* and *Grewia monticola* (Table 2). The indicator species is *Xeroderris stuhlmannii* (Fig. 5). Other species which differentiate this type from the other two types of this group are *Kirkia acuminata*, *Cassia abbreviata*, *Sclerocarya birrea* and *Pterocarpus rotundifolius* (Table 2).

Plate 5. **Type 9 *Colophospermum mopane - Combretum elaeagnoides* thicket on Basement Complex.** This photograph was taken on the way to Robins Camp 5km from the turn-off to Robins Camp, from the road to Sinamatella. Note the *Xeroderris stuhlmannii* tree in the left foreground, and the *Combretum elaeagnoides* thicket behind.

This non-Kalahari sand type has a greater diversity (119 species) than the other non-Kalahari sand types in this group, and many of the species which are found on rocky terrain are common here too. For example, *Diospyros quiloensis*, *Xeroderris stuhlmannii*, *Markhamia acuminata* and *Carphalea pubescens* are common in this type as well as in the rocky habitats of types 4 and 5.

Most of the soils of this type are shallow overlying bedrock, rocky soils or gravelly soils (Table 3).

Type 8 *Colophospermum mopane - Terminalia prunioides* woodland on Madumabisa mudstones.

This type, found on Madumabisa mudstone on slightly raised ground, above type 2, next to which it occurs (Figs. 2, 4 and 8), is found only in the Sinamatella sub-region on Karoo mudstones. It covers 120,4 square kilometres (Table 4a).

Colophospermum mopane is always present as a tree and dominates this type forming a uniform woodland about 8 to 10 m tall. *Erythroxylum zambesiacum*, *Acacia nigrescens* and *Diospyros quiloensis* trees are scattered throughout this type. In the understorey *Combretum elaeagnoides, Terminalia prunioides, Erythroxylum zambesiacum, Commiphora pyracanthoides, Commiphora africana, Diospyros quiloensis, Grewia monticola* and *Vepris zambesiaca* are found. The indicator species are *Terminalia prunioides*, *T. stuhlmannii* and *Grewia flavescens* var *flavescens* (Fig. 5). Other species which separate this from the other types in this group are *Commiphora karibensis*, *Gardenia resiniflua* and *Vepris zambesiaca* which is also the character species of this type.

Most of the soils of this type were clay and sandy clay and in a third of the samples the soils were rocky and gravelly (Table 3).

Type 9 *Colophospermum mopane - Combretum elaeagnoides* thicket on Basement Complex.

This thicket is found from Deteema to Chingahobe, Dolilo and to below Bumboosie Hill. It covers a large area about 5 km on either side of the Inyantue River and north of Shumba Pans to the eastern edge of the Dandari Vlei (a total of 102,8 square kilometres). The topography is typically rocky and dissected with stream and river lines in Basement Complex areas (Fig. 2).

This is a *C. mopane - Diospyros quiloensis - Combretum elaeagnoides* thicket type with *Erythroxylum zambesiacum*, *Dichrostachys cinerea*, and *Carphalea pubescens*. *Diospyros quiloensis* trees and *Berchemia discolor* are the indicator species. *B. discolor* is also the character species (having the centre of its distribution in Hwange National Park in this type, see introduction to results), although it is not common in any of the samples representing this type.

Other species include *Combretum mossambicense*, *Lonchocarpus capassa*, *Flueggea virosa* (formerly *Securinega virosa*) and *Combretum imberbe* which are indicative of a sometimes riverine habitat. Thicket species such as *Xeroderris stuhlmannii*, *Canthium glaucum*, *Markhamia zanzibarica*, *Carphalea pubescens*, *Grewia flavescens* var. *flavescens*, *Combretum apiculatum* and *C. zeyheri* are commonly found in this community. The presence of species such as *Bauhinia petersiana*, *Combretum collinum*, *C. zeyheri*, *Pseudolachnostylis maprouneifolia*, *Vitex payos* and *Baphia massaiensis* are indicative of the sandier soils of this type compared to the other mopane types of this group.

This vegetation type is found on rocky or gravelly soils, and sometimes on clay to sandy clay soils (Table 3).

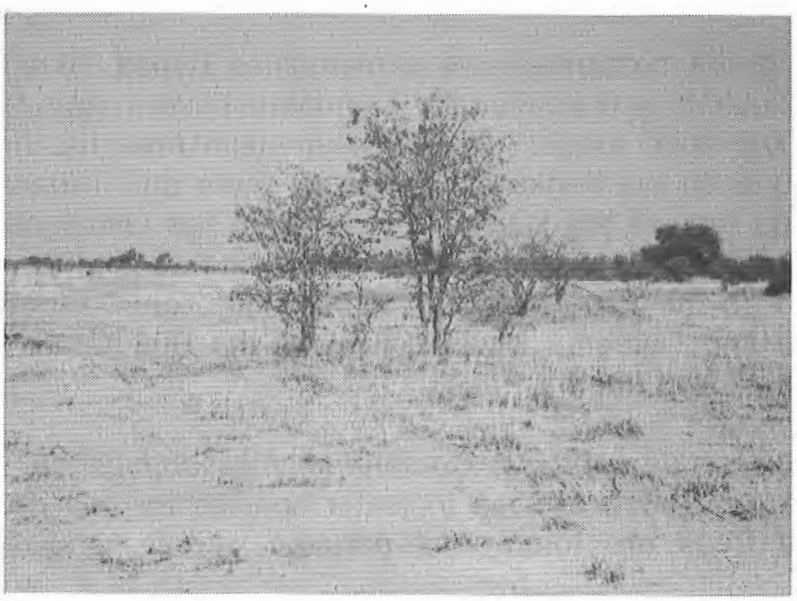
Group D. *Colophospermum mopane - Combretum imberbe* woodland to bushed grassland in seasonally inundated areas.

This group comprises two communities (types 10 and 11) which occur on alluvium and seasonally inundated soils in the Sinamatella, Robins and Dzivanini areas. In the Sinamatella area the first type in this group is found on the banks of the Lukosi River and Tshakabika Rivers, and the second type in the Dzivanini area along the Gwabasabuya, Limpande and Dzivanini Rivers. In the Robins area the second type in this group is found on the upper reaches of the Little Toms, Big Toms, Salt Pans, Dolilo and Deteema Rivers, all along the Bumboosie River and surrounding Shumba Pans.

Lonchocarpus capassa, Combretum mossambicense and *Combretum imberbe* (>3m) are the indicator species for this group (Fig. 8). All of these trees are tolerant of periodic waterlogging.

Plate 6. **Type 10 Riverine vegetation with *Diospyros mespiliformis* and *Combretum mossambicense*.** This photograph was taken of the Lukosi River from the main road.

Type 11 *Colophospermum mopane - Acacia - Combretum* grassland to woodland in seasonally inundated areas in the Shumba, Big Toms and Salt Pans areas. This photograph was taken at Salt Pans in the Robins sub-region.



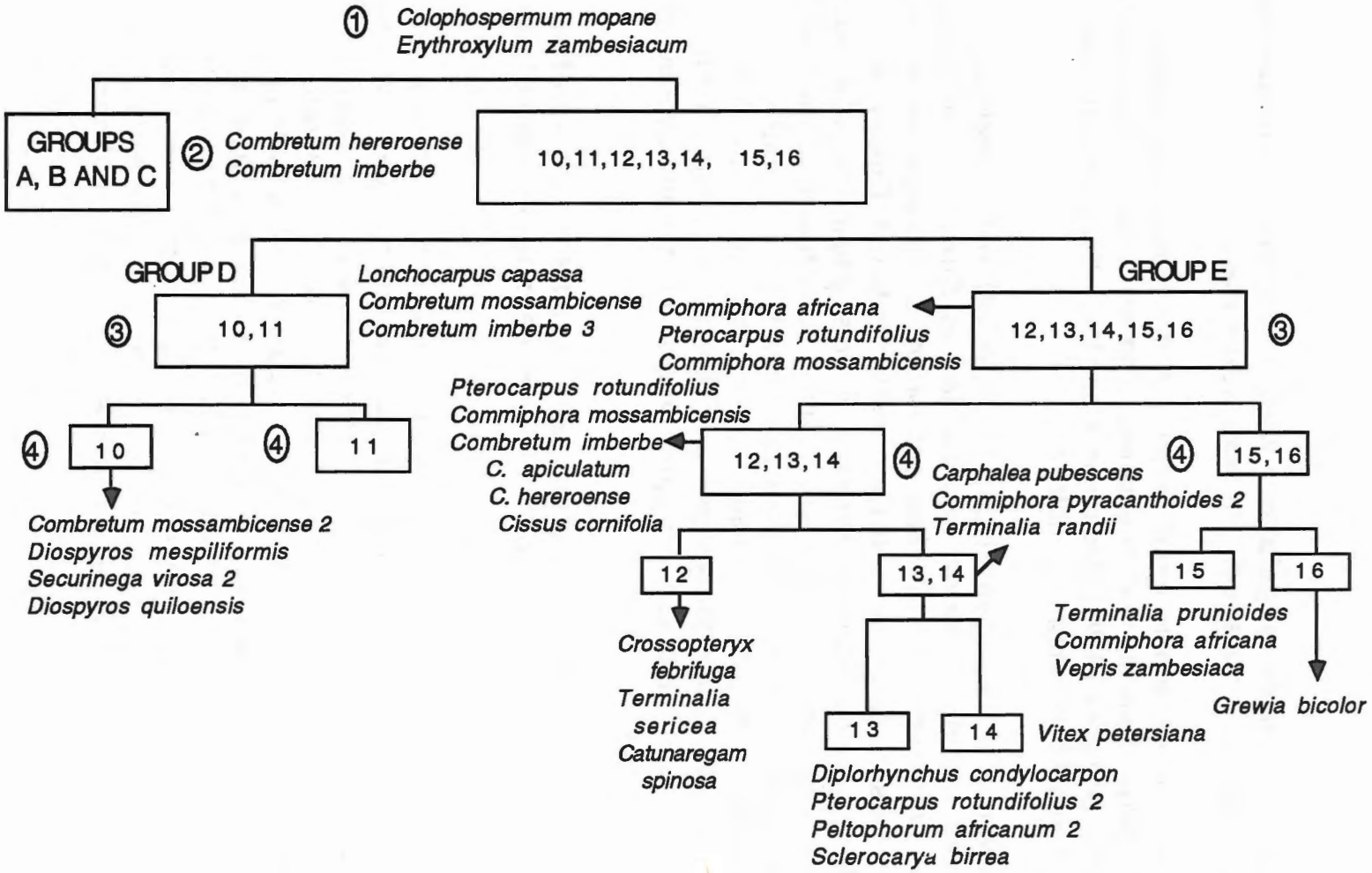


Fig. 8. Dendrogram showing the TWINSPAN classification of types 10 to 16 in groups D and E.

The numbers in circles denote the level of division in the classification. The species listed below or adjacent to each type number are the TWINSPAN indicator species.

The numbers which sometimes follow the name of a species refers to the height class of the indicator species.

The first type is diverse in species composition. Type 10 accounts for 124 of the total of 148 species for the group. Type 11 is bushed grassland to riverine *C. mopane* woodland with relatively few woody species.

Type 10 Riverine vegetation with *Diospyros mespiliformis* and *Combretum mossambicense*.

This riverine vegetation is found mainly on the banks and terraces (Fig. 6) of the large rivers in the Sinamatella area on Karoo sediments and the granitic gneisses of the Basement Complex. It covers an area of only 92,8 square kilometres (Table 4a).

It is a diverse, tall woodland type (124 species) with a well developed understorey tending to thicket with species as *Diospyros quiloensis*, *Canthium glaucum* and *Strychnos potatorum*. *Combretum hereroense* is always present as a tree, and *Combretum imberbe*, *Diospyros mespiliformis*, *Lonchocarpus capassa*, *Acacia galpinii*, *Kigelia africana* and *Colophospermum mopane* are common constituents of the canopy. *Flueggea virosa* (formerly *Securinega virosa*), *Combretum mossambicense* and *Dichrostachys cinerea* are common in the understorey. The indicator species are *Diospyros mespiliformis*, *Combretum mossambicense, Flueggea virosa* (1-3m) and *Diospyros quiloensis* (Fig. 8).

Type 11 *Colophospermum mopane - Acacia - Combretum* grassland to woodland in seasonally inundated areas.

This community which varies from open bushed grassland to bushland, thicket and woodland, is usually dominated by *Colophospermum mopane* with scattered *Combretum imberbe*, *C. hereroense, Lonchocarpus capassa* and *Ziziphus mucronata*. Other common species include *Acacia nigrescens* and *Dichrostachys cinerea* (Table 2). There are no indicator species for this type, instead it is by the absence of *Diospyros mespiliformis*, *Flueggea virosa* (formerly *Securinega virosa*) (1-3m), *Combretum mossambicense* and *Diospyros quiloensis* that this type is defined (Fig. 8). Species which also differentiate this from the type 10 include *Acacia nigrescens*, *A. luederitzii*, *Hyphaene petersiana* and *Maytenus senegalensis* (Table 2). Within this type, where it occurs along rivers in the Dzivanini area, there are groves of *Acacia kirkii*, which occur nowhere else in the Park

(this species is not represented in Table 2 as it is a rare species, but was used in the classification of vegetation types). It is more extensive than type 10 covering 216,7 square kilometres (Table 4a).

Most of the samples representing this vegetation type occur on clays and sandy clays, with some samples on gravelly and rocky soils (Table 3).

According to Sweet (1971) some or all of the soils of this type may be sodic. More sampling of the soils and species composition of this type is required. Boreholes yield salty water in the Dzivanini area.

Group E. *Colophospermum mopane* bushed grassland to woodland on the watershed, on Basalt and Karoo formations.

This group consists of a seasonally waterlogged type on deep soils derived from basalt (type 12), two types on shallow soils derived from basalt (typically in the Robins area, types 13 and 14) and two types on deep clay - one in the Sinamatella area (type 15) and the other (a seasonally waterlogged type) widespread in the Dzivanini area (type 16). It is the most geographically extensive group of the non-Kalahari sand types covering an area of 1475,4 square kilometres (Table 4a).

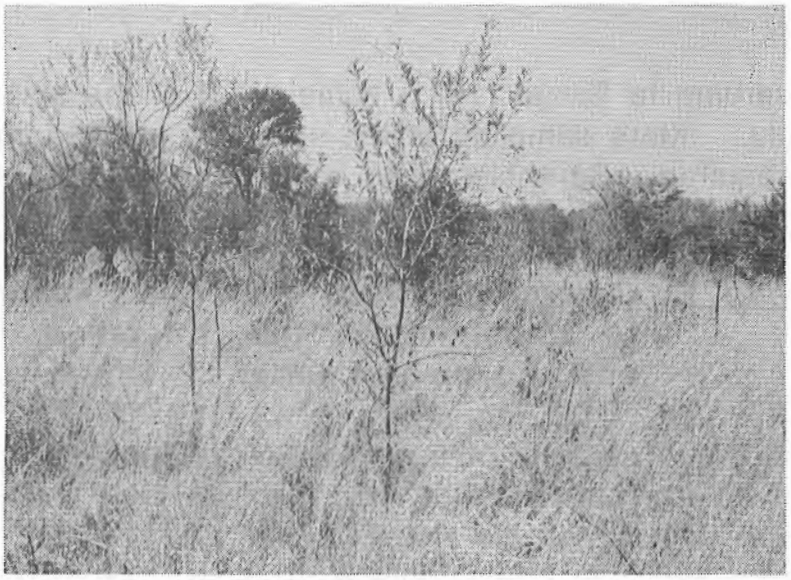
Only *Colophospermum mopane* is consistently present in almost all samples in this group (Table 2).

Among the five types which constitute this group there is a decline in the number of species associated with each type from 134 species to only 26 species, the lowest number of species in any woody vegetation type in Hwange National Park (Appendix 3). There are a total of 174 woody species represented in this group.

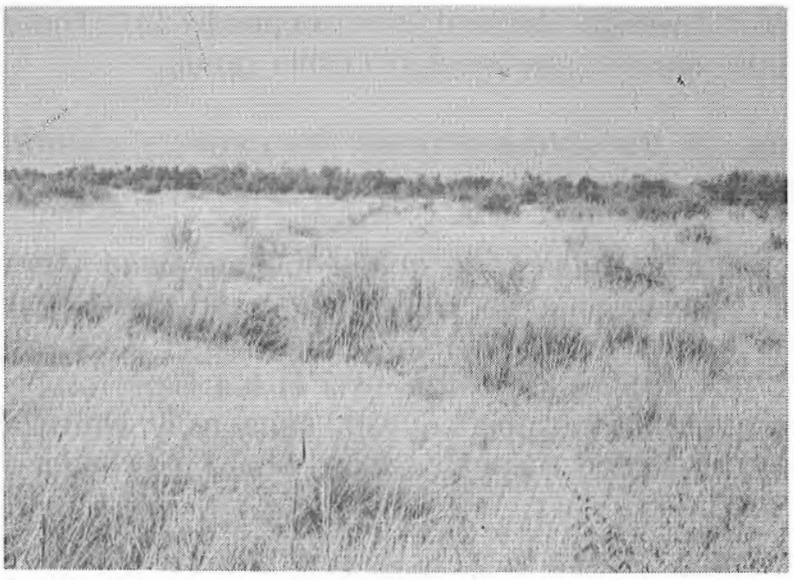
Type 12 *Colophospermum mopane - Combretum hereroense* bushed grassland to bushland on the watershed.

Type 12 is widespread in distribution along the watershed, stretching from Dete to Shumba, Dandari Vlei and the Botswana border. It is the most extensive of the non-Kalahari sand vegetation types with an area of 592,4 square kilometres (4% of the Park) (Table 4a). This community is associated with seasonally waterlogged soils derived from basalt and Kalahari sands, where they meet (Fig. 2). In the north

Plate 7. **Type 12 *C. mopane* - *Combretum hereroense* bushed grassland to bushland on the watershed.** This photograph was taken east of Manzimbomvu, in a lens-shaped dune trough. Note the *Combretum apiculatum* in the foreground.



Type 12 *Colophospermum mopane* - *Combretum hereroense* bushed grassland to bushland along basalt drainage lines in the Robins sub-region. This photograph was taken close to Robins Camp, at the first vlei encountered on the main road to Sinamatella. Note the small *Combretum imberbe* shrubs in the grass.



western Kalahari sands of the Robins area, this type occurs in eroded dune troughs.

In this mixed bushed grassland type *C. mopane* is almost always present but is not always dominant. Co-dominant species include *Combretum apiculatum*, *C. hereroense*, *C. imberbe*, *C. adenogonium* (formerly *Combretum fragrans*), *Terminalia sericea* and *Bolusanthus speciosus*.

Other common species include *Pterocarpus rotundifolius*, *Commiphora mossambicensis*, *Diplorhynchus condylocarpon*, *Dalbergia melanoxylon*, *Euclea divinorum*, *Peltophorum africanum* and *Grewia monticola* (Table 2). The indicator species are *Crossopteryx febrifuga*, *Terminalia sericea* and *Catunaregam spinosa* (Fig. 8). Some of the differential species include *Albizia harveyi*, *Lonchocarpus capassa*, *Terminalia brachystemma*, *T. sericea*, *Ziziphus mucronata* and *Burkea africana* (Table 2).

Three species which are most representative of this watershed habitat are *Bolusanthus speciosus* (common in high rainfall or highveld areas), *Crossopteryx febrifuga* and *Lannea discolor* (common on the highveld).

The surface soils of samples in this type vary from rocky soils to shallow sand, though most are sandy clay soils (Table 3). The situation of type 12, and species composition and vegetation structure, are indicative of a seasonally waterlogged habitat.

Type 13 *Colophospermum mopane* - *Combretum* bushland on basalt.

This bushland and bushed grassland type is the typical *C. mopane* bushland of the Robins area and is found along the boundary with the Matetsi Safari Area, west of the Big Toms River and north of Tsamahole. It is confined to basalt geology and lies adjacent to type 14 (*C. mopane* bushland). It covers an area of 322,9 square kilometres, nearly double that of type 14 (188,6 square kilometres) (Table 4a). The vleis of type 12 are interspersed in this type. The topography is undulating with low hills, and is dissected by many small streams.

The species composition within type 13 varies with the topography; ie. *Kirkia acuminata* is common in rocky areas, on hill tops; while *Diplorhynchus condylocarpon* may be found in more moist conditions; and *Combretum*

imberbe, C. hereroense and *Peltophorum africanum* are typical of seasonally waterlogged locations.

The only low trees (about 3 to 4 m tall) usually found in this bushland are *C. mopane, Combretum apiculatum* and *C. hereroense*. The indicator species are *Diplorhynchus condylocarpon, Pterocarpus rotundifolius* (1-3m height stratum), *Peltophorum africanum* (1-3m stratum) and *Sclerocarya birrea* (Fig. 8). Other differential species (which separate this type from type 14) include *Kirkia acuminata* and *Cassia abbreviata* (Table 2).

Most of the samples of this type are on rocky or gravelly soils according to a descriptive assessment of the surface soils in this survey. Some of the soils are clay and sandy clay soils (Table 3).

Some additional sampling, using transects, would help in the description of species composition in relation to topographic changes within this type, and the next. They both cover large areas and considerable variation in species composition.

Type 14 *Colophospermum mopane* bushland on basalt.

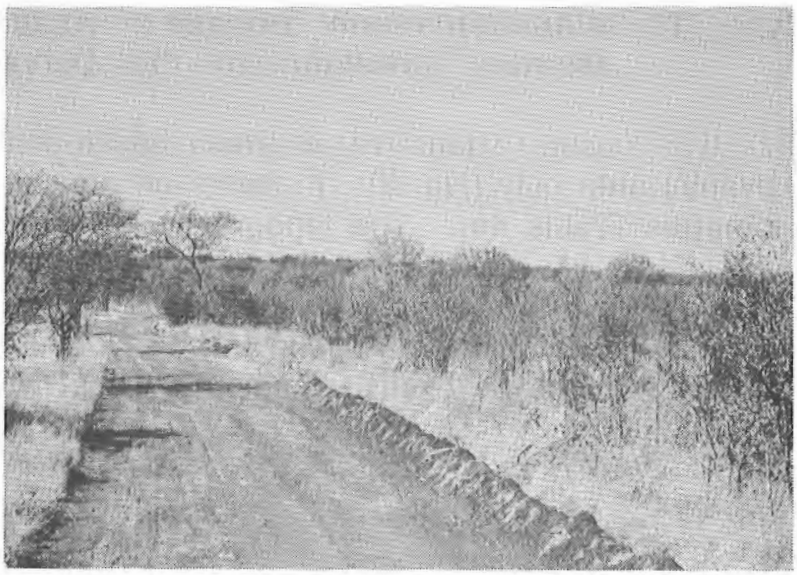
This is the second type of bushland confined only to the basalt of the Robins area. It is found at or near (up to 8 km away from) the contact between basalt and the Basement Complex and Kalahari sand (Fig. 2). The topography is undulating with low hills and many seasonal streams.

Other than *Colophospermum mopane*, common species of this slightly more dense bushland type include *Combretum apiculatum, Commiphora pyracanthoides, Acacia nigrescens* and *Dalbergia melanoxylon* (Table 2). The indicator species is *Vitex petersiana* which is present in over half of the samples representing this type (Fig. 8). Other species which differentiate this type from type 13 include *Terminalia prunioides, T. stuhlmannii* and *Dichrostachys cinerea* (Table 2).

Types 14 and 13 are very similar, and may be difficult to separate in the field. However, if the species lists are compared, it appears that type 14 has more species which usually occur on sandy soils, such as *Commiphora angolensis, Croton gratissimus* and *Bauhinia petersiana* (Table 2). According to the vegetation map type 14 is usually positioned adjacent to the Kalahari sand types and types on Basement Complex. This may indicate that the soils of type 14 are colluvial, with clays derived from the weathering of basalt, and sands from the

Plate 8. **Type 13 *Colophospermum mopane - Combretum* bushland on basalt.** This photograph was taken about 3 km north of Robins Camp on the road to the Nantwich lodges. Note the *C. mopane* bushes and the *Combretum apiculatum* in the right foreground. Rounded basalt rocks can be seen in the middle foreground.

Type 14 *Colophospermum mopane* bushland on basalt. This photograph was taken about 9 km from the turn-off from Salt Pans to Manzimbomvu. Note the sandy clay basalt soils, the good grass cover and the *C. mopane* bushland and scattered *Acacia nigrescens*.



adjacent geological types (Sweet, 1971). Almost half of the samples of this type had clay and sandy clay surface soils, and the rest rocky, gravelly soils (Table 3).

Only *Colophospermum mopane* occurs as a tree in almost all samples. It may be that the generally deeper vertisollic soils of this type, which become seasonally waterlogged, cause the stunting of species which are less tolerant than *Colophospermum mopane.* of these conditions.

Type 15 *Colophospermum mopane - Vepris zambesiaca* woodland on Madumabisa mudstones.

This mopane woodland type occurs predominantly on Madumabisa mudstones in the Sinamatella area (Fig. 2), and perhaps should be grouped with type 8, which has a similar if more diverse (possibly less disturbed) flora. *Dichrostachys cinerea*, an indicator of disturbance, is always present in this type. Type 15 is mapped together with type 8.

The well developed understorey consists of *Diospyros quiloensis*, *Commiphora africana*, *C. pyracanthoides*, *Terminalia stuhlmannii*, *Dalbergia melanoxylon* and *Grewia bicolor* (Table 2). The indicator species are *Vepris zambesiaca, Terminalia prunioides and Commiphora africana.* There are relatively few species in this type compared with the former types of this group (Appendix 3).

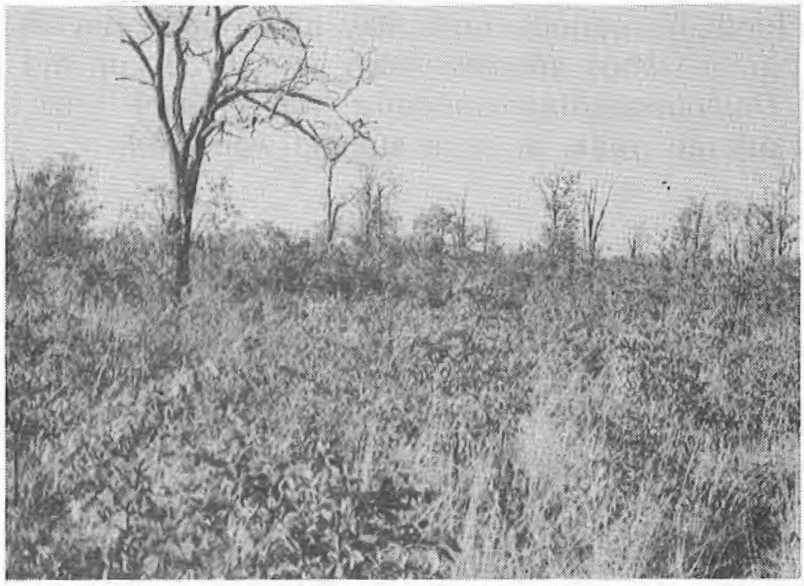
Most of the surface soils on the samples of type 15 were clay (Table 3), derived from Madumabisa mudstones.

Type 16 *Colophospermum mopane - Acacia - Grewia bicolor* stunted woodland in the Dzivanini area.

This type occurs extensively on deep basalt-derived clays in the Dzivanini area only (Fig. 2). It covers an area of 371,5 square kilometres (Table 4a). The topography is flat to gently undulating.

There are only 26 species represented in the samples of this type, the least diverse in the Park (Appendix 3). *C. mopane* is the dominant species, with the next most common species *Dichrostachys cinerea*

Plate 9. **Type 16 *C. mopane* - *Acacia* - *Grewia bicolor* stunted woodland in the Dzivanini area.** The top photograph was taken 4 km past Leasha looking south-east. Note the stunted *C. mopane* and the scattered taller mopane, and on the left a dead *Acacia nigrescens* tree. The bottom photograph was taken a further 2 km along the road, again looking south-east across the stunted *C. mopane* of the Dzivanini flats.



(Table 2). *Dalbergia melanoxylon*, *Acacia sieberana*, *A. robusta*, *A. nilotica*, *Acacia erubescens*, *Ximenia americana* and *Grewia monticola* are also common. The indicator species is *Grewia bicolor* (Fig. 8) which is found as a low shrub with *Boscia matabelensis*.

The soils are mostly grey to black deep, self churning clays, which crack when dry. In depressions in these areas, shallow lakes and marshes are formed, the extent of which depend upon the rainfall. In the dry season the areas can be seen as grasslands interspersed in the stunted mopane woodland. Periodic prolonged waterlogging, together with long dry periods from May to October, severely restrict the number of woody species which can survive on the Dzivanini mud flats. Only *Colophospermum mopane* was present in all samples, sometimes as scattered trees, or as a stunted woodland.

Kalahari Sand Types

There are 6 groups (F to K) described below. They cover three quarters of the Park (Table 4b) from Main Camp to the Botswana border and south to the edge of the Dzivanini flats. *Baikiaea plurijuga* is the most common constituent of woodlands, and *Terminalia sericea* of bushlands. The TWINSPAN indicator species of Kalahari sand types are *Baphia massaiensis*, *Acacia erioloba*, *Terminalia sericea*, *Ochna pulchra* and *Rhus tenuinervis* . *Acacia erioloba*, *A. fleckii*, *Rhus tenuinervis*, *Lonchocarpus nelsii* are found in every Kalahari sand vegetation type. Species which are only found in the Kalahari sand types are *Croton pseudopulchellus*, *Combretum psidioides* and *Guibourtia coleosperma*.

The terrain of the Kalahari sands is characteristically flat. Topographic features which are evident on aerial photographs and satellite images, such as fossil sand dunes, fossil vlei lines, areas of redistributed sand and the watershed, are difficult to discern from the ground except by their vegetation. It is interesting to note that elephant paths radiating from pans and through bushland, can also be seen, not only on aerial photographs but also on Thematic Mapper (TM) satellite imagery.

Group F. *Combretum imberbe* bushed grassland on periodically waterlogged soils.

This group is widely distributed in the Kalahari sands and consists of types 17, 18 and 19. It extends over 1302 square kilometres or 9% of the Park (Table 4b).

Group F is differentiated by *Combretum imberbe* (Fig. 9), and is composed of bushed grassland to bushland types on sandy clay soils which are periodically inundated.

Combretum hereroense, C. zeyheri, Colophospermum mopane, Acacia erioloba, Lonchocarpus nelsii, Peltophorum africanum, Ziziphus mucronata and *Terminalia sericea* are common in this group (Table 2). There are 128 species in this group.

Group F is mainly found on clay and sandy clay soils (Table 3).

Type 17 *Colophospermum mopane* woodland - *Combretum* bushed grassland mosaic on ecotone Kalahari sands

This type is found in an extensive area just south of Shumba Pans, around Mopane Pan, and in the Dzivanini area at the edge of the Kalahari sands and adjacent to the Gwabasabuya River and in patches along the Botswana border south of Korodziba Pan. It covers an area of 185,8 square kilometres and is the least extensive type in this group.

It is a mosaic of *Colophospermum mopane* woodland or bushland interspersed with areas of *Combretum apiculatum, C. hereroense, C. collinum* and *Acacia nigrescens.* On aerial photographs this type has a marbled appearance.

Only *Colophospermum mopane* and *Acacia nigrescens* are commonly found as trees in representative samples (Appendix 4). Common species are *Commiphora africana, Grewia flavescens* var. *flavescens, Terminalia sericea,* and *Lonchocarpus nelsii.* The indicator species are *Acacia nigrescens, Lonchocarpus capassa, Commiphora edulis, Vangueria infausta* and *Combretum collinum* (Fig. 9) Differential species which also separate this type from types 18 and 19, are *Pterocarpus rotundifolius, Commiphora mossambicensis, Combretum apiculatum* and *Flueggea virosa* (formerly *Securinega virosa*).

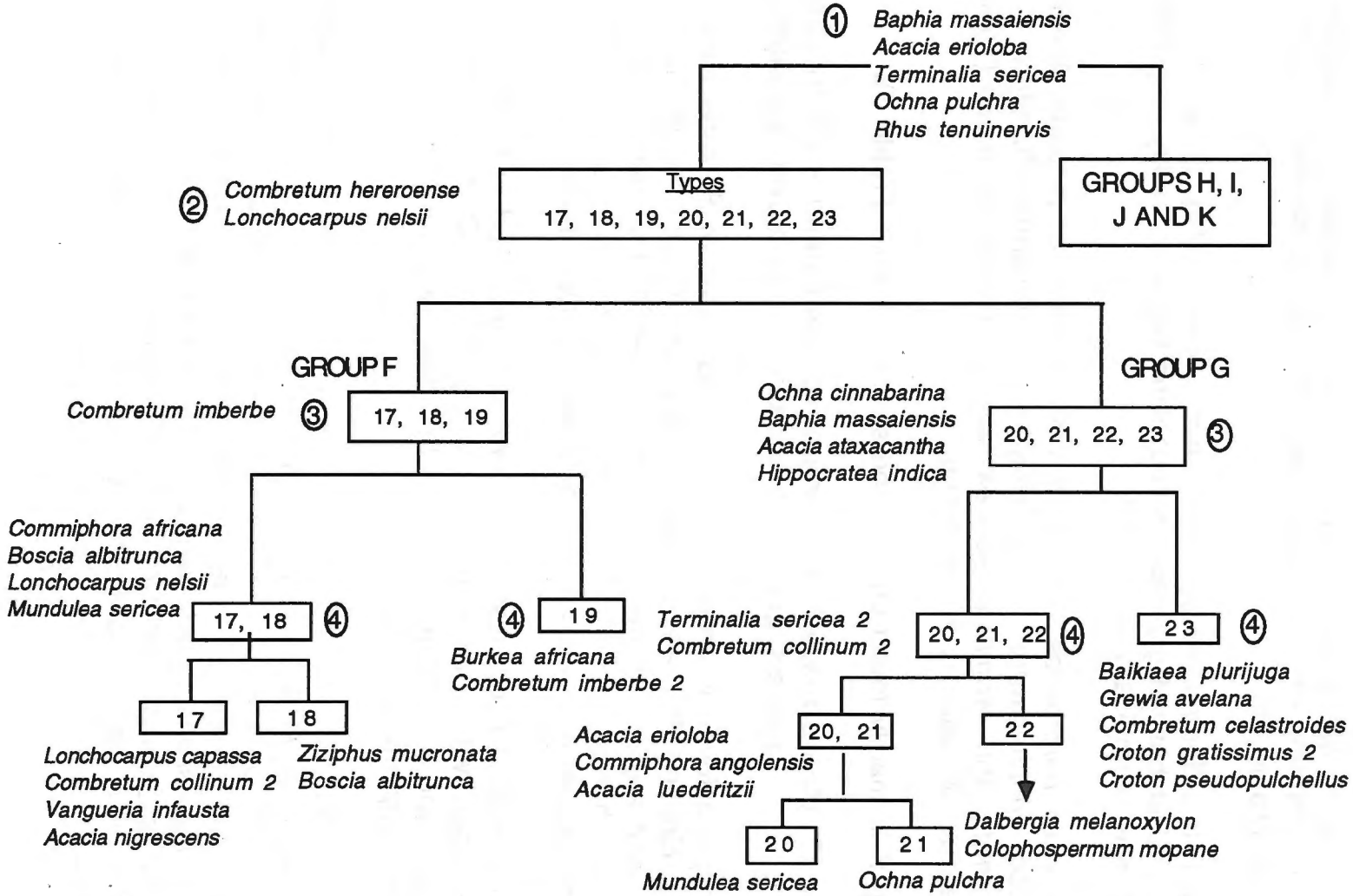
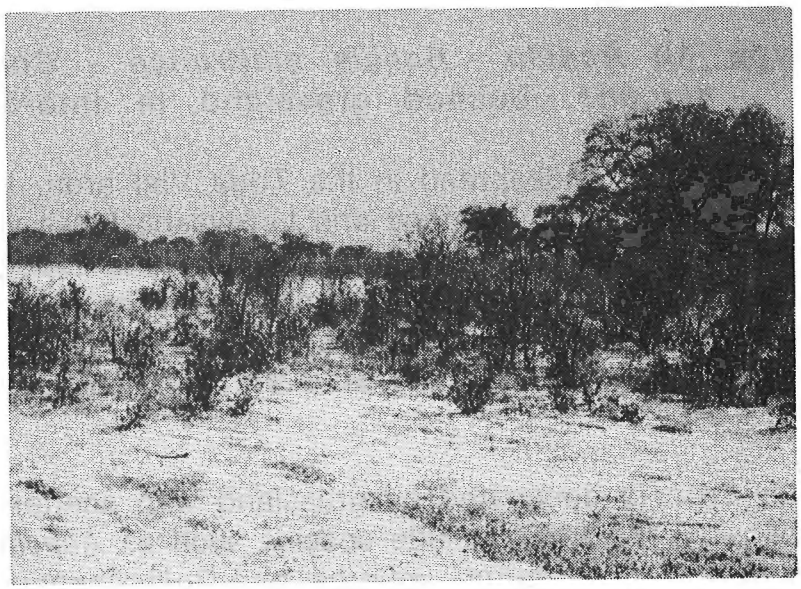


Fig. 9. Dendrogram showing the TWINSPAN classification of types 17 to 23 in groups F and G.

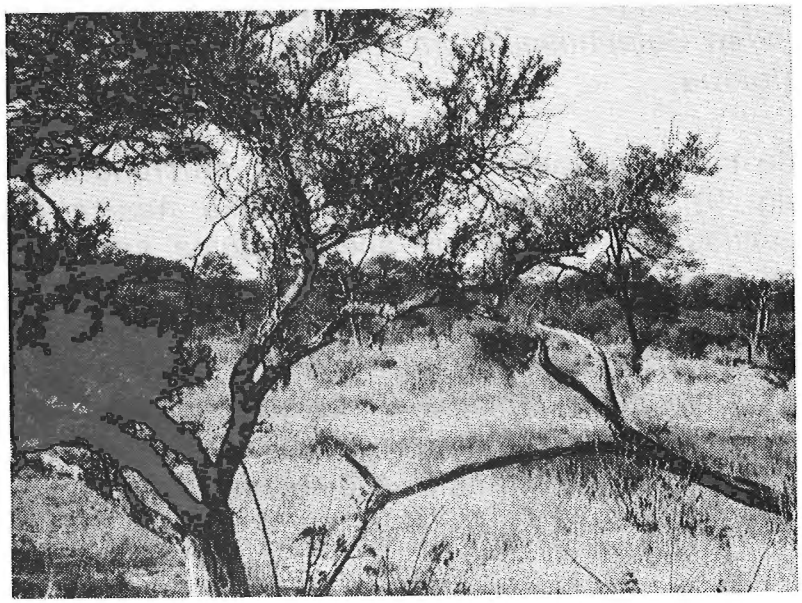
The numbers in circles denote the level of division in the classification. The species listed below or adjacent to each type number are the TWINSPAN indicator species.

The numbers which sometimes follow the name of a species refers to the height class of the indicator species.

Plate 10. **Type 17 *Colophospermum mopane* woodland - *Combretum* bushed grassland mosaic on ecotone Kalahari sands.** This photograph was taken south-west of Nehimba. Note the large *C. mopane* trees and the mopane scrub interspersed with the *Combretum* bushed grassland on the left.



Type 18 *Acacia - Boscia albitrunca - C. mopane* bushed grassland in interdune troughs. The dune trough just before Josivanini, coming from Makona. Note the big *Boscia albitrunca* bush in the foreground on the left, and the acacias and mopane trees behind in the bushed grassland.



The surface soils are mostly sandy clays, and the rest clays (Table 3). They are derived from the underlying geology, which is basalt, in the Dzivanini area and possibly in the Mopane Pan to Nehimba areas. There are several species which frequently occur in this type which are more typical of non-Kalahari sand vegetation types such as *Colophospermum mopane*, *Combretum apiculatum*, *Lonchocarpus capassa* and *Acacia nigrescens* (Table 2) indicating the ecotonal nature of this community.

Type 18 *Acacia - Boscia albitrunca - Colophospermum mopane* bushed grassland in interdune troughs.

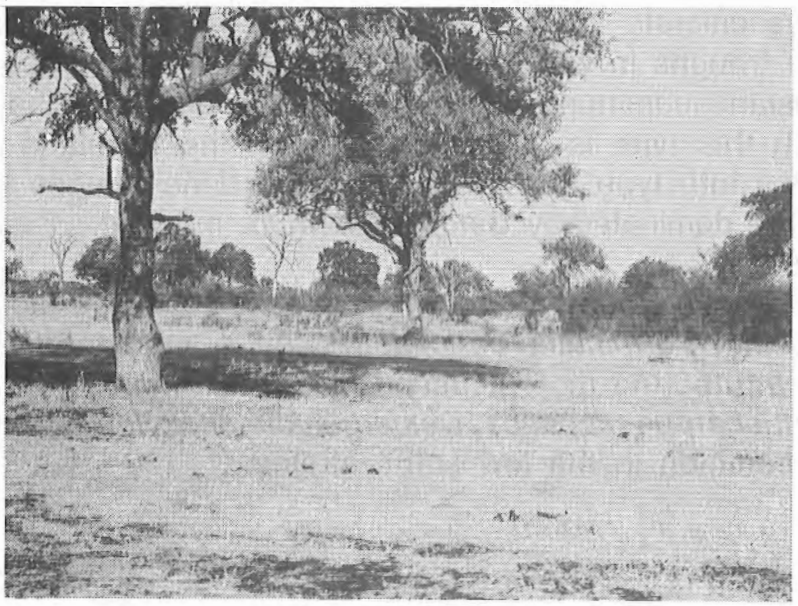
This type is widespread in the Triga Vlei area, Libuti, Josivanini, on the Jupanda, Manga, Kennedy and Linkwasha fossil vleis. It is associated with inter-dune troughs and fossil vlei line topography of the Kalahari sands (Figs. 10 and 11). It is also found on the ecotone Kalahari sands in an area south of Libuti, near Leasha. It is the most extensive type within this group covering an area of 781,8 square kilometres (Table 4b).

This type is dominated by grassland with scattered clumps of trees and bushes. The trees include species such as *Acacia erioloba*, *A. luederitzii*, *Combretum imberbe* and *Colophospermum mopane*, and the bush species are mainly *Combretum hereroense*, *C. apiculatum*, *Acacia erubescens*, *Grewia flavescens* var. *flavescens*, *Dichrostachys cinerea*, *Commiphora africana*, *Diospyros lycioides* and *Ziziphus mucronata*. *Boscia albitrunca* is a very noticeable evergreen constituent of this community with its striking gnarled, white trunk. Some individuals grow to about 5m in height, and they are often associated with anthills. There are scattered seasonal pans all along the dune troughs, with clumps of *Ziziphus mucronata* and *Diospyros lycioides* often fringing the pan edge. There is also typically a large tree at the pan edge - a 15 to 20m *Colophospermum mopane*, *Combretum imberbe* or *Acacia erioloba*.

The indicator species are *Ziziphus mucronata* and *Boscia albitrunca* (Fig. 9). Differential species include *Acacia luederitzii*, *A. fleckii*, *Commiphora angolensis* and *Mundulea sericea*, which separate this type from both types 17 and 19 in this group (Table 2). Type 18 is distinguished from type 19 in calcrete areas, mainly by *Colophospermum mopane* which is more common in this type, but also by *Commiphora africana*, *C. pyracanthoides*, *C. angolensis*, *Combretum albopunctatum*, *Mundulea sericea*, *Acacia luederitzii*, *Lonchocarpus nelsii*, *Boscia albitrunca* and *Grewia flava*.

Plate 11. **Type 18 *Acacia - Boscia albitrunca - C. mopane* bushed grassland in interdune troughs.** A dune trough at Mvalasangwane Pan which is north of Basha Pan. Such seasonal pans are common in dune troughs. *Ziziphus mucronata* is almost always found at the pan edge. Note the stunted Mopane, and the *Boscia albitrunca* on the right.

Type 19 *Combretum hereroense - Hyphaene* bushed grassland on calcrete. Makwa Pans. Both of the large trees seen here are *Combretum imberbe*, which is the indicator species for this type. Note the clumps of *C. hereroense* and *Diospyros lycioides* bushland. In the distance are *Diospyros mespiliformis* trees.



This type occurs mainly on sandy clay soils, clays and on shallow sands.

Type 19 *Combretum hereroense - Hyphaene* bushed grassland on calcrete.

Type 19 is found mainly in the east of the Park, in calcrete areas such as the ten mile drive, Ngweshla, Makwa, at the top of the Kennedy vlei, Mbiza to Ngamo at the heads of fossil vlei lines and in the Josivanini and Shape areas (Fig. 12). It is also found in inter-dune troughs of the northern dunes ie. from Josivanini north and east to the Mbazu and Mandiseka area in the Park (Figs 10 and 11). Some of the larger areas of calcrete, such as Makalolo and Ngamo, may have been playa lakes during the third pluvial of the Pleistocene era (Thomas, 1982). Type 19 covers an area of 334,3 square kilometres (Table 4b).

This type is the most diverse of the Kalahari sand types (107 species). The community is characteristically open bushed grassland dotted with *C. imberbe* trees and sometimes tall (25 metre) *Hyphaene* palms, and clumps of *C. hereroense*, *Diospyros hereroense* and *Dichrostachys cinerea* bushes. There is some concern over the regeneration of the *Hyphaene* palms since there are no palms of intermediate height or age (eg. on the Mbiza or Makalolo flats).

Common species include *Terminalia sericea* and *C. zeyheri* (Table 2). The indicator species are *Burkea africana* and *Combretum imberbe* (Fig. 9). Differential species include *Diospyros mespiliformis*, *Maytenus senegalensis*, *Peltophorum africanum*, *Ochna pulchra* and *Diplorhynchus condylocarpon*.

These calcrete areas are more extensive in area than the long, narrow dune troughs in which the *Acacia - Boscia albitrunca* - Mopane bushed grassland community is found. At the edges of the calcrete areas, with which this type is usually associated, the bushland becomes thicket and grades into type 30. In the northern dune troughs this vegetation type may be dominated by *Colophospermum mopane*.

Combretum imberbe and *C. hereroense* are the most common species of tree, with *Terminalia sericea*, *Maytenus senegalensis* and *Peltophorum africanum* the most common of the tall shrubs (Appendix 4). *Lonchocarpus capassa*, *Dalbergia melanoxylon* and *Grewia monticola* are common in the low shrub stratum.

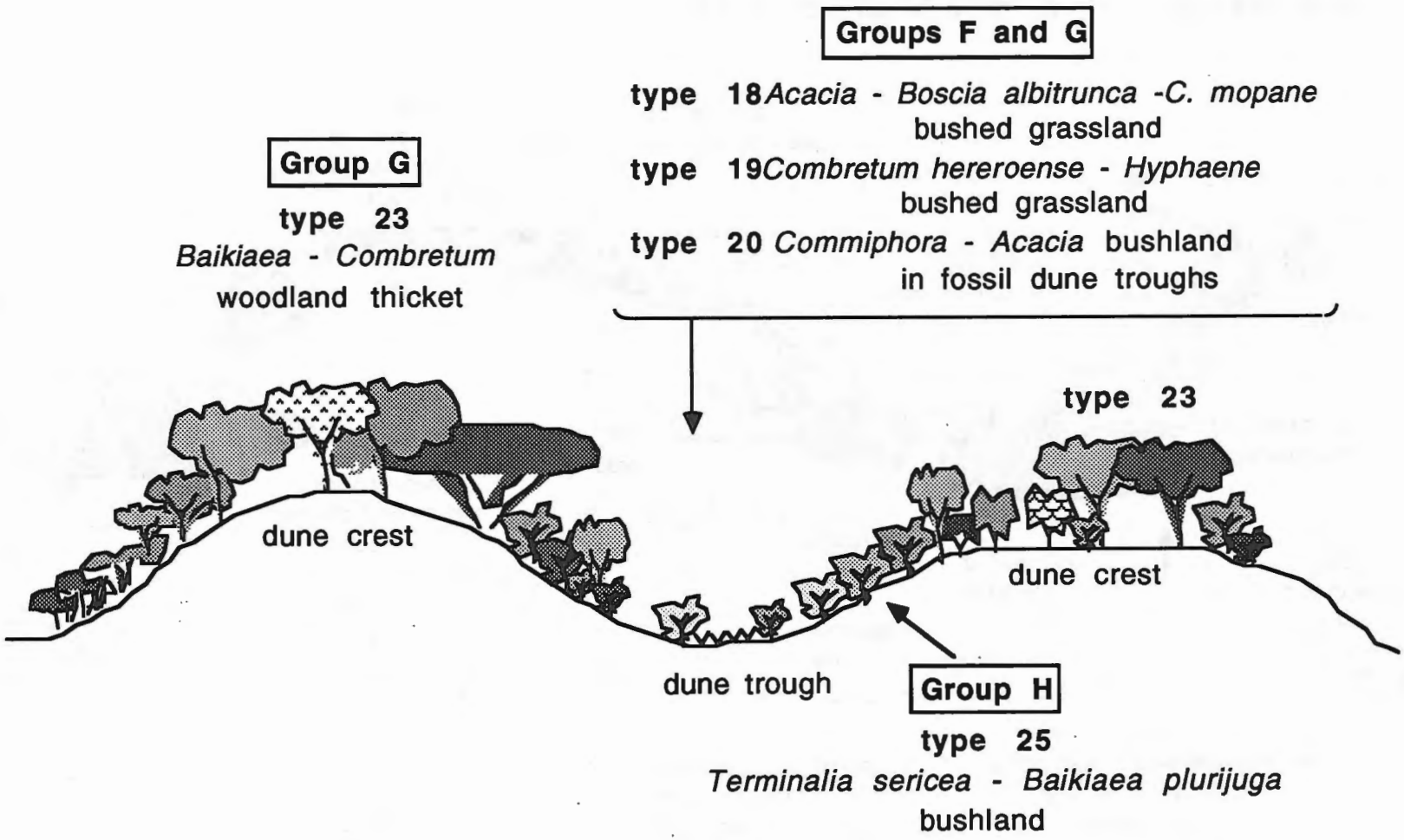


Fig. 10. The relationship of vegetation types to fossil sand dune topography.

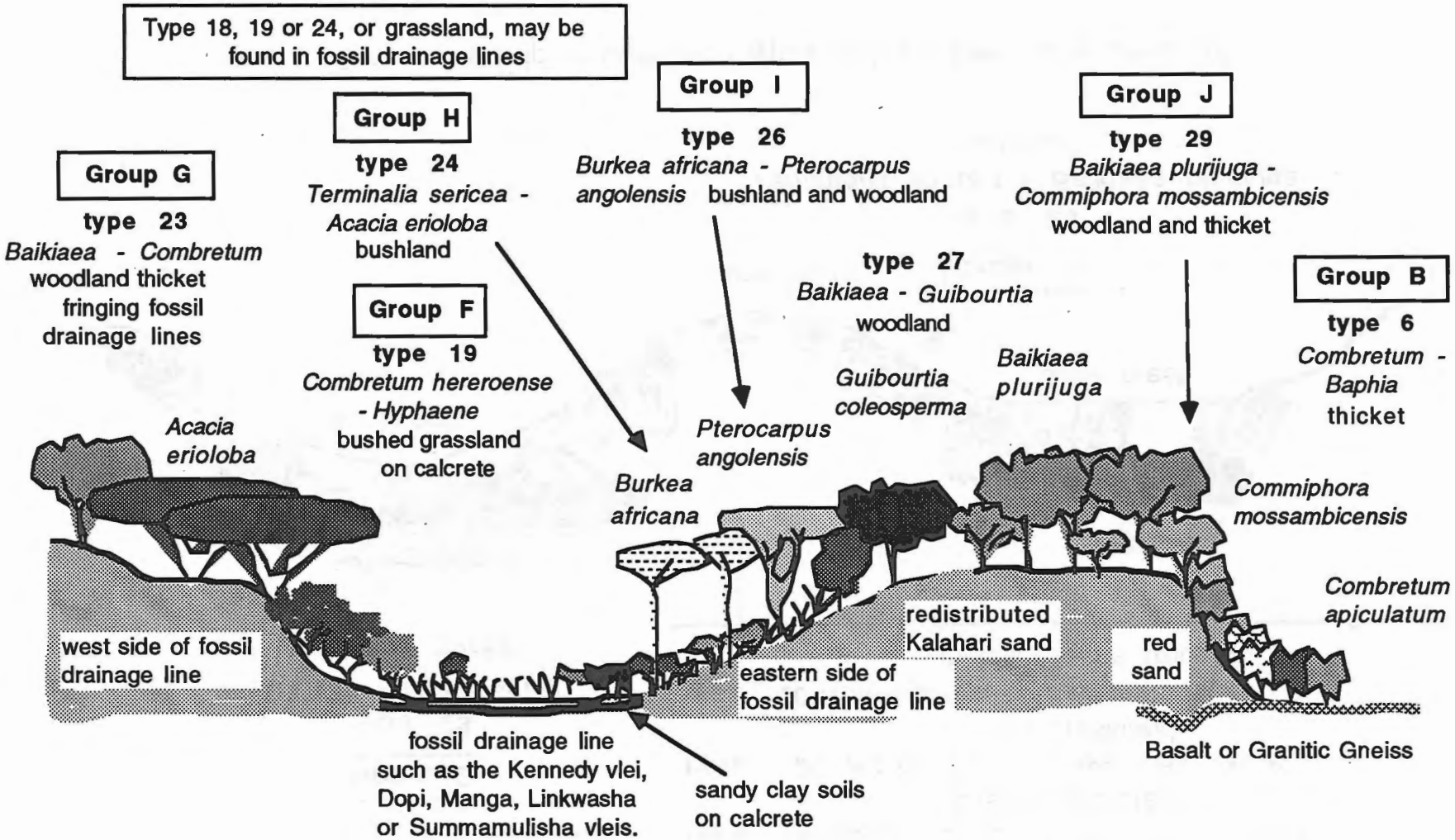


Fig. 11. The relationships of vegetation types to fossil drainage lines and redistributed Kalahari sands.

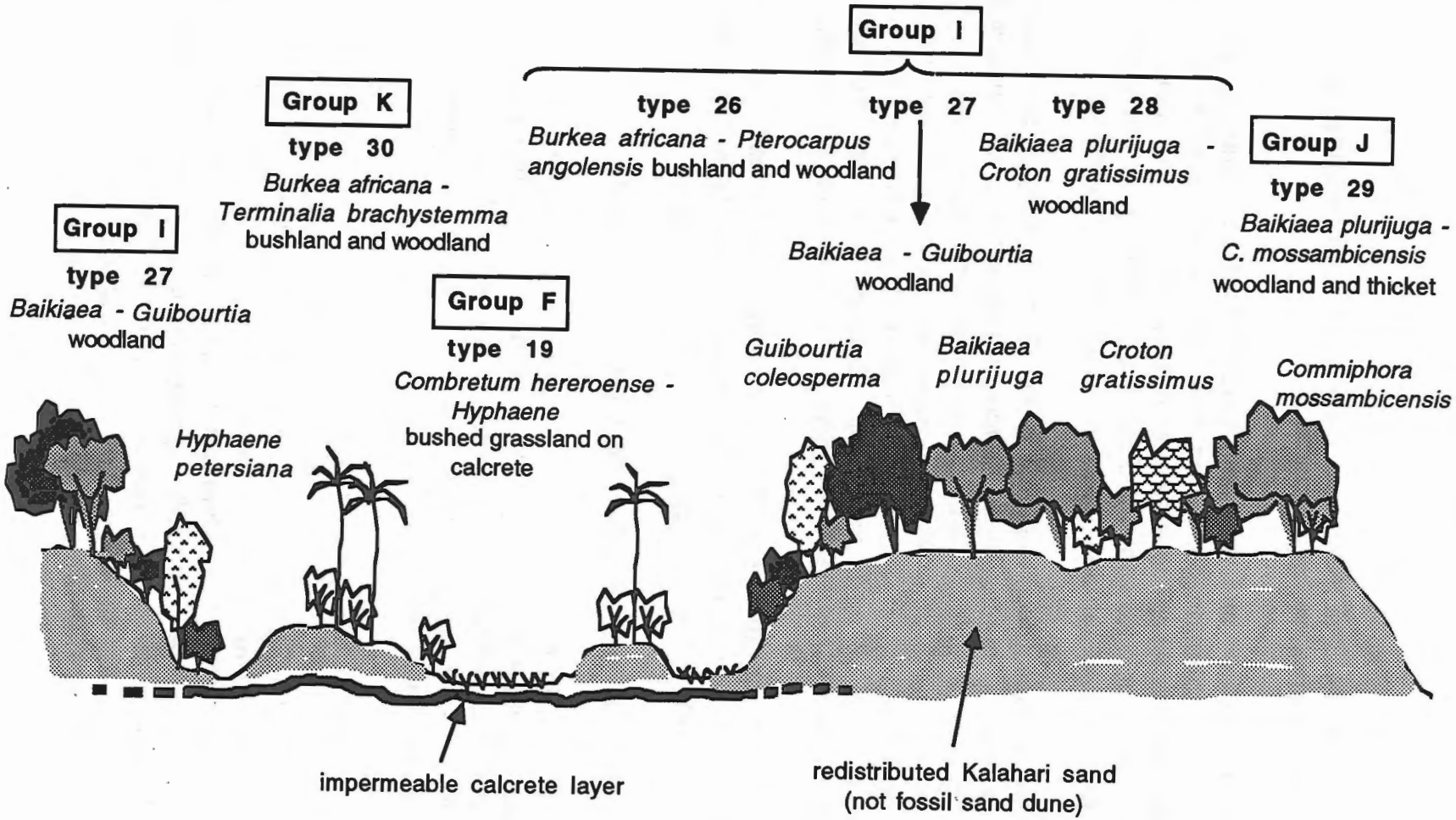


Fig. 12. The relationship of vegetation types to calcrete areas and deeper soils of the Kalahari sands.

Most samples were associated with sandy clay soils, some with clay soils and the rest with shallow sand and deep sand (Table 3), all on calcrete.

Group G. *Acacia - Baikiaea* bushland and woodland on Kalahari sands.

This group of bushland and woodland types (20, 21, 22 and 23) is widespread in distribution, occurring from the railway line in the east to the Botswana border. The area covered by the group is about 3106,6 square kilometres or 21,8% of the Park (Table 4b). It is the most extensive group of vegetation types with 106 woody species.

The indicator species which separate group G from group F are *Ochna cinnabarina*, *Baphia massaiensis*, *Acacia ataxacantha* and *Hippocratea indica* (Fig. 9). Species which are relatively well represented in this group compared to the other Kalahari sand groups include *Mundulea sericea*, *Lonchocarpus nelsii*, *Acacia luederitzii* and *Boscia albitrunca*. These species are all particularly well represented in type 20 which is widespread in the Triga Vlei area (Shakwanki and Mitswiri areas).

The trend in this group has shifted from clayey soils, associated with group F, to more sandy soils and deep sands (possibly with a relatively high clay content) in the last type (type 23) (Table 3).

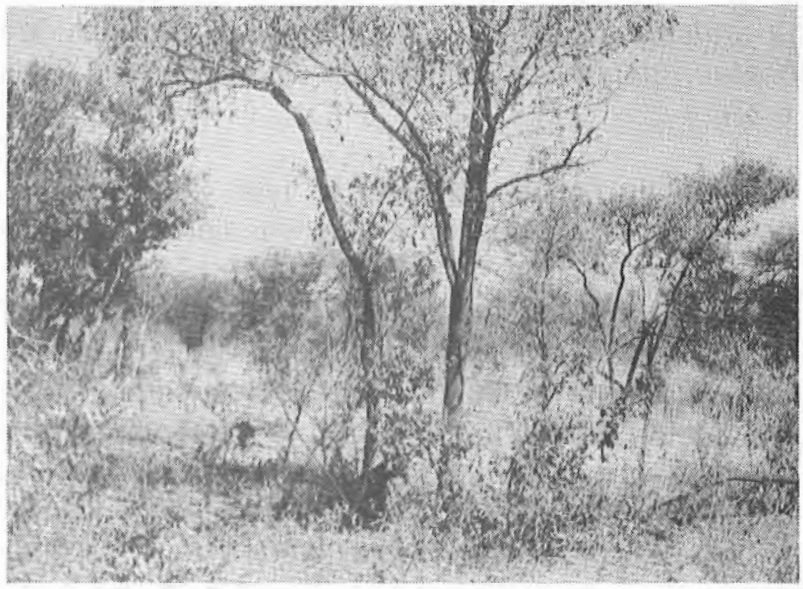
Type 20 *Acacia - Mundulea sericea* bushland.

Type 20 is found in the Triga vlei, Wexcau area, Josivanini, Umkowazaan, Shape and Guvalala area and is associated with inter-dune troughs and eroded dune troughs especially in the Triga Vlei system (Fig. 10). It covers an area of 967,2 square kilometres, nearly 7% of the Park (Table 4b).

This bushland is usually dominated by *Acacia* species such as *A. luederitzii* and *A. ataxacantha*, and sometimes *A. erubescens*. *Colophospermum mopane*, *Lonchocarpus nelsii* and *Boscia albitrunca* may also be dominant or very common, although the latter species is not found in the northern Kalahari sand areas. In the tree canopy layer only three species are commonly represented in samples - *Acacia erioloba*, *Lonchocarpus nelsii* and *A. luederitzii*. *Mundulea sericea* is almost always present as a tall shrub, and *Dichrostachys cinerea*, *Terminalia sericea*, *Combretum collinum*, *Grewia flavescens* var.

Plate 12. **Type 20** ***Acacia - Mundulea sericea*** **bushland.** 35 km north of Little Dzivanini along the Botswana border road. Note the *Mundulea sericea* in the foreground (left) and the *Acacia luederitzii* and *Boscia albitrunca* on the right in the background.

Type 21 ***Terminalia sericea - Lonchocarpus nelsii*** **bushland.** 24 km from the turn-off to Little Dzivanini on the Botswana border. Note the *Combretum collinum* bush in the foreground, and the *Lonchocarpus nelsii*, *Terminalia sericea* and *Dichrostachys cinerea* in the background.



flavescens, *Combretum hereroense* and *Ochna cinnabarina* are also very common shrubs.

The indicator species is *Mundulea sericea* (Fig. 9). Other species which differentiate this type from other types in this group include *Combretum albopunctatum* and *Rhigozum brevispinosum* (Table 2).

This type is mostly found on sandy clay surface soils, some on shallow sandy soils and a few on clay soils (Table 3).

Type 21 *Terminalia sericea* - *Lonchocarpus nelsii* bushland.

Type 21 is found in the Guvalala, Nyamandhlovu, Sinanga and Umkowazaan to Libuti areas on flat terrain, in shallow fossil drainage lines and in or adjacent to dune troughs on sandy clay soils (Table 3). It extends over an area of 782 square kilometres (Table 4b).

This type has a variable physiognomy, from bushland to thicket and woodland, but is most often bushland. *Lonchocarpus nelsii*, *Combretum collinum*, *Terminalia sericea* and *Acacia erioloba* trees are often present (Appendix 4). In the tall shrub layer *Dichrostachys cinerea* and *Acacia ataxacantha* are the most frequently encountered species, with others such as *Acacia fleckii*, *Combretum collinum*, *Ochna pulchra*, *Grewia flavescens* var. *flavescens* (which is always present) *Combretum zeyheri* and *Lonchocarpus nelsii*. The indicator species is *Ochna pulchra* (Fig. 9). Differential species include *Burkea africana*, *Combretum psidioides*, *Diospyros lycioides* and *Ziziphus mucronata* (Table 2).

This community occurs adjacent to type 23 *Baikiaea* woodland and type 26 *Burkea africana* bushland and woodland. It mainly occurs in an area which was logged from the 1920's until 1944 and has a high elephant density in the dry season. This vegetation may thus be a degraded form of *Baikiaea* woodland as Childes and Walker (1987) have suggested. However, in terms of its woody species composition this seems unlikely, since *Baikiaea plurijuga* is rarely present. In areas where there is evidence of large *Baikiaea* trees having been present in the past, *Baikiaea* is commonly present as a coppicing shrub (Rushworth, 1975). Species such as *Acacia luederitzii*, *Diospyros lycioides* and *Mundulea sericea* which are not normally associated with disturbed

sites (in semi-arid ecosystems), but rather with sandy clay soil types, are present in a third of the representative samples.

There are equal numbers of samples on sandy clay and shallow sands and few samples on clay and deep sands (Table 3).

Type 22 ***Colophospermum mopane - Combretum apiculatum*** **bushland.**

This type occurs in the Manga Two area, Makona, Wexcau, Triga vlei and Josivanini area in flat, depressed areas on sandy clay soils. It covers an area of only 28,3 square kilometres, the least extensive of the Kalahari sand types (Table 4b).

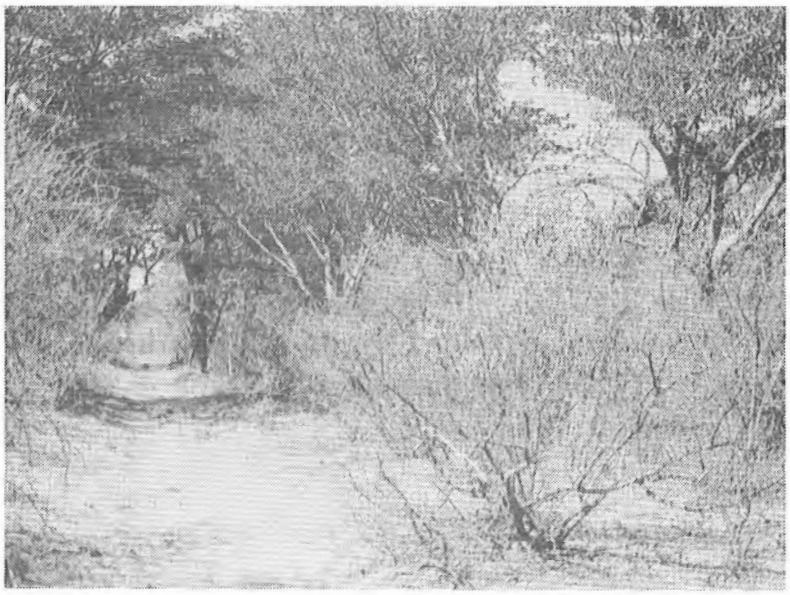
This type is most often a bushland but can vary in physiognomy from bushed grassland to woodland and thicket. *Colophospermum mopane* trees are common although not usually dominant. Scattered *Combretum apiculatum*, *Acacia fleckii*, *Boscia albitrunca*, *Terminalia sericea* and *Baikiaea plurijuga* trees are also common. In the tall shrub layer *Lonchocarpus nelsii* and *Combretum collinum* are common constituents. The presence of *Colophospermum mopane* and *Baikiaea plurijuga* together in the same community is unusual. They are usually representative of the shallow clay soils and deep sandy soils respectively. This type is represented by only 8 samples and needs more study to confirm or re-classify it. The samples may have been situated on local ecotones between deep sand and shallow clay soils.

The indicator species are *Colophospermum mopane* and *Dalbergia melanoxylon* (Fig. 9). Other species which differentiate this type from the other types in group G include *Markhamia zanzibarica*, *Erythroxylum zambesiacum*, *Cissus cornifolia*, *Commiphora mossambicensis*, *Allophyllus africanus*, *Combretum apiculatum*, *Euclea divinorum*, *Peltophorum africanum*, *Dichapetalum rhodesicum* and *Pterocarpus angolensis* (Table 2).

This type occurs mostly on sandy clay soils (Table 3). It was separated from type 21 (*Terminalia sericea - Lonchocarpus nelsii* bushland) in the 5th level of divisions, by the high percentage of *Colophospermum mopane* . This type may be a sub-type of type 21 and could be grouped with it.

Plate 13. **Type 22 *Colophospermum mopane - Combretum apiculatum* bushland.** 5 km past Wexcau on the way to Mfagazaan. Note the unusual association of *C. mopane* and *Baikiaea plurijuga* .

Type 23 *Baikiaea - Combretum* woodland thicket on fossil sand dune crests. This photograph was taken in the wide band of *Baikiaea* woodland bordering the northern edge of the Dzivanini flats, from the road which goes to Leasha Pan. Note the *Combretum celastroides* bushes in the foreground and the *Baikiaea plurijuga* trees behind.



Type 23 *Baikiaea* - *Combretum* woodland thicket on fossil sand dune crests.

This woodland thicket type is found mainly on fossil sand dune ridges in the central and southern Kalahari sand areas of the Park and on the western edges of most fossil drainage lines in the eastern part of the Park (Figs. 10 and 11). It occurs west and south of the Dopi fossil drainage line as small patches of woodland surrounded by *Terminalia* - *Baikiaea* bushland (type 25). It covers an area of 1329,1 square kilometres in over 600 patches of woodland thicket and is the most fragmented vegetation type (Table 4b).

This type is dominated by *Baikiaea plurijuga* which is present in the canopy layer in all samples of this type. Other trees include *Acacia erioloba*, *Lonchocarpus nelsii* and *Croton gratissimus* the latter two of which may be classified as tall shrubs (over 3m tall). Common tall shrubs (1 - 3m tall) include *Combretum celastroides* (can be over 3m in height), *Dichrostachys cinerea*, *Ochna cinnabarina*, *Acacia ataxacantha*, *Grewia flavescens* var. *flavescens*, *Baphia massaiensis*, *Croton gratissimus* and *Acacia fleckii*. Of the low shrub (<1m tall) species *Grewia avellana* is the most commonly encountered, with *Rhus tenuinervis*, *Hippocratea indica* and *Croton pseudopulchellus*. The indicator species are *Baikiaea plurijuga*, *Combretum celastroides*, *Grewia avellana*, *Croton gratissimus* and *C. pseudopulchellus* (Fig.9).

At the edge of this woodland, *Baikiaea* trees may be replaced by pure samples of *Acacia erioloba* trees (Fig. 11). The woody understory is often poorly developed, herbaceous cover predominating (as for example opposite Kennedy 2). However in some woodlands *Combretum celastroides* and *Croton gratissimus* form dense thickets, especially on fossil sand dune crests.

According to the surface descriptions of soil texture this type mostly occurs on deep Kalahari sands (Table 3). Despite this soil description, the species composition is reflective of fine sands or sands with a proportion of clay, since there are many species in this type which are usually found on more clayey soils. Such species include *Combretum celastroides*, *Vangueria infausta*, *Acacia ataxacantha*, *Lonchocarpus nelsii* and *Ochna cinnabarina* from species group 1 (Table 2). Termite mounds are a common feature of this community.

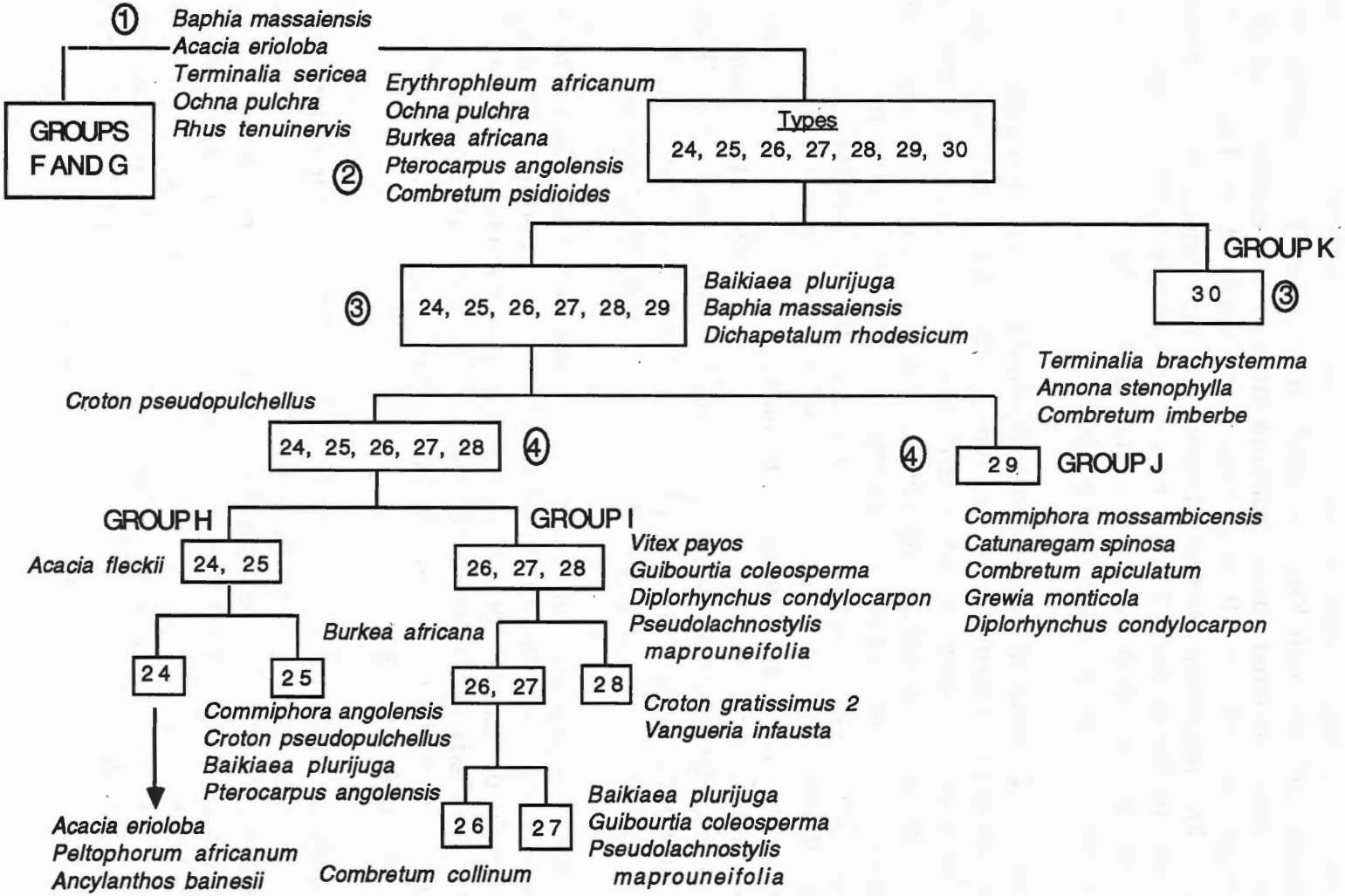


Fig. 13. Dendrogram showing the TWINSPAN classification of types 24 to 30 in groups H, I, J and K.
The numbers in circles denote the level of division in the classification. The species listed below or adjacent to each type number are the TWINSPAN indicator species.
The numbers which sometimes follow the name of a species refers to the height class of the indicator species.

Group H. *Terminalia - Combretum* bushland.

This group of bushland types (24 and 25) occurs extensively in the Kalahari sand area covering an area of 2830,7 square kilometres or about 20% of the Park (Table 4b). It differs from the former group in that the species which are typically associated with Kalahari sands, are better represented in this group (Table 2). The types of this group are part of the catena from shallow to deeper Kalahari sands, that is, between the edge of fossil drainage lines or dune troughs and the deeper Kalahari sands.

Combretum species (*C. collinum* and *C. zeyheri*) and *Terminalia sericea* dominate these types. Also common are *A. erioloba*, *Baphia massaiensis*, *Ochna pulchra*, *Combretum psidioides*, *Croton pseudopulchellus*, *Erythrophleum africanum* and *Burkea africana* (Table 2). There are only 70 species in this group which is the least diverse of all groups of vegetation types within the park.

Differential species *Acacia fleckii* and *Lonchocarpus nelsii* are more common in this group than in the *Baikiaea* woodland group (Group I). Group H and I bushland and woodland respectively, are more similar to each other than to Group J Ecotone *Baikiaea* woodland thicket (Fig. 13).

Type 24 *Terminalia sericea - Acacia erioloba* bushland.

This vegetation is found in or beside fossil drainage lines (especially the Dopi vlei) and in the Triga vlei where sands have been eroded (Plate 14). It thus has a relatively restricted distribution. It is much less extensive than type 25 and covers only 258,3 square kilometres, which is only a tenth of the area of type 25 (Table 4b). Soils are generally sandy clays (Table 3).

The main difference between this bushland and type 25 bushland is that *Baikiaea plurijuga* is completely absent from this type. *Terminalia sericea*, *Acacia erioloba* and *Burkea africana* are always present (usually as scattered trees), and in the tall shrub layer *Ochna pulchra* is always present with *Baphia massaiensis, Combretum psidioides* and *Acacia fleckii.* Common low shrubs are *Bauhinia petersiana*, *Ancylanthos bainesii* and *Acacia ataxacantha.*

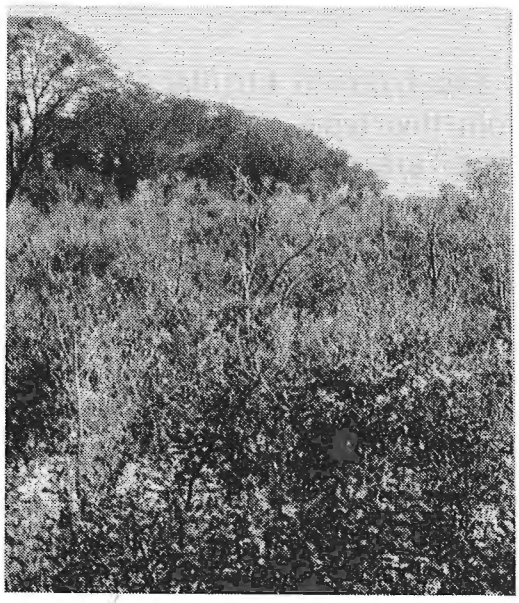
The indicator species are *Acacia erioloba*, *Peltophorum africanum* and *Ancylanthos bainesii* (Fig. 13). Other differential species (which separate this type from type 25), are *Commiphora africana*,

Plate 14. **Type 24 *Terminalia sericea - Acacia erioloba* bushland.** North of Ngwasha on the Botswana border. Note the *Burkea africana* on the left, and the *Terminalia sericea* on the right with *Acacia erioloba* some metres behind it.

Type 25 *Terminalia sericea - Baikiaea plurijuga* bushland.

(Left) South of Matambonyati Pan, looking from the road through stunted *Baikiaea plurijuga* bushland on the edge of a dune trough, toward dune crest woodland (type 23).

(Right) 8-9 km north of Mitswiri. *Terminalia sericea* bushland.



Diplorhynchus condylocarpon, *Combretum hereroense*, *Strychnos spinosa* and *Vitex payos* (Table 2).

This bushland often forms the intermediate part of a continuum from bushed grassland types on clayey sands (types 18, 19 or 20) in fossil drainage lines to woodlands on deep sands (types 27 and 28). Depending on the soil conditions, this type may also be the lowest community on the catena (eg. in the fossil drainage line of Dopi). It grades into *Terminalia - Baikiaea* bushland (type 25) up the slope, then into *Burkea - Pterocarpus* bushland and woodland (type 26), and finally into *Baikiaea* woodland (type 27 or 28) on the deepest sands at the top of the slope (Fig. 11).

Half of the samples of this type are found on sandy clay soils, and a third on shallow sand, at the edges of fossil vlei lines (Table 3).

Type 25 ***Terminalia sericea - Baikiaea plurijuga*** **bushland.**

This *Terminalia sericea* bushland is the most widespread of all vegetation types covering an area of 2572,4 square kilometres or 18% of the Park (Table 4b). Although *Baikiaea plurijuga* does not occur in every sample representing this type, species which are usually associated with *Baikiaea* do. Thus *Bauhinia petersiana*, *Combretum collinum*, *Baphia massaiensis* and *Croton pseudopulchellus* are almost always present in this type. The latter species is one which differentiates this type from the former *Terminalia* bushland type.

It is found west of Nyamandhlovu Pan and near Caterpillar, to the Botswana border and to the southern-most limit of the Kalahari sand. It occurs on deep redistributed Kalahari sand and on fossil dune crests adjacent to type 23 *Baikiaea plurijuga - Combretum celastroides* woodland (Fig. 10). *T. sericea* bushland is often intermediate in the catena from fossil drainage lines to the top of the redistributed sand (Fig. 11).

Species which occur with the dominant *Terminalia sericea* include *Baikiaea plurijuga*, *Combretum collinum*, *C. zeyheri*, *Ochna pulchra*, *Baphia massaiensis*, *Dichrostachys cinerea*, *Acacia ataxacantha*, *A. fleckii* and *Croton pseudopulchellus*. The indicator species are *Commiphora angolensis*, *Croton pseudopulchellus*, *Baikiaea plurijuga* and *Pterocarpus angolensis*. Another species which differentiates this type from type 24 in this group is *Lonchocarpus nelsii* (Table 2).

Most of the samples of this type are on deep sand, with a few samples on sandy clay and shallow sands (Table 3). This is reflected in the species composition; whereas *Acacia erioloba* is present in fewer samples, *Baikiaea plurijuga* is a more common species in this type.

There may be two types of *Terminalia* bushland within this type - one with *Baikiaea* shrubs present and one without.

Group I. *Baikiaea plurijuga* woodland and bushland on deep Kalahari sands.

Within this group are two typical *Baikiaea* woodland types and a bushed woodland type (Fig. 13). It covers an area of 2352 square kilometres or 16,5% of the Park (Table 4b). Type 27 is widely distributed in the Main Camp to Mandiseka area in the east of the Park (Fig. 1). Types 26 and 28 are found in the eastern Kalahari and west of the extension of Manga fossil drainage line and between Dina pan, Tibukai and Cement on the Botswana border. From the distribution pattern it appears that the types of this group are mainly confined to sand that has been redistributed, and are not found on fossil dune crests, as is type 23 *Baikiaea* woodland thicket (Fig. 10).

There is a gradient in physiognomy from bushland to *Baikiaea* woodland in this group. Type 26 is predominantly bushland, sometimes woodland, while types 27 and 28 are mainly woodland in physiognomy (Appendix 2). There is a large scale catena which can be seen on the vegetation map as follows: type 26 is often found adjacent to fossil drainage lines, grading into type 27 (which may also be found adjacent to type 30 and calcrete areas (type 19)); type 27 grades into type 28 toward the edge of the Kalahari sands; and type 28 grades into type 29 ecotone *Baikiaea* woodland on the fringes of the Kalahari sands. Like Group H this is not very diverse in species composition with only 72 woody species.

The indicator species for this group are *Vitex payos*, *Guibourtia coleosperma*, *Diplorhynchus condylocarpon* and *Pseudolachnostylis maprouneifolia* (Fig. 13).

Type 26 ***Burkea africana - Pterocarpus angolensis*** **bushland and woodland.**

This type is usually found in the eastern edges of fossil vlei lines, on redistributed Kalahari sands. It is often found adjacent to *Baikiaea - Guibourtia coleosperma* woodland, type 27 (Figs 11 and 12), and is also widely distributed west of the Manga vlei line. This type and type 27 grade into each other, and thus a definite boundary between the two is difficult to identify. It is the most extensive of the three types within this group covering 1336,8 square kilometres (Table 4b).

This bushland to woodland type is dominated by *Burkea africana*, *Terminalia sericea* and *Erythrophleum africanum*. Common shrubs include *Combretum zeyheri*, *C. psidioides*, *Baphia massaiensis*, *Combretum collinum* and *Ochna pulchra* and *Vitex payos* (Table 2). *Diplorhynchus condylocarpon*, *Bauhinia petersiana*, *Strychnos spinosa* and *Guibourtia coleosperma* are common as low shrubs.

The indicator species is *Combretum collinum*, separating this type from type 27 (Fig. 13). Other differential species include *Acacia ataxacantha*, *Croton pseudopulchellus* and *Dichapetalum rhodesicum*. *Baikiaea plurijuga* is present in only two thirds of the samples of this type, which is similar to type 25 (Table 2).

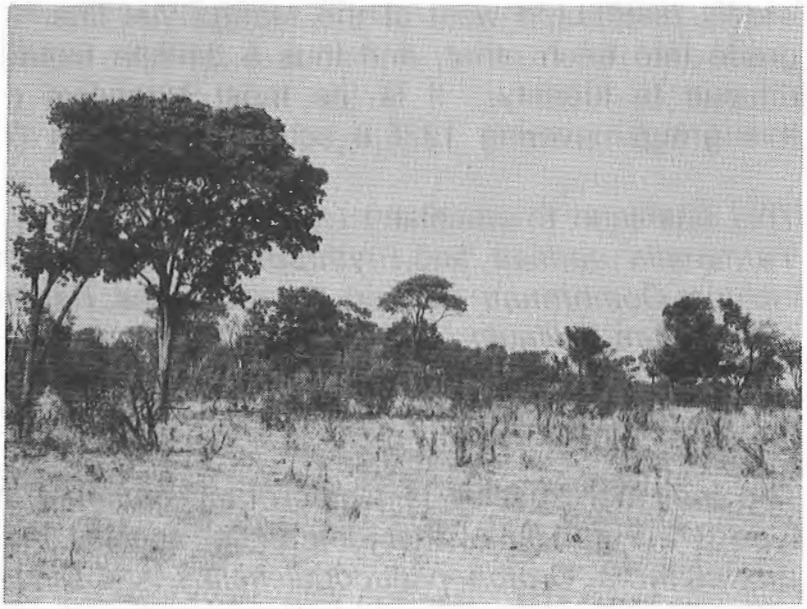
This type differs from type 25 in that *Guibourtia coleosperma* and *Diplorhynchus condylocarpon* are virtually absent from type 25. Also species which are relatively common in type 25, such as *Lonchocarpus nelsii*, *Acacia fleckii*, *A. ataxacantha*, *Grewia flavescens* var. *flavescens*, *Commiphora angolensis* and *Dichrostachys cinerea* are less frequently present in this type (Table 2).

Most of the samples representing this type were found on deep sands, with a few samples on shallow sandy clay soils (Table 3).

Type 27 ***Baikiaea plurijuga - Guibourtia coleosperma*** **woodland.**

This vegetation type is found only in the eastern Kalahari sand areas, on deep redistributed sand, and is often situated adjacent to type 30 and calcrete areas (Figs 11 and 12). It is more extensive than type 28 covering an area of 604 square kilometres. It is found around Main Camp and down to Ngamo in the east, and as far as Manga Vlei in the west. It is not found west of the Manga Vlei extension in this Park.

Plate 15. **Type 26 *Burkea africana - Pterocarpus angolensis* bushland and woodland.** Near Kennedy I Pan looking south-east. Note the large *Erythrophleum africanum* tree on the left and the *Burkea africana* trees in the distance.



Type 27 *Baikiaea plurijuga - Guibourtia coleosperma* woodland. At the turn-off to Mtchibi Camp on the main road to Makwa Pans, looking back along the road. Note the large *Guibourtia coleosperma* trees in the foreground, the leaning *Baikiaea plurijuga* tree and the light-grey foliage of the *Erythrophleum africanum* trees in background on the left.

Since the rainfall is thought to be on average higher in the east of the Park than the west, one could hypothesize that this type is associated with more moist or mesic conditions.

This woodland is dominated by *Baikiaea plurijuga* and *Guibourtia coleosperma*. *Croton pseudopulchellus*, *Erythrophleum africanum* and *Pterocarpus angolensis* are important constituents (Table 2). *Burkea africana* and *Terminalia sericea* are also often present as trees. *Ochna pulchra*, *Terminalia sericea*, *Combretum zeyheri* and *Pseudolachnostylis maprouneifolia* are common tall shrubs. In the low shrub stratum *Diplorhynchus condylocarpon*, *Strychnos spinosa*, *Vitex payos* and *Pterocarpus angolensis* are common. The indicator species are *Baikiaea plurijuga*, *Guibourtia coleosperma* (1-3 m) and *Pseudolachnostylis maprouneifolia*. Other species which differentiate this type from type 29 are *Dichrostachys cinerea* and *Acacia erioloba* (Table 2).

All the samples representing this type were described as being on deep sands from a surface assessment (Table 3).

Type 28 ***Baikiaea plurijuga - Croton gratissimus*** **woodland.**

This type is very similar to type 27, and is found near Dete, on White Hills and in the west of the Kalahari sand area near Shakwanki and north east of Xibi Amabandi. It covers an area of 411,4 square kilometres (Table 4b). It is found on deep redistributed Kalahari sand, and is characteristically found on the catenal position between type 27 and ecotone *Baikiaea plurijuga* woodland to bushland (type 29) (Figs 11 and 12).

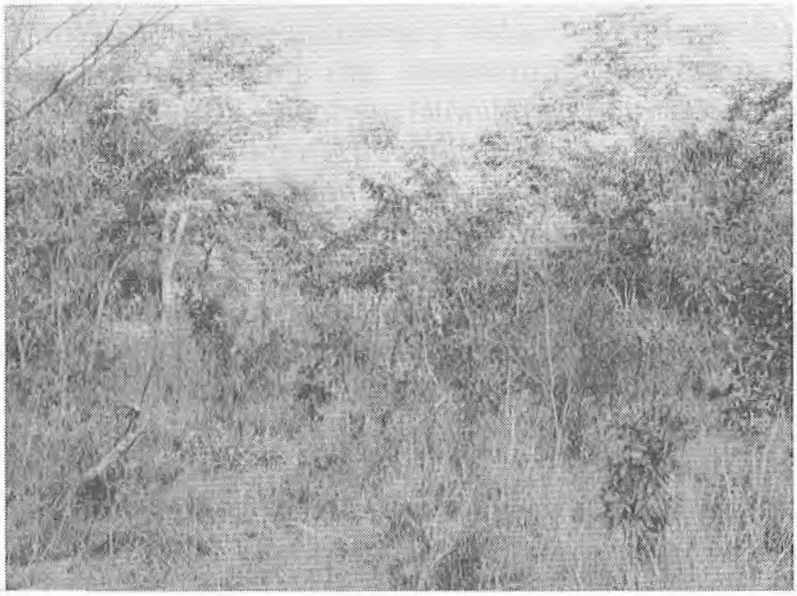
This type could be divided into two communities on the basis of distribution ie.

i) the woodland on White Hills
ii) the woodlands near Njekwa and south of Dandari to the Botswana border and south of Mitswiri

More sampling would be needed to establish floristic differences.

The TWINSPAN indicator species are *Croton gratissimus* (1-3m) and *Vangueria infausta* (Fig. 13). Other species which differentiate this

Plate 16. **Type 28 *Baikiaea plurijuga - Croton gratissimus* woodland.** White Hill, past Bembesi on the way to Tshabema. Note the small *Baphia massaiensis* bush in the foreground and the *Baikiaea plurijuga* trees behind.



Type 29 Ecotone *Baikiaea plurijuga - Commiphora mossambicensis* woodland and thicket. Near Manzimbomvu Pan in the Robins sub-region. Note the *Commiphora mossambicensis* bushes on the right and the *Baikiaea plurijuga* trees on the left and in the background.

type from types 26 and 27 are *Grewia monticola*, *Rhus tenuinervis* and *Grewia avellana* (Table 2).

In this woodland type *Baikiaea plurijuga* is almost always present as a tree, with *Guibourtia coleosperma* and *Croton gratissimus*. In the tall shrub layer *Croton pseudopulchellus*, *C. gratissimus*, *Baphia massaiensis*, *Combretum zeyheri*, *C. collinum*, *C. psidioides*, *Ochna pulchra*, *Terminalia sericea* and *Vangueria infausta* are common. In the low shrub layer *Dichapetalum rhodesicum*, *Dichrostachys cinerea*, *Grewia avellana*, *Bauhinia petersiana* and *Burkea africana* are common (Appendix 4).

Most samples occurred on deep sands and a few on shallow sands (Table 3). In terms of species composition type 28 is intermediate between typical *Baikiaea - Guibourtia* woodland (type 27), and *Baikiaea - Commiphora* woodland thicket (type 29) found on the red Kalahari sands in the north of the Park. It is similar to type 27 in that *Guibourtia coleosperma*, *Baikiaea plurijuga*, *Combretum psidioides* and *Ochna pulchra* are common; and to type 29 in that *Grewia monticola*, *Vangueria infausta*, *Croton gratissimus*, *Rhus tenuinervis*, *Combretum collinum* and *Dichapetalum rhodesicum* are common. The distribution of type 28 is, in some areas such as north of Main Camp and on White Hill, in an intermediate position between type 27 and 29.

Brachystegia spiciformis is an uncommon constituent of this type, at the edges of its distribution in the east of the Park (mostly around Dete). Near Dete type 28 grades into a tall (about 20 m) woodland type dominated by *B. spiciformis*, *Baikiaea plurijuga* and *Guibourtia coleosperma*. This type occurs just outside the Park at Dete through the Ganda Forest Reserve to the Hwange Main Airport and the main Bulawayo - Victoria Falls road. The sands appear deep and white, but the altitude of these woodlands is over 1100 m, and they are in a rainfall area in which over 600mm generally falls.

Group J. Ecotone *Baikiaea plurijuga* woodland and thicket on red Kalahari sands.

Type 29 Ecotone *Baikiaea plurijuga - Commiphora mossambicensis* woodland and thicket.

Ecotone *Baikiaea plurijuga - Commiphora mossambicensis* woodland thicket is found in the northern reaches of the Kalahari sand - the most extensive tracts of this type being in the Robins sub-region. It covers

an area of 855,4 square kilometres within the Park (Table 4b). It is a well developed *Baikiaea* woodland type, in terms of canopy cover and its diverse and dense understorey. It is not as tall as the *Baikiaea* woodlands of Group I, which have an average height of 8 m, as opposed to 10 to over 15 m in the other *Baikiaea* woodland types.

This Teak woodland being on the ecotone, has the greatest species diversity of the teak woodland types, with 99 species (Appendix 2).

In the canopy, which is dominated by *Baikiaea plurijuga*, there is also *Erythrophleum africanum*, *Combretum apiculatum*, *Terminalia sericea*, *Erythroxylum zambesiacum* and *Burkea africana*. In the tall shrub layer *Ochna pulchra*, *Baphia massaiensis*, *Combretum collinum*, *Bauhinia petersiana* and *Terminalia sericea* are common. *Catunaregam spinosa* (formerly *Xeromphis obovata*), *Diplorhynchus condylocarpon*, *Grewia monticola* and *Dichapetalum rhodesicum* are common in as low shrubs.

The indicator species are *Commiphora mossambicense*, *Catunaregam spinosa*, *Combretum apiculatum*, *Grewia monticola* and *Diplorhynchus condylocarpon* (Fig. 13). Of these, except for *Diplorhynchus condylocarpon* and *Grewia monticola*, all the other species are more typical of shallow clayey soil environments. *Commiphora mossambicensis* is a conspicuous constituent of this woodland thicket (Figs 11 and 12 and Plate 16).

Differential species include *Euclea divinorum*, *Vangueria infausta* and *Croton gratissimus*. *Croton pseudopulchellus* and *Guibourtia coleosperma* are almost always absent from this type (Table 2).

The soils of this type are mostly red and brown sands, sandy clay and clay soils (Table 3). Anthills or termite mounds are a feature of this community.

Group K. *Burkea africana* bushland surrounding calcrete areas.

Type 30 *Burkea africana* - *Terminalia brachystemma* bushland.

This Kalahari sand group is restricted in distribution to the east of the Park, from Main Camp to Ngamo, adjacent to or surrounding calcrete areas, along the top of the eastern watershed area (Fig. 12). It covers

an area of 221,8 square kilometres (Table 4b). This type appears to be periodically inundated, as is evidenced by the species composition. Its species diversity is rather low (71 species).

The vegetation is bushland, thicket or woodland dominated by *Burkea africana* and *T. sericea* with *Erythrophleum africanum*, *Combretum imberbe* and *Combretum hereroense*. It is the presence of the latter *Combretum* species, which are tolerant of waterlogged conditions, and which separate this type from type 26 *Burkea* bushland and woodland. The latter type is also found adjacent to calcrete areas.

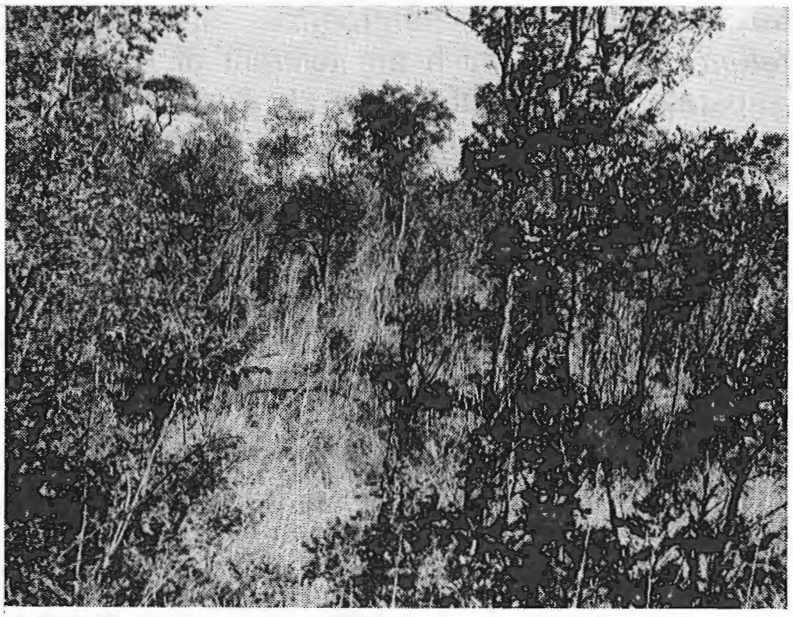
Scattered *Guibourtia coleosperma* and *Combretum imberbe* trees may be found in this type. Other common constituents include *Ochna pulchra*, *Combretum psidioides*, *Annona stenophylla*, *Diplorhynchus condylocarpon*, *Strychnos spinosa* and *Swartzia madagascariensis*. Type 30 is differentiated from Type 29 by the obvious absence of *Baikiaea plurijuga* and the presence of *Terminalia brachystemma*, *Annona stenophylla* and *Combretum imberbe* (Fig. 13). Most of the species typifying this community are from the deep sand or miombo communities.

Hyphaene petersiana is a notable species in this type, but its distribution is patchy (it is not a consistent component of the samples representing this type (Table 2)). It may form uniform stands of widely spaced palms which grow to 25 m in height, on calcrete areas (type 19). Other unusual species to be found here, but rarely so, are *Parinari curatellifolia* (found nowhere else in the Park) and *Kigelia africana* (usually only found in riverine fringe in Hwange).

This type grades into the more open bushed grassland of type 19 on calcrete, and into the bushland and woodland types 26 (*Burkea* - *Pterocarpus*) and 27 (*Baikiaea* - *Guibourtia*).

The soils of this vegetation type appear from surface assessment to be mainly deep sand, some shallow sand and sandy clay (Table 3). From the description of the soils, the real nature of this habitat is not evident. The species composition is more indicative of the fact that this vegetation type/habitat is seasonally or periodically flooded and has a high water table. The presence of *Combretum imberbe*, *Combretum hereroense* and *Terminalia brachystemma* as trees in many of the samples representing this type are indicative of waterlogging.

Plate 17. **Type 30 *Burkea africana* - *Terminalia brachystemma* bushland.** A few kilometres before Makalolo Pan. Note the *Burkea africana* bushes in the foreground, and the scattered *Erythrophleum africanum* and *Burkea* trees in the background.



DISCUSSION

"Vegetation is an integrated expression of physical environment (and animals, time and treatment)", (Daubenmire, 1952, 1968).

that is, **vegetation = f** (flora, climate, topography, soils, animals, time, treatments).

Although the TWINSPAN classification of the samples was based solely on species composition, there is an ecological basis to the mapping of types in this survey. In the first instance, species have certain tolerances and are associated with specific environmental conditions pertaining to geology, soil texture type, topography, water regime and altitude. Thus when the samples and the associated environmental data were assembled in the order of the TWINSPAN classification, their association with certain geological types, soils and topography was immediately apparent (Appendix 2).

In terms of the mapping of types, the interpretation of the aerial photographs was based not only on woody cover or physiognomy (classified as woodland, bushland, scrub, thicket, bushed grassland and grassland), but also on topography and geology.

Thus the final compilation of the vegetation map involved not only identifying strata by the classification of the representative samples, but also identifying topographic units within geological types with similar vegetation. However, in cases where a type could not be distinguished on topography alone, the floristic classification served to identify the stratum. Where the topography was the same over an extensive area with different types represented by samples, then the floristic classification of the unit took precedence. For example, in the case of dune troughs, there are basically two main types of vegetation associated with this one topographic unit - type 18 (*Acacia - Boscia albitrunca* - Mopane bushed grassland) and type 19 (*Combretum hereroense - Hyphaene* bushed grassland) The samples determined the vegetation type to be assigned to each stratum in the topographic unit.

The following discussion, which describes the associations between vegetation types and the environment, is divided into four sections:

1) geology,
2) soil texture class, fertility and depth,
3) rainfall patterns, and
4) altitude.

Then various factors which affect the vegetation are briefly considered:

5) vegetation types in relation to logging and other anthropogenic disturbance,

6) vegetation types in relation to the frequency of fire and frost, and

7) vegetation types in relation to elephant density.

After this section is a comparison of this survey with others done in Hwange National Park and an evaluation of the sampling method used in this survey.

Vegetation patterns in relation to the environment.

In this section the general vegetation patterns observed will be briefly described, in relation to field descriptions of geology, soil texture, rainfall patterns, altitude, logging, fires and frost and elephant density.

1. Vegetation patterns in relation to geology.

There is a clear separation of vegetation types into those which occur on Kalahari sands and those which occur in the non-Kalahari sand areas of the Park. The ecological factors which seem to be fundamental in this separation are the soil depth and texture which affect soil moisture characteristics. Whereas there is a high infiltration rate of rain water into sands, there is greater run-off in the non-Kalahari sand areas; there are no rocks or hills in the Kalahari sand areas; and the Kalahari sands are nutrient poor compared with the soils derived from Basalts, Basement Complex and Karoo sediments, in general.

The vegetation of non-Kalahari sand areas.

The non-Kalahari sand areas (represented by vegetation groups A to E) are of a complex geology. In these areas there is a predominance of rocky, shallow soils and broken hilly topography. There are large areas of "contact zones" where soils are derived from two or more geological sources. The result of these conditions is vegetation which is diverse in species composition and complex in pattern. Even the larger mapped areas of Group B, are composed of a complex of species' associations confined to microtopographic features such as slight depressions, flat areas and rock outcrops (eg. Fig. 7), too fine in detail to map at this scale.

The clear catenary associations seen in the Kalahari sand areas (at the scale of the aerial photographs, 1:80 000) are not as easily discerned in non-Kalahari areas, because of the close proximity of different geological formations in a relatively small area, and the complex dissection of the landscape by streams and rivers. In Kalahari sand areas gradients in altitude and topography are less steep or sharp, areas of homogeneous environmental conditions are larger and there is relatively little dissection of the landscape by rivers and streams.

The vegetation types associated with each of the geological strata will be described in the following paragraphs.

The vegetation of the Basement Complex.

From the formations of the ancient Basement Complex are derived the kopjes, rock outcrops and boulders seen in the Robins and Sinamatella sub-regions. This topography characterises the environment of vegetation types 4 and 5 (group B) and type 7 and 9 (group C).

There is a broad catena in species composition in relation to the topography on the Basement Complex geology. This gradient is basically related to 'rockiness'. From the rockiest to the least rocky habitat one passes through four communities which have been identified in this survey (Fig. 7). The vegetation of the rockiest areas is composed mainly of miombo elements, interspersed with patches of low, open mopane woodland in clay depressions (Castle kopje mixed woodland and thicket, type 4); this grades into more extensive open woodland and bushland of mixed miombo (type 5, *Julbernardia globiflora* and *Diplorhynchus condylocarpon*) and mopane community species (*Erythroxylum zambesiacum*). Type 5 grades into an extensive, variable open woodland and bushland dominated by mopane, with some thicket species (Mopane - *Combretum* woodland, type 7) which grades into two mainly thicket types: the first of type 9 (Mopane - *Combretum elaeagnoides* thicket) which is found in the Sinamatella area along watercourses and in the Robins area more extensively in an area around Deteema where there is faulting and where springs arise; and the second of which is the ecotone thicket (*Combretum - Baphia* thicket, type 6) grading into Kalahari sand vegetation (Fig. 7).

The vegetation of the Karoo series.

The sedimentary series of the Karoo covers a relatively small area of the Park in the Sinamatella area. There is a gradient from the well

developed riverine vegetation on the deep alluvial soils of broad river terraces (*Colophospermum mopane - Combretum imberbe* woodland to bushed grassland, type 10) to Mopane woodland with *Acacia robusta* (type 2) which is up-slope on more shallow soils, to Mopane woodland with *Terminalia prunioides* (type 8), which is usually associated with the higher ground of interfluves and at the base of escarpments, such as the one on which Sinamatella Camp is situated (Fig. 6). On the slopes of the escarpments *C. mopane - Commiphora marlothii* mixed woodland (type 3) occurs. The soils are shallow and there are sandstone rocks possibly derived from the Upper Karoo sandstone capping the escarpments. At the top of the catena on the tops of escarpments capped by Escarpment Grits, there is a form of type 6 thicket dominated by *Diospyros quiloensis* and *Combretum elaeagnoides*. There is also type 5 wooded bushland on the more extensive outcrops of the Escarpment Grits in the Sinamatella area.

Combretum - Boscia angustifolia open scrub to thicket (type 1), occurs on the low dome shaped hills of the Lower Karoo sandstone. The vegetation of these sandstones is not extensive and usually grades into Mopane woodland with *Acacia robusta* (type 2) and sometimes Mopane woodland with *T. prunioides* (type 8). At the edge of the Karoo sediments, *Combretum - Boscia angustifolia* open scrub and thicket (type 1) grades into castle kopje mixed woodland and thicket (type 4) or Mopane - *Combretum* woodland (type 7) on Basement Complex.

<u>The vegetation of Basalt areas.</u>
On the Basalt soils of the Robins - Sinamatella area, there is a very broad gradient from *Colophospermum mopane - Combretum hereroense* bushed grassland to bushland along drainage lines (type 12), up-slope to Mopane - *Combretum* bushed grassland (type 13). Adjacent to type 13, in the broad contact zones between basalt and Kalahari sand and basalt and Basement Complex, Mopane bushland (type 14) is found. It is possible that the soils of this vegetation type are influenced by the sandy soils derived from the latter geological types. The corresponding gradient in soil condition is from poorly drained clay soils in depressions to slightly better drained rocky, shallow soils to relatively well drained sandy clay soils near the edges of the basalt outcrop.

Colophospermum mopane - Acacia - Combretum grassland to woodland (type 11), is found along the drainage lines of the Big Toms and Salt Pans areas near the contact between basalt and Basement Complex. It appears that this type is associated with sodic soils according the the soil map by Sweet (1970). It is well known that salty and freshwater

springs are common at the contact between two different types of geology, or on fault lines. Type 11 was distinguished on the aerial photographs by the presence of large bare areas of high reflectance. The vegetation in the Big and Little Toms and Salt Pans areas is well utilized by herbivores, and the presence of such large bare areas may be a result of over-grazing and vegetation damage. Thus there may be some areas of vegetation included in this type which are not necessarily associated with sodic soils, but resemble such areas because they have been over-utilized by herbivores.

The bushed grassland surrounding Shumba is floristically classified as type 11. Whether the soils of this area are sodic or derived from basalt is not clear, and thus requires more investigation.

Type 11 is found only on alluvium in the Dzivanini area and may be replaced further from the river by Mopane - *Acacia* - *Grewia bicolor* stunted woodland (type 16) which covers an extensive area. The physiognomy of the type varies between low stunted woodland on poorly drained, deep self churning clays, to taller woodland on slightly better drained soils. There is an interesting pattern created in this vegetation type by an interweave of meandering drainage lines, which can be seen on the aerial photographs. Before conducting the field work it was thought that the drainage channels might be vegetated by low stunted mopane with the taller mopane on the interfluves; however, this was not substantiated on the ground. There are large areas of dry season grassland found adjacent to type 11 which are surrounded by Mopane - *Acacia* - *Grewia bicolor* (type 16). These grassland areas are mostly underwater or waterlogged during the rainy season.

<u>The vegetation of the watershed and the contact between Kalahari sand and other geological formations.</u>

The watershed which traverses the Park (Fig. 15), roughly coincides with the boundary between Kalahari sand and underlying geological types. This area is vegetated by a "band" of ecotone bushland, thicket and woodland, and periodically inundated bushed grassland types (Fig. 2). There are also some "islands" of Kalahari sand in the area of non-Kalahari sand vegetation south of Deteema and north east of Kapula. They are vegetated with *Combretum* - *Baphia* thicket (type 6), and *Baikiaea* - *Commiphora mossambicensis* woodland and thicket (type 29), respectively.

There is a gradient from sandy clays and shallow sands to deeper sands in this ecotone area. Mopane - *Combretum hereroense* bushed grassland

to bushland in depressions and pan areas (type 12), is widespread from east to west following the watershed within the Park.

Type 12 occurs on the edge of ecotone *Baikiaea - Commiphora mossambicensis* woodland thicket (type 29) and *Combretum - Baphia* thicket (type 6). The Kalahari sands supporting the latter two types may act as a sponge for rainfall which collects where the sand meets the underlying rock (either basalt or basement complex) forming the waterlogged areas of the Mopane - *Combretum hereroense* (type 12) community.

At the northern edge of the Dzivanini flats type 12 again occurs at the edge of the Kalahari sands where it grades into Mopane woodland - *Combretum* bushed grassland mosaic (type 17) which occurs along the full length of the contact between Kalahari sand and the deep basaltic clays of the Dzivanini flats. Type 17 is also found south east of Shumba in the Mopane Pan - Nehimba area. This type appears also to become waterlogged during the rainy season. There are many scattered seasonal pans in this type and type 12 on the watershed which often hold water late into the dry season. This fact is significant in affecting the distribution of elephant.

Combretum - Baphia thicket (type 6) occurs on the northern edge of *Baikiaea - Commiphora mossambicensis* woodland thicket (type 29). Type 6 is associated with red sandy clay soils which are probbly shallower than the red sands supporting ecotone *Baikiaea* woodland thicket. *Combretum - Baphia* thicket, where it meets *Baikiaea* woodland thicket, is very similar in structure and may even have the odd scattered *Baikiaea* tree in the community. There is a gradient from predominantly Kalahari sand species to species which are usually associated with clay or shallow soils in the transition from type 29 to type 6.

The vegetation of the Kalahari sands.

The Kalahari sands cover a vast area within the National Park. The main influence on vegetation patterns is the depth of sand, which is a result of the deposition and erosion of sand by wind and water over the last ten to twenty thousand years (Flint and Bond, 1968; Thomas 1983).

The predominantly deep-soil ecosystem of the Kalahari sands is very different from the mainly shallow soil ecosystems to be found in the north and south of the Park. Whereas woody species found in the non-

Kalahari sand areas are mainly shallow rooting, and species composition is dominated by *Colophospermum mopane*, woody species in the Kalahari sand ecosystem are mainly deep rooting. Rushworth (1975) found that over 80% of the woody biomass was below ground and that many woody species of the Kalahari sand coppice when burned or damaged.

The following section is a description of the vegetation types in relation to the topographic features of the Kalahari sands.

The vegetation of the sand dunes.

The regular pattern of the ancient sand dunes are the most obvious influence on the distribution of woody vegetation on the Kalahari sand areas in the Park (Fig. 10). The pattern of the sand dunes is preserved in the vegetation patterns which are easily discernible even on satellite imagery.

The *Baikiaea - Combretum* woodland thicket, (type 23) found typically on sand dune crests in the north east of the Park , is also found on the western edges of fossil drainage lines (Figs. 10 and 11). The soils of type 23 are loose surface sands (Table 3), with an impervious layer at a few metres' depth and with a high clay content (Table 7; Childes and Walker, 1987).

Baikiaea - Combretum woodland thicket (type 23), is often found in association with *Combretum celastroides*, which occurs as a tall shrub forming a thicket in the understorey. It has been suggested by Huckaby (1986) that the presence of *Combretum celastroides* in pure stands as understorey of *Baikiaea* woodland is indicative of fire-damaged *Baikiaea* forest. The purest thickets of *C. celastroides,* in the understorey of *Baikiaea* woodland in Hwange, are found in the south-west where the dune system is well developed. According to a fire frequency map (Fig. 17) that area has been burned only twice in the 23 years. It may be that the condition of a *Baikiaea* woodland which Huckaby described, pertains only to conditions influenced by a higher rainfall in Zambia. Many of the species listed as common in Zambezi Teak forests by Huckaby are rare or absent from the *Baikiaea* woodland here. Timberlake (pers. comm.) suggests that the presence of *C. celastroides* is a natural response to more acidic sub-soils since the distribution of *C. celastroides* is too patchy to be a result of disturbance and the species is generally found in a similar topographic position within its range.

From the top of the dune *Baikiaea* woodland (type 23) grades into *Terminalia - Baikiaea* bushland (type 25), found on the slopes (Fig. 10). *Baikiaea* woodland patches on dune crests are usually round or oval shaped as viewed on the aerial photographs. This may be a result of the gradual "erosion" of woodland at its edges through the effects of fire carried by the surrounding bushland. This pattern of *Baikiaea* woodland patches may also be a result of the effects of soil texture, soil depth and soil moisture along the dune crest (Jonathan Timberlake, pers. comm.).

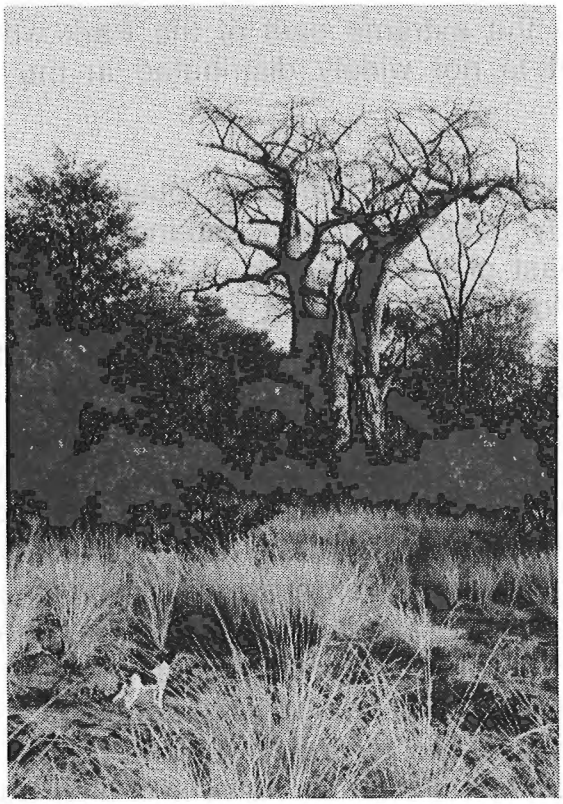
The vegetation of inter-dune troughs, calcrete areas and fossil drainage lines.

The woody vegetation of dune troughs is heterogeneous in character and varies along the length of each dune trough (which unbroken, may be up to about 25km in length). For example, driving west along the dune trough from Josivanini to Matambonyati, one passes through *Boscia albitrunca* bushed grassland (type 18), patches of bushland dominated by *C. mopane*, and *Combretum - Acacia* bushland. A unique feature of this drive is the line of Baobab trees (*Adansonia digitata*) which fringe the dune trough (Plate 18). *A. digitata* was seen nowhere else on the Kalahari sands. It is thought that these trees may have grown from seed dropped by passing San hunter-gatherers who used this dune trough as part of a hunting route.

The woody vegetation of each dune trough was mapped as one type on the basis of the sample placed within the same, or a stratum of similar appearance. Thus where one type is shown there may be a mosaic of the other two types as well.

Three types of woody vegetation are generally found in the dune troughs in different areas of the Park. The first two types clearly represent the transition of the flora from mainly Zambesian in the relatively moist north and east, to more Kalaharian type vegetation in the drier west and south (White, 1983). *Acacia - Boscia albitrunca -C. mopane* bushed grassland (type 18) is found in the dune troughs of the southern fossil sand dune system. Many of the species found in this community are common in the Kalaharian phytogeographic region. *Boscia albitrunca* does not usually occur east of the Manga fossil drainage line or north of Makona. It does occur in the west in the Triga Vlei. The second type, *Combretum imberbe - Hyphaene* bushed grassland to bushland (type 19), occurs mainly in the dune troughs of the northern fossil sand dunes ie. from around Josivanini, north and east to Mbazu and Mandiseka areas. Most of the species found here are common in the

Plate 18. One of the 8 or 9 large baobabs (*Adansonia digitata*) which are found east of Josivanini, on the northern edge of the dune trough. Note the fruit on the branches on the left.



Zambesian floristic region (White, 1983). The third type which is found in the broadly eroded dune troughs found primarily in the Triga vlei system is *Acacia - Mundulea sericea* bushland (type 20). This type occupies an intermediate position in distribution between the former two types. It is found as far east as Guvalala (further east than type 18) but not in the extreme east of the Park where type 19 is widely distributed. It is not widely distributed in the extreme south of the Park.

Combretum hereroense - Hyphaene bushed grassland to bushland (type 19), is typically associated with expanses of calcrete areas mainly in the extreme east of the Park (Fig. 12). Only woody species which can tolerate waterlogging in the wet season and very dry conditions in the winter, are found in this type. Grasses dominate the vegetation, and woody species are clumped and scattered in distribution, sometimes on raised ground where there are slightly deeper sands. Although there is no surface evidence of calcrete in association with *Burkea - Terminalia brachystemma* bushland (type 30), it seems possible from the distribution of the type, that the hard calcrete layer visible at the surface in *Combretum hereroense - Hyphaene* (type 19), may extend under the loose white sands of type 30. Such a shallow hard layer would account for the presence of many of the constituent species which are tolerant of seasonal waterlogging. Tinley (1982) states that "a pan horizon covered by loose sand is highly efficient as an aquifer" since loose sand is full of air spaces which inhibit evaporation especially of deeper water (below the first few centimetres from the surface).

Types 18, 19 and 20 can also be found in fossil drainage lines (Fig. 10), as does *Terminalia sericea - Acacia erioloba* bushland (type 24) and *Terminalia sericea - Lonchocarpus nelsii* bushland (type 21). *Acacia - Boscia albitrunca -C. mopane* bushed grassland (type 18) is found in the Amandundamella fossil drainage line, and *Combretum imberbe - Hyphaene* bushed grassland to bushland (type 19) is found in the upper reaches of the Kennedy vlei and half way down the vlei towards Kennedy 2. *Terminalia sericea - Acacia erioloba* bushland (type 24) is found in the Dopi, Manga and Linkwasha fossil drainage lines. This type is in the same group as type 25, *Terminalia - Baikiaea* bushland on deeper Kalahari sands. It appears to be intermediate in the catena from vegetation on sandy clay soils (such as type 18 or 19) to vegetation on deeper sands (such as type 25), especially in the Triga Vlei. Where *Terminalia - A. erioloba* bushland occurs in the Dopi and Manga fossil drainage lines it may be indicative of drier soil conditions or slightly

better drained soil conditions, since woody species have become dominant over grasses. The invasion of woody species into grassland could also be due to overgrazing or low fire frequency. *Terminalia - Lonchocarpus nelsii* bushland (type 21) occurs in the fossil drainage lines from about Umkowazaane Pan, and south of the junction of the Manga and Kennedy vlei line down to Makona and Libuti Pans. It is usually associated with shallow sands and appears to be similar in catenal position to *Terminalia - A. erioloba* bushland (type 24).

The vegetation of redistributed Kalahari sands.
Where dunes have been eroded, and deep sands deposited by fluvial action, the *Baikiaea* woodlands and mixed bushlands are more extensive and have a different woody species composition from the vegetation of the fossil dune topography (Figs 10 and 11). Deep redistributed sands support *Terminalia - Baikiaea* bushland (type 25) and Group I *Baikiaea* bushland and woodland (types 26, 27 and 28). The distribution of the Group I woodland, may at least in part reflect the the pattern of medium to deep redistributed sand in Hwange National Park.

There is a catena from shallow Kalahari sands to deep redistributed Kalahari sands. At the bottom of the slope, or on shallow sands, one may find *T. sericea - A. erioloba* bushland (type 24), in fossil dune troughs, or *Combretum imberbe - Hyphaene* bushed grassland (type 19), which is the vegetation type characteristically found on calcrete. These types grade into *Burkea africana - Pterocarpus angolensis* bushland to woodland (type 26) on deeper sands on the eastern edge of the vlei. There is usually an abrupt transition to *Baikiaea - Combretum* woodland thicket (type 23), on the western edge of the fossil vlei lines.

An explanation for this pattern of woodland (type 23) on the western edge and bushland (type 26) on the eastern edge might be the greater insolation, and thus drier growing conditions which prevail on the more north-facing eastern edge (Fig. 14). The deeper sands and steeper slopes on the western edge, may also favour the establishment of *A. erioloba* woodland. Another explanation for the presence of *Burkea - Pterocarpus* bushland on the eastern slope of fossil vlei lines is that the soil is likely to retain its moisture for longer periods into the dry season as a result of the the flow of water down the slope or "telluric water" (Childes and Walker, 1987). The bushland physiognomy of this type could also be a result of regular burning or disturbance.

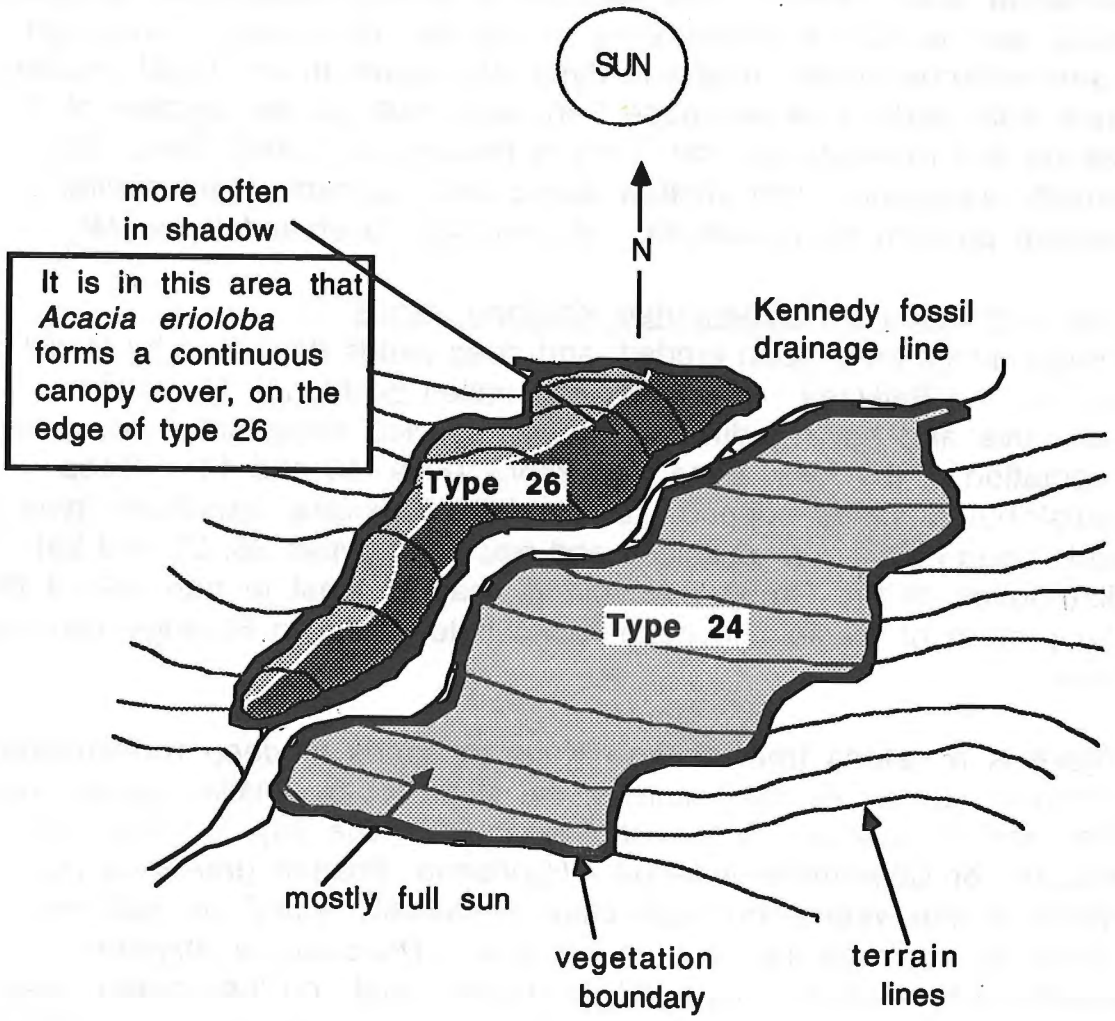


Figure 14. Showing the greater insolation of the eastern side of fossil drainage lines.

At the top of the slope on deep Kalahari sands *Baikiaea - Guibourtia* woodland (type 27) is usually found, especially in the extreme east of the Park on the interfluves between fossil drainage lines. East of the Manga fossil drainage line the transition is from *T. sericea - A. erioloba* bushland (type 24) to *T. sericea - Baikiaea* bushland (type 25) and *Baikiaea - Combretum* woodland thicket at the top of the slope. Adjacent to the *Baikiaea - Combretum* woodland thicket (type 23), *T. sericea - L. nelsii* bushland is often found over large areas in the Dopi to Sinanga region. The latter type was not intensively sampled in this area, and may be a degraded form of *Baikiaea* woodland as a result of logging activities during the 1920 to 1940's and subsequently of frequent fires in more recent times.

Baikiaea - Croton gratissimus woodland (type 28) is also found on deep sands, but mainly in areas toward the edge of the Kalahari sands in the north and east. It appears to be intermediate in a Park wide gradient from *Baikiaea - Guibourtia* woodland (type 27) on deep white sands, to ecotone *Baikiaea* woodland on red or (type 29) pink Kalahari sands.

2. Vegetation types and species composition in relation to soil texture class, fertility and depth.

Since **soil texture** influences the moisture holding capacity of a soil (Hillel, 1971), its texture should thus be representative of soil moisture conditions. In the non-Kalahari sand types, the trend in soil texture class is from shallow sandy soils in rocky areas (vegetation Group A), to shallow to slightly deeper sandy soils (Group B), to sandy clays and clays (Group C), alluvial soils (Group D), and medium and deep clays (Group E). In the Kalahari sand areas there is a trend from clay and sandy clay soils (Group F) to shallow fine grained sands (Group G), deep, coarse, well drained sands (Groups H, I and J) and coarse, poorly drained loose sands (Group K). Thus the soil moisture gradient would generally be from drier to more moist environments in the non-Kalahari sand vegetation types, and in the Kalahari sand types from shallow, seasonally waterlogged sandy clays to deep, coarse well drained sands.

Soil fertility is another factor which affects species distribution. In the non-Kalahari sand areas with the complexities of geology and topography, soil fertility is probably highly variable, although there are some generalities which can be made. Soils derived from basement complex are generally nutrient poor, while those derived from more recent volcanic material, such as the basalts are relatively more

nutrient rich (Bell, 1982). Sedimentary rock is generally intermediate in nutrient status between the former geological types. None of the types described, besides types on alluvium, can obviously be associated with soils of a particularly low or high fertility.

The Kalahari sands are characteristically nutrient-poor (Huckaby, 1986). Huckaby (1986) suggested that "soil fertility is relative, and the red Transitional Sands on which *Baikiaea* forest is best developed (in Zambia) are more fertile than the bleached podsols." The type of "best developed" Teak forests described by Huckaby are most similar to ecotone *Baikiaea - Commiphora mossambicensis* woodland and thicket (type 29) on red sands in this survey.

Baikiaea - Croton gratissimus woodland (type 28), is usually found on white sands adjacent to ecotone *Baikiaea - Commiphora mossambicensis* woodland and thicket (type 29). Many of the species from type 29 are represented in type 28. Some of the species which occur in both types include *Commiphora mossambicensis*, *Grewia monticola* and *Rhus tenuinervis*, all of which are rare or absent from the other Kalahari *Baikiaea* woodland types. It could thus be postulated that the soil nutrient status of type 28 is intermediate between the soils of type 29 and type 27 *Baikiaea* woodland which occurs on nutrient poor white Kalahari sands (Huckaby, 1986).

The **depth of soil** is an important factor which directly influences the soil moisture balance (Tinley, 1982), thereby affecting the spacing and distribution of plant species and thus vegetation types. Childes (1984) discussed the importance of soil depth in Kalahari sands, and emphasised the following. There are two types of pan horizons or pan layers; a cemented type which is the calcrete or ferricrete layer and a compacted sand or clay type formed in duplex sands (two sand grain sizes in layers) or "illuviated humic clays" (Tinley, 1976, 1982). The process of illuviation is that of the repeated 'washing' downwards and deposition of dissolved salts (such as calcium carbonate) to a certain level in the sands. This deposition of salts may also occur by the movement of salts upwards through evaporation or the filling up of the water table.

Thus types which occur in areas where there is an obvious shallow calcrete or ferricrete layer, such as *Acacia - Boscia albitrunca* - mopane bushed grassland (type 18) and *Combretum hereroense* - *Hyphaene* bushed grassland (type19), are dominated by grasses with scattered clumps of woody species. Although *Acacia - Mundulea*

sericea (type 20) is predominantly a bushland type, it is associated with shallow sandy clay soils. Many of the species which are common in Group F (the types of which occur mainly on sandy clay soils) are also common in this type - such as *Acacia luederitzii*, *Boscia albitrunca* and *Grewia flava*. This type is almost certainly influenced by the presence of a hard pan layer, even though such a layer is not obvious at the surface. *Acacia - Mundulea* bushland (type 24) is not related to any specific topography, although it is widespread in the Triga Vlei.

The relative cover of grasses and woody species, and their spacing, are indirectly affected by the sub-surface topography of the pan layers because of their effect on soil moisture conditions. The hard pan layers do not necessarily follow the surface topography of the sands and vary in depth (Tinley, 1982). Where the hard pan layer is even slightly deeper it is more difficult to discern its presence in the field. One possible way is through the species composition. Where there are species which are tolerant of waterlogged conditions or prefer moist soil conditions, even though the surface sands appear loose and coarse, one could suggest that a hard pan layer is present at some depth. An example of such a type would be *Burkea africana - Terminalia brachystemma* bushland (type 30). Within this community, which typically occurs on coarse, white sands, there are many species which are tolerant of periodic inundation or prefer more moist conditions, such as *Combretum imberbe*, *C. hereroense*, *Hyphaene petersiana* and *Diplorhynchus condylocarpon*.

The presence of a pan layer in Kalahari sands increases the possible soil saturation and reduces the rate of water loss (Childes, 1984). Tinley (1971, in Childes, 1984) found that "where there are gley layers or fine compacted sands the vegetation becomes noticeably denser than that on the surrounding deep horizonless sands. Examples are the *Acacia erioloba* woodland patches in the Central Kalahari and the *Baikiaea* thicket in Caprivi". In Hwange National Park, there are several types, mostly belonging to Group G, the species composition and physiognomy of which may be influenced in this way. Of the four types in this group two tend toward thicket, the surface sands of which were assessed as loose and possibly deep. *Terminalia sericea - Lonchocarpus nelsii* bushland (type 21) and *Baikiaea - Combretum* woodland thicket (type 23) are composed of many thicket-forming species such as *Acacia ataxacantha*, *A. fleckii*, *Commiphora angolensis*, *Grewia flavescens* var. *flavescens* and *Ochna cinnabarina* (Table 2), which are less common in the bushlands and woodlands of the deep

Kalahari sands (in Groups H and I). These species occur frequently on sandy clay soils.

Baikiaea plurijuga has an average rooting depth of 8 - 10 m (Rushworth, 1975) and thus becomes a dominant canopy species only where there are deep soils. In 60% of the samples representing *Terminalia - Baikiaea* bushland (type 25), *Baikiaea* is present as a shrub (*Baikiaea* was not present in the other 30% of samples). Childes and Walker (1987) found that the presence of stunted *Baikiaea* was correlated with the presence of a hard pan layer in 60% of the samples in which *Baikiaea* was present. Thus approximately 36% of *Terminalia - Baikiaea* bushland (type 25) in which *Baikiaea* is present as a shrub, is affected by the presence of a hard pan layer in the soil.

3. Vegetation patterns in relation to rainfall patterns.

The effects of small variations in rainfall are likely to be enhanced on the Kalahari sands in Hwange National Park. Most Kalahari sands are medium grained, so that all moisture penetrates the soil profile and there is little or no run-off (Lal, 1987). The depth of moist or saturated sands can thus be correlated to the amount of rainfall. Seventy two millimetres of rain is sufficient to moisten arenosols (wind blown sands) to a depth of one metre (Agritex-FAO). Thus 500mm moisture may be found up to a depth of 6.9 m and 650mm may penetrate up to a depth of 8.67 m in an average rainfall year (if all rain falls within one continuous period). There is a long term higher rainfall average in the east of the Park (Fig. 15, Meteorological Department, 1991; Davies, 1991), which indeed coincides with a flora representative of moister conditions. In the area from Dete to Kennedy (approximately) the average rainfall is about 600mm (Fig. 15), decreasing to 550mm toward the centre of the Park, and to 500mm along the southern Botswana border to Josivanini in the east.

<u>600mm to 650mm rainfall zone.</u>

Baikiaea - Guibourtia coleosperma woodland (type 27) only occurs in the east of the Park. *Combretum imberbe - Hyphaene* bushed grassland to bushland on calcrete (type 19) and *Burkea africana - Terminalia brachystemma* bushland and woodland (type 30) also only occur in the east of the Park. All three types, from their species compositions appear to be associated with moist soil conditions (type 27) or periodic waterlogging (types 19 and 30).

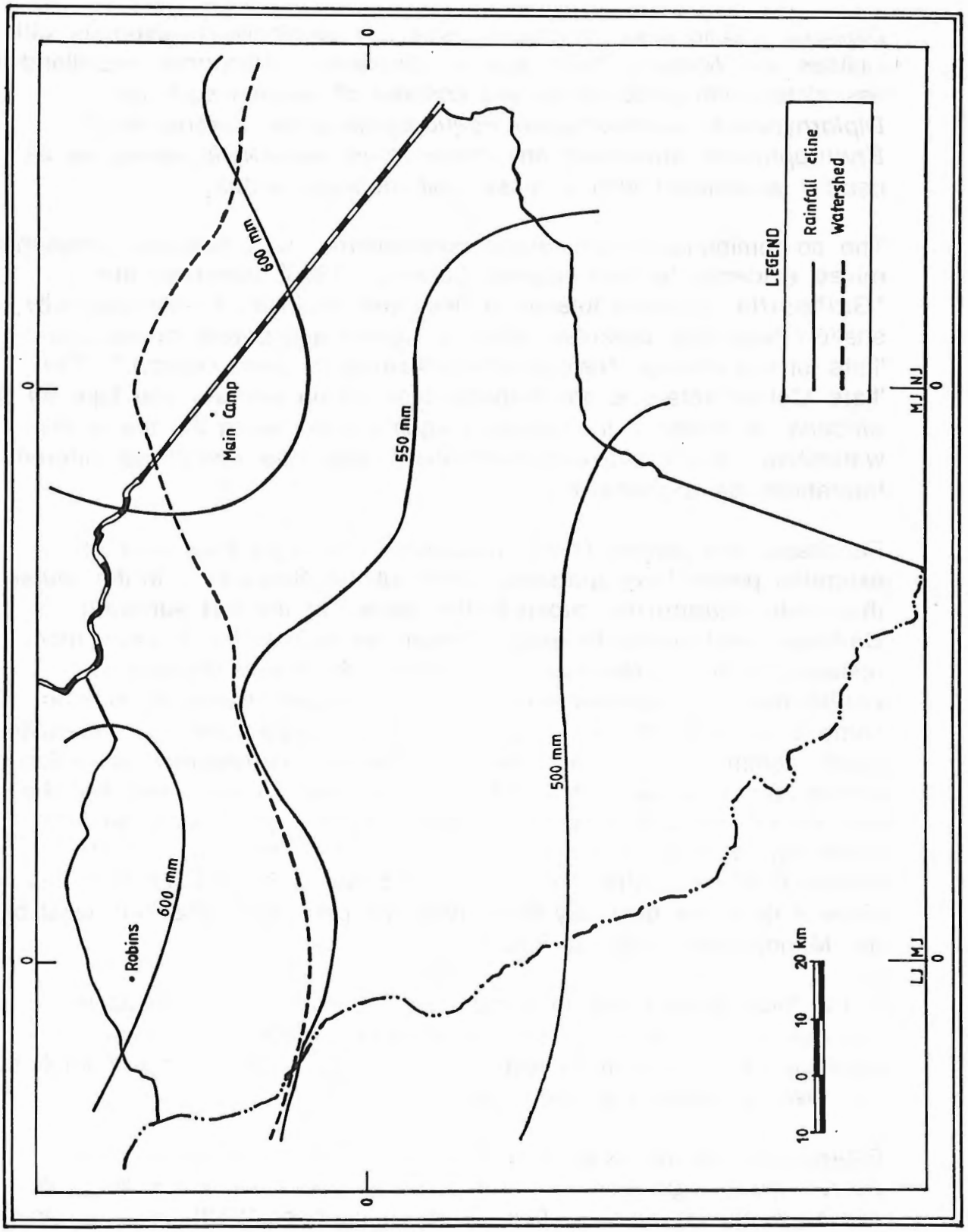


Fig. 15. RAINFALL CLINES AND THE APPROAXIMATE POSITION OF THE WATERSHED IN HWANGE NATIONAL PARK

Baikiaea - Guibourtia woodland (type 27) generally corresponds with Childes and Walker's (1987) type 4. *Baikiaea - Guibourtia* woodland is associated with white sands and consists of species such as *Diplorhynchus condylocarpon*, *Pseudolachnostylis maprouneifolia*, *Erythrophleum africanum* and *Pterocarpus angolensis* which are all usually associated with a mesic soil moisture status.

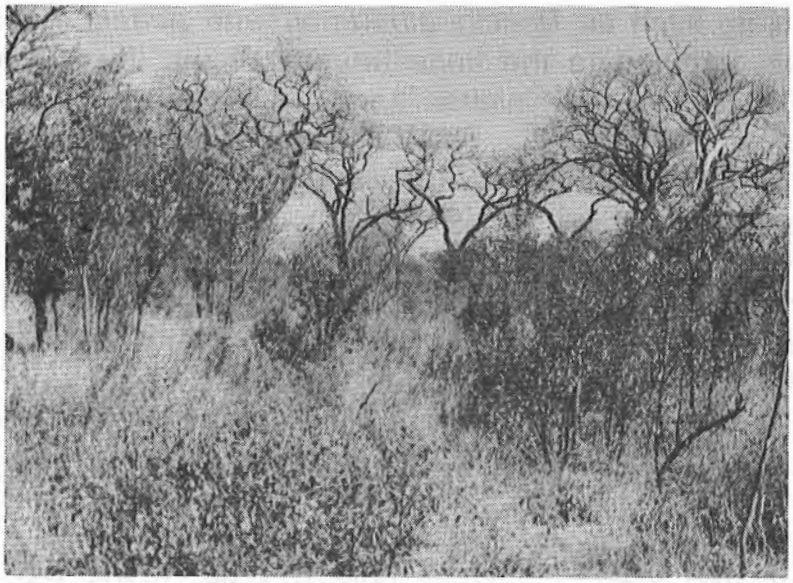
The co-dominance of *Guibourtia coleosperma* with *Baikiaea* , presents mixed evidence for and against Calvert's (1986) postulate that "*Guibourtia* is more tolerant of less well drained or physiologically shallow sites than *Baikiaea*, such as Ngamo and Gwaai forests and 'flats' of the Hwange National Park (Rushworth, pers. comm.)." The 'flats' Calvert refers to are probably type 19 on calcrete and type 30 *B. africana* bushland in the Mbiza to Ngamo areas along the top of the watershed. If the two are co-dominant, then how can these different tolerances be explained?

Fanshawe and Savory (1964) postulated that "light fires over an extended period have gradually killed out the *Baikiaea* . In the course of this cycle *Guibourtia* arose in the shelter of the still surviving *Baikiaea* and eventually replaced them, as *Guibourtia* is much more resistant to fire." However, like Calvert, they also referred to *Guibourtia* as a species "known to occur on poorly drained soils on some of its sites by reason of its shallow rooting habit." Timberlake (pers. comm.) believes that the distribution of *Guibourtia* is related to higher calcium levels in the soil near pans and on flats, and that the root system of *Guibourtia* is complex and not particularly shallow. However, in studying the distribution of this species in this survey, it seems more likely that *Guibourtia* is found where rainfall is higher, since it does not generally occur near the pan areas and flats west of the Manga fossil drainage line.

In the Sinamatella Camp to Bumboosie and Robins Camp areas the average annual rainfall is also approximately 600mm and over. However, it is difficult to isolate the effects of the higher rainfall in this area of complex geology and topography.

<u>600mm to 500mm rainfall zone.</u>
Pterocarpus angolensis is rarely found in areas where the average annual rainfall is below 500mm (Von Breitenbach,1973), and in Hwange the boundary of *Burkea africana - Pterocarpus angolensis* woodland (type 26) roughly coincides with the 500mm isocline. However, good stands of scattered, mature *Pterocarpus angolensis* trees do occur in

Plate 19. 9 km north of the turn-off to Little Dzivanini along the Botswana border road, looking west. An open woodland of fruiting *Pterocarpus angolensis* in the low rainfall zone (an average of 450 - 500 mm per annum).



the south of the Park, near the edge of the Kalahari sands (Plate 19), where the shallow sands may be underlain by impermeable material, which might have an ameliorative effect on the generally drier conditions in this region.

500mm to 450mm rainfall zone.
Certain species, such as *Boscia albitrunca* and *Acacia hebeclada* appear to be confined to the dune troughs of the lower rainfall areas (ie. below 500mm) of the Kalahari sands in Hwange National Park.

There seems to be a pattern in the flora of the dune troughs, which coincides with the rainfall zones (Fig.15). In the 500mm to 550mm zone *Combretum hereroense - Hyphaene* bushed grassland (type 19) is the main type associated with dune troughs, and in the 450mm to 500mm zone *Acacia - Boscia albitrunca* - Mopane bushed grassland (type 18) is the main type associated with dune troughs. The Park is within the transition zone between the Zambesian floristic region and the Kalaharian region, which is well represented in Botswana.

Acacia - Mundulea sericea bushland, (type 20) is a type which is mainly associated with the lowest rainfall zone in the Park. Species which occur rarely or are absent elsewhere in the Park, such as *Acacia arenaria, A. mellifera, A. erubescens* and *Combretum albopunctatum* are found in this area. The centre of the distribution of *Acacia luederitzii* in southern Africa is in Botswana. This species is most commonly found, in Hwange National Park, in type 20. It is also found in over half the samples of *Acacia - Boscia* - mopane bushed grassland (type 18) in dune troughs.

4. Vegetation patterns in relation to altitude.

In comparing the vegetation map with a map of the altitude (Fig. 16), some interesting observations can be made. There is a coincidence of the 1100 m contour line near Dete with the presence of *Brachystegia spiciformis* in type 28 *Baikiaea - Croton gratissimus* woodland. The presence of this species could be attributable to the change in soils as one approaches the ecotone of the Kalahari sands. However, the same phenomenon is observed on approaching the Hwange main airport, where the sands are apparently deep, and white. Deep white sands are not usually associated with ecotone areas within the Park. Ecotone *Baikiaea* woodland and thicket is usually found on red Kalahari sands. The airport is about 1100 m above sea level, and in the vicinity tall *B. spiciformis* trees are a common constituent of the *Baikiaea* woodland.

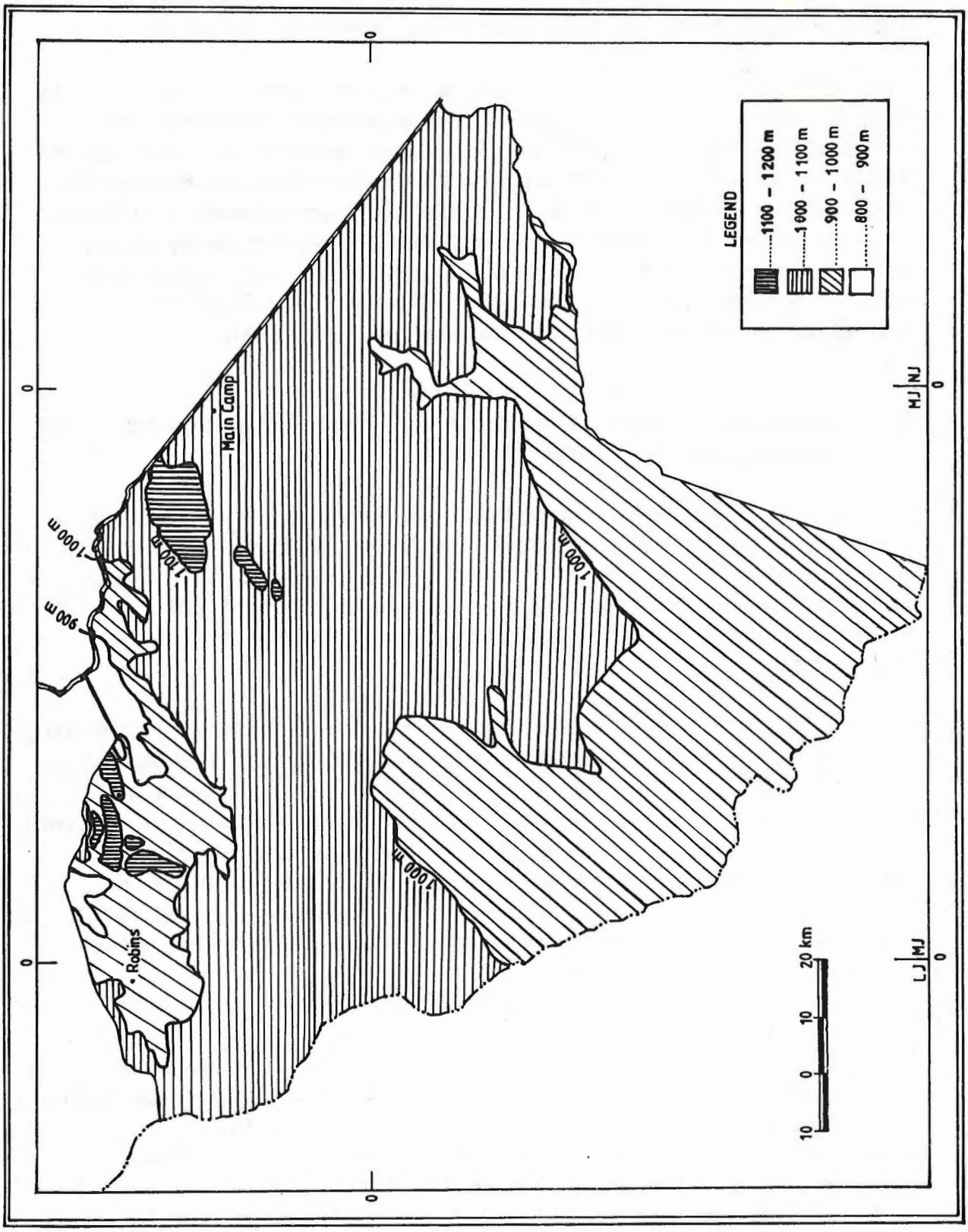


Fig. 16 THE RELIEF OF HWANGE NATIONAL PARK.

Only three or four kilometres away, at the Safari Lodge and within the Park, *B. spiciformis* is rarely seen in the *Baikiaea* woodland.

The 1000 m contour line is coincident with the southern boundary of type 26 *Burkea africana - Pterocarpus angolensis* bushland and woodland (Fig. 16). This can be seen in two areas in the Park: on the boundary running in a north east to south west direction; and in the west on the northern side of the Triga vlei, also oriented in a north easterly direction. *Pterocarpus angolensis* does not occur in any abundance approximately south of these lines. It is possible that altitude affects rainfall in Hwange, which in turn affects the distribution of species such as *Pterocarpus angolensis*.

5. Vegetation types in relation to past logging and other anthropogenic disturbance.

In 1903 and 1904 timber was taken from *Baikiaea* woodlands by contractors during the construction of the Bulawayo - Victoria Falls railway line. In 1925 and until 1944, a large area of what is now Hwange National Park was logged. Woodland within 16 km (10 miles) of the railway line and within a 32 km (20 mile) radius of Intundhla siding was logged.

Kelly-Edwards (1940) said that the woodland left behind after logging was a "mere travesty" of the *Baikiaea* woodlands which existed before. With this drastic opening up of the woodland, and the advent and continued use of the steam train which has been the cause of frequent fires ever since (Jones, 1988), it is highly likely that *Baikiaea* woodlands have been adversely affected, in the east of the Park. *Baikiaea - Guibourtia* woodland (type 27) occurs only in the area which was logged, and may be a successional form of the previous woodland.

Rushworth (1975) found evidence of large *Baikiaea* trees in his study sites (which were situated in *Terminalia sericea - Baikiaea* bushland (type 25)). His study area falls within the 16 km (10 mile) zone in which logging took place between 1925 and 1944. It is possible that the opening up of the community left it susceptible to the effects of fire and frost which sustain bushland (Rushworth, 1975; Childes, 1984). The slow increase of elephants (which were not up to "carrying capacity" until the late 1970's) should not have had a negative impact on these cleared woodlands - especially with regard to *Baikiaea* which is an unpalatable species. The effect of browsers is more likely to

favour the regeneration of *Baikiaea* since browsers reduce the frequency and cover of other competitive species such as *Combretum collinum* (Huckaby, 1986; Conybeare, 1991).

It is the contention of some that most of the Kalahari sands of the Park were once covered by extensive *Baikiaea* woodland and that those existing today are greatly reduced in area. This certainly appears to be possible in the east of the Park within the former zone of logging activities. However, the extent of woodland in the rest of the Kalahari sand area, may be more a result of edaphic factors, such as depth of soil and waterlogging which are limiting to the growth of trees.

For example, only 60% of each of types 25 and 26 *Terminalia* bushland (which occur on apparently deep Kalahari sands) were found to have *Baikiaea* present. Thus *Baikiaea* is absent in 40% of *Terminalia* bushlands, which may mean that *Baikiaea* was never present due to edaphic conditions. Of the 60% of bushland in which *Baikiaea* occurred, Childes and Walker (1987) found that there was a hard pan layer 2,0 to 2,5 m below the surface of the sands. Such a hard layer is thought to stunt the growth of the *Baikiaea plurijuga*. Thus of the *Terminalia* bushland types 25 and 26 in which stunted *Baikiaea* occurs in the Park, about 76% (40% plus 36%) are likely to be edaphic *Terminalia* - *Baikiaea* bushlands. If one adds to this the percentage of bushland that exists as a result of logging activities during the first half of this century, then most of the bushland in which *Baikiaea* occurs would be accounted for.

Ranching in the Sinamatella and Robins areas.

Since the 15th century cattle have been ranched in the Sinamatella and Robins areas. The most intensive period of cattle ranching was between 1914 and 1952 in the Sinamatella area, and between 1910 and 1939 in the Robins area (Tafangenyasha, 1990). Past sites of cattle kraals have been associated with present sites of erosion by Tafangenyasha (1990). Areas of erosion are mainly associated with Mopane - *Acacia robusta* woodland (type 2) according to this survey. It has been suggested that impala are maintaining this landscape in a degraded state (Tafangenyasha and Campbell, 1990). Indeed Jones (1987) has noted an increase in the area of eroded ground in the Sinamatella area.

6. Vegetation types in relation to the frequency of fire and frost.

The frequency of wild and man-induced fires within the Park varies between 0 and 12 fires in 23 years (Fig. 17). No fires have been recorded since 1967 in an area just south of Main Camp, north of Makona and between Sinamatella and Bumboosie. The most frequently burned areas are those on the periphery of the Park, especially in the east along the railway line and in the north just west of Dete and in the west of the Robins area along the international border.

Several factors contribute to the high incidence of fires in certain areas of Hwange National Park - in the east: steam trains which eject burning coals into the veld; the prevailing wind blowing into the Park; and the distance from Main Camp which slows down reaction time of fire fighters; - and in the north west, it is fire coming into the Park from Botswana which is lit annually by pastoralists. Just west of Dete at Mambanje, subsistence poachers regularly light fires during their hunting forays.

The woodland in the east of the Park, particularly in the area between Intundhla and Kennedy and Intundhla and Ngamo and down to Ngweshla and Makalolo, has been the most frequently burned *Baikiaea* woodland in the Park. It is interesting to note that the 32 km radius of logging around Intundhla roughly coincides with an area which is more frequently burned than the surrounding woodland. Most frequent burning occurred close to the railway line with the frequency decreasing with distance from the railway. Logging of the woodland opened up the canopy and facilitated the fuel loading of the understorey which carried hot fires thereby removing more trees from the already depleted canopy layer. Fire is acknowledged as being the greatest threat to *Baikiaea* woodland, since *Baikiaea* trees are not fire resistant and have a thin bark (Childes, 1984). Most of the Kalahari sand vegetation in the Park has burned between 3 and 6 times in the 23 years between 1967 and 1991 (Fig. 17).

Even with regular burning of the Kalahari sand *Terminalia* bushland near Guvalala (Rushworth, 1975), it was not converted to grassland as was previously thought might happen (Boughey, 1963). In fact with regular burning of Kalahari bushland, there is an increase in the number of woody stems per unit area (Rushworth, 1975). Deep sands which trap and preserve moisture at depth, and seasonal drying out of the top layers predispose this environment to the dominance of woody species.

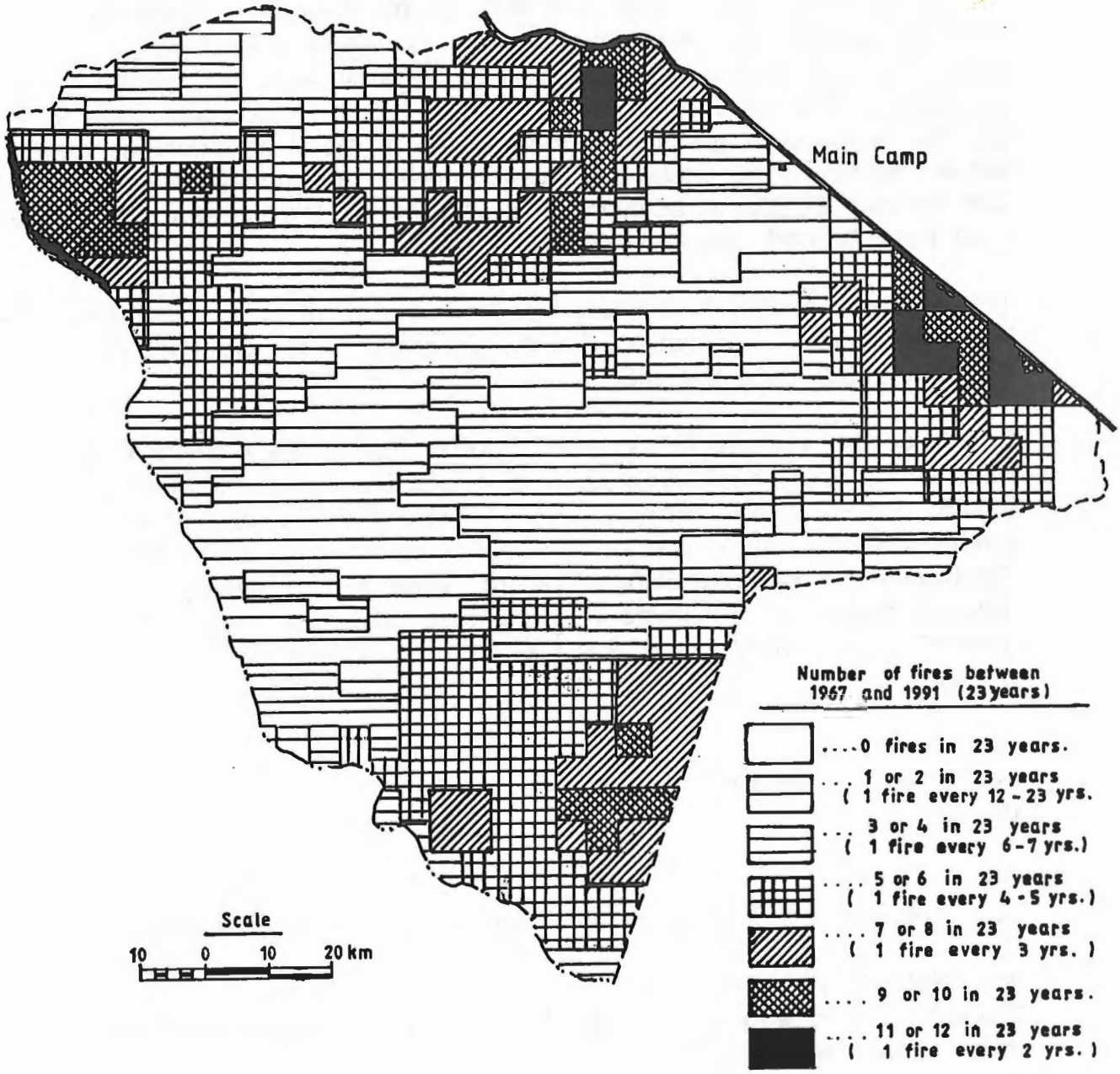


Fig. 17. THE FREQUENCY OF FIRES WHICH OCCURRED IN HWANGE NATIONAL PARK BETWEEN 1967 AND 1991.

The woody species themselves, which occur in these bushlands are also adapted to fire and frost (which can be classified as non-specialist herbivores) by regenerating from vast underground root stocks. Rushworth (1975) found that over 80% of the biomass of Kalahari bushland species was underground. Mopane woodland on Karoo sediments, has only burned infrequently between once and six times in 23 years. This low frequency of wild fires is probably mainly due to the low biomass of grass and undergrowth in these communities during the dry season. The mopane bushland and bushed grasslands on basalt, and ecotone *Baikiaea* bushland and woodland in the extreme west of the Park have burned frequently (Fig. 17).

To determine exactly how many times each area of each vegetation type has been burned one can overlay the vegetation map with the fire frequency map using the GIS.

Frosts occur regularly in Hwange National Park. Black frosts (lower than -7° C) occur approximately once every five years. Rushworth (1975) observed that certain species were more severely affected than others after the black frost of 1972. For example *Acacia fleckii*, *Terminalia sericea* and *Ochna pulchra* were more resistant to frost damage than *Combretum zeyheri*, *Baikiaea plurijuga* coppice (re-growth), *Vitex mombassae* and *Pterocarpus angolensis* coppice (re-growth).

Conybeare (1991) found that frost effects were most serious in bushland, with negligible effects in woodland and little in wooded grassland.

7. Vegetation types in relation to elephant density.

The highest concentrations of elephant occur during the dry season around pumped waterholes. The highest density of pumped waterholes occur along the watershed and into the Robins and Sinamatella areas, as well as in a broad belt parallel to the railway line in the east of the Park. Thus the vegetation types most likely to be affected by elephant include ecotone types along the watershed, mopane woodland bushland and bushed grassland in the Robins and Sinamatella areas and Kalahari sand communities in the east of the Park. The vegetation of the fossil sand dunes and of the Triga vlei, and down to the Dzivanini flats inclusive are probably less affected by elephant. Two maps by Gibson (1989) show what could be the typical density and distribution of

elephant during the dry season before the rains in 1989 and just after some rain in 1988. Such maps could be overlain with the vegetation map to determine more precisely the vegetation types which are likely to have been affected during each sampling period since 1980.

It is possible that the high concentration of elephants, especially in recent years, has been effective in opening up the understory of shrubs in *Baikiaea* woodland. In this way the negative effects of fire on *Baikiaea* trees may have been suppressed. Since the removal of large herbivores (such as buffalo and elephant) from *Baikiaea* woodland in Zambia, it was noticed that the effects of fire on *Baikiaea* woodland (regeneration and survivorship of mature trees) were much more severe (Huckaby, 1986). Thus, in Zambia, cattle and clearing of the mutemwa (understory) by hand are used to reduce the impact of fires on *Baikiaea* woodland (Huckaby, 1986).

Childes (1984) suggested that elephant may impede succession of *Baikiaea - Terminalia* bushland to woodland by removing *T. sericea* which may act as a frost shelter to *Baikiaea* regeneration. She also suggested that elephant trample *Baikiaea* seedlings, thus reducing their percent regeneration, especially from seed.

Conybeare (1991) studied the effects of elephant on *Baikiaea* woodland in the Jambile area which is in the east of the Park in an area that has burned only once or twice in 23 years. Damage to vegetation was greatest where there was the highest elephant occupancy. He found that elephant were very selective in their feeding. They caused the conversion of deep rooted species such as *Combretum collinum* and *Burkea africana* trees to shrubs. Elephants were more likely to kill shallow rooted trees such as *Terminalia sericea* which are more easily pushed over and up-rooted. Conybeare found that there was 5% damage to trees per annum in bushland, 2% damage in woodland and 7% in wooded grassland. Elephants had little overall effect on *Baikiaea plurijuga* and *Terminalia sericea*, except on the latter where it occurred in wooded grassland. Conybeare also found that the amount of damage was correlated to the previous season's rainfall. If there had been good rains damage was less than if there had been poor rainfall during the preceding season.

The amount of elephant damage was not as clearly related to the distance from water as was expected. Several factors caused elephant to feed in those areas which were not close to permanent water supplies such as the previous removal of palatable species in

vegetation closer to water, sodium content of different pans (Jambile has a low sodium content of its water compared to Dopi or Manga 1), and disturbances to feeding patterns caused by culling. Sodium content is important to the palatability of water and plants to elephant (Weir, 1972; Jachmann and Bell, 1985, in Conybeare, 1991).

Brief comparison of other woody vegetation surveys conducted in Hwange National Park

Non-Kalahari sand areas

Robinson's (1974) survey of the Robins area was aimed at delineating the main vegetation types. He separated twenty-two different types in four categories: 1) *Baikiaea plurijuga* ; 2) *Colophospermum mopane* chiefly on basalt areas and on soils derived from Basement Complex; 3) *Combretum* sp. on Karoo sandstone or soils of Cretaceous origin; 4) "Grassland" or vlei areas on deep basalts which are not hydromorphic.

Robinson's type 1 *Baikiaea* woodland is obviously equivalent to type 29 of this survey, according to the distribution on his vegetation map. Robinson's type 2 *Burkea* - *Julbernardia* tree bush savanna to shrub savanna is similar in distribution to that of Mopane - *Julbernardia globiflora* - *Combretum* wooded bushland (type 5) in this survey (Table 6) and so on.

The similar names and qualitative descriptions of Robinson's types make it difficult to separate out one type from another in terms of species composition, and without the map. Thus it has been very difficult to make a proper comparison of his survey with this one. Robinson also mapped the Robins area in more detail and had more vegetation types on basalt soils than were separated out in this survey.

Clifford Tafangenyasha surveyed the Sinamatella area in 1986 (unpublished). His 90 samples were incorporated into this survey.

Worsley's results of the (1987) survey of the Matetsi Complex are comparable with the results obtained in this survey (Table 7). The vegetation of Matetsi is composed predominantly of bushed low woodland on basalt derived soils, with pockets of Kalahari sands, except for where they are more extensive in the northern areas (Kazuma and Panda-Masuie to Fuller Forest areas). There are no Karoo sediments in the Matetsi Safari area. Of the non-Kalahari sand types,

Table 6. A comparison of the types described by Robinson (1974) with the types defined in this survey.

typ	Robinson (1974) survey Robins area	typ	gr	This survey whole Park
1	Baikiaea woodland	29	J	Baikiaea-Commiphora mossambicensis woodland and thicket, with Combretum apiculatum, Catunaregam spinosum and Diplorhynchus condylocarpon.
2	Burkea-Julbernardia, tree bush savanna to scrub savanna	5	B	Mopane - Julbernardia - Combretum wooded bushland
3	C. mopane bush clump savanna to shrub savanna	12	E	C. mopane - Combretum hereroense bushed grassland to bushland
4	Ischaemum grassland to shrub savanna	11	D	C. mopane- Acacia-Combretum
5	C. mopane woodland to tree savanna	"	"	in seasonally inundated areas
6	Combretum bush savanna to bush thicket	6	B	? Combretum-Baphia thicket
7	Combretum-C. mopane tree bush savanna to bush savanna	7	C	? Combretum-Baphia thicket
8	C. mopane-Combretum tree savanna to tree bush savanna	13	E	C. mopane - Combretum bushed grassland on basalt
		14	E	C. mopane bushland on basalt
9	Ischaemum grasslands	11	D	C. mopane - Acacia - Combretum in seasonally innundated areas
10	Hyparrhenia grassland			Not surveyed
11	C. mopane-Combretum bush savanna	14	E	? C. mopane bushland on basalt (with D. condylocarpon)
12	Combretum-Bolusanthus bush clump savanna to shrub savanna	13	E	C. mopane - Combretum bushed grassland on basalt
13	Combretum-Bauhinia bush scrub savanna	4	B	?Castle kopje mixed woodland & thicket
		5	B	? C. mopane - Julbernardia wooded bushland
14	Combretum-other species-C.mopane bush clump savanna to scrub savanna	11	D	C. mopane-Acacia-Combretum in seasonally inundated areas
15	C. mopane woodland to woodland savanna	11	D	"
16	C. mopane woodland	7	C	C. mopane- Combretum woodland (with Xeroderris stuhlmannii)
17	C.mopane-Combretum woodland to tree bush savanna			?
18	Combretum-other species woodland to scrub savanna			?
19	Acacia-Terminalia woodland to scrub savanna			?
20	Combretum tree bush savanna to scrub savanna	6	B	? Combretum-Baphia thicket
21	C. mopane tree scrub savanna to scrub savanna			?
22	C. mopane tree bush savanna to bush savanna			?

two of her basalt woodland types (2.3 and 2.4) are roughly equivalent to the two basalt types (in Group E) defined in this survey (Table 7).

These two types are similar in terms of major species, physiognomy, topography and soils, and in that they were difficult to differentiate on the aerial photographs. They differ only in terms of some of the less common species - but a comprehensive comparison is not possible without Worsley's phytosociological table which was not available.

Table 7. A comparison of two of Worsley's Basalt woodland types from her survey of the Matetsi Complex (1987), with the two basalt vegetation types defined in this survey.

Worsley's Matetsi Complex vegetation survey types and description (1987)	type no	group no	This survey types, groups and description
C. mopane - T. stuhlmannii - C. apiculatum tall to medium height open woodland and tall shrubland on red-brown, brown clay with small stones or brown gravel, on flat terrain or low ridges on the mid to lower slopes of the catena.	14	E	Colophospermum mopane - bushland on basalt Terminalia stuhlmannii a differential species for this type.
C. mopane - Kirkia acuminata - C. apiculatum low to medium height open woodland with open to moderately open shrub layers. This is a very broad type containing 17% of the total number of stands.	13	E	Colophospermum mopane - Combretum bushed grassland on brown and black clay in rocky areas. Kirkia acuminata common.

Kalahari sand areas.

Mitchell's (1961) survey described six types of vegetation in the ten mile drive area. It is difficult to compare these two surveys since they were done at different scales and using a different methodology. However, there are some similarities as is shown in Table 8.

Wiltshire's (1964) enumeration survey of Hwange National Park for the Forestry Commission, showed the distribution of harvestable timber, mainly on the Kalahari sands (the Mopane areas were mapped as one unit). He paid little attention to the differentiation of vegetation types based on species composition, and was concerned mainly with estimating the amount of timber available. Although his enumeration maps of certain areas of the Park are presumably accurate, he did not map the composite of the Park accurately. He differentiated four main

Table 8. A comparison of the results of Mitchell's (1961) survey of the ten mile drive and this survey.

Mitchell, 1961.	typ	grp	This survey
Kalahari sand woodland. Covers extensive areas entirely surrounding the 10-mile dve. area. Main components are Terminalia sericea, B. plurijuga, E. africanum, P. angolensis and G. coleosperma, all of which assume local dominance in the main woodland.	2 6 2 7	I I	Burkea africana- P. angolensis bushland and woodland Baikiaea -Guibourtia woodland
Areas of young saplings of Kalahari sand species. Uniformity in the size of the usually rather dense stand of young trees and shrubs. Mainly T. sericea, E. africanum and B. africana.	3 0	K	Burkea - Terminalia brachystemma bushland (Uncertain - but species composition very similar; possibly a mixture of several types from this survey).
Combretum woodland. Occupies the better drained portion of the floor of a basin (calcrete area) which lies within the Kalahari sand woodland proper.	1 9	F	Combretum hereroense - Hyphaene bushed grassland on calcrete
Areas of Diospyros lycioides and young saplings from the Combretum woodland association.	1 9	F	"
Acacia erioloba woodland. In certain restricted areas A. erioloba becomes dominant and these patches tend to be on the ecotone between the Kalahari sand woodland and type 2.	?		
Areas of encroachment of saplings from the A. erioloba woodland. In the vlei in front of Main Camp the only mature trees are a number of Ziziphus mucronata growing on termitaria.	?		

categories in the composite map: Mopane woodland and bushland, *Terminalia* bushland, *Baikiaea* woodland, and *Pterocarpus* woodland.

The findings of this survey pertaining to the Kalahari sand areas, tend to support the results of Childes and Walker's (1987), although more vegetation types were identified here. The *Terminalia prunioides* type identified by Childes and Walker was not described in this survey. Table 9 below shows how the types identified in this survey correspond with those Childes and Walker recognised.

Childes and Walker (1987) found that there were two major gradients - "one describing the physiognomic and species composition gradients from open scrubby stands dominated by *Terminalia sericea* and *Burkea africana*, through to dense, well-developed stands of *Baikiaea* ". The

Table 9. A comparison of the results of classifications of Kalahari sand vegetation and the soils on which they were found, by Childes and Walker, 1987 and this survey.

Childes and Walker (1987)			This survey		
Typ	Name and description	Soil character.	Typ	Gr	Name and description
1	Terminalia sericea scrub with Baikiaea plurijuga, Combretum collinum, C. zeyheri, Baphia massaiensis	Deep sands	25	H	T. sericea - Baikiaea plurijuga bushland (with B. plurijuga)
2	Burkea africana & T. sericea with Bauhinia petersiana, C. collinum & C. zeyheri scrub	Deep sands	24	H	Terminalia sericea - Acacia erioloba bushland
3	Diverse, poorly developed, mixed woodland with B. plurijuga, B. africana, Erythrophleum africanum, T. sericea & Brachystegia spiciformis Few Acacia erioloba, Lonchocarpus nelsii & Colophospermum mopane.	Slight incr. in clay content or hard layer present in some sands.	21 26	G I	T. sericea - Lonchocarpus nelsii bushland or B. africana-Pterocarpus angolensis bushland and woodland
4	Mixed woodland of B. plurijuga & Guibortia coleosperma with E. africanum, B. africana & T. sericea	Deep sands	27	I	Baikiaea-Guibourtia woodland
5	Open sparsely wooded grassland with Combretum hereroense	Calcrete layer in upper 1m of profile.	19	F	Combretum hereroense - Hyphaene bushed grassland on calcrete
6	C. mopane woodland	Clay content about 35%	18	F	Acacia-Boscia albitrunca-C. mopane bushed grassland in inter-dune troughs
7	Mature, undisturbed woodland: a)B.plurijuga canopy with Baphia massaiensis & C. pseudopulchellus b)B.plurijuga with some L.nelsii trees and Croton gratissimus in addition to above shrubs.	10-40% clay <10% coarse sand	28	I	Baikiaea-Croton gratissimus woodland
8	Mature woodland of L.nelsii, A. erioloba & B.plurijuga with a large number of species in shrub layer. A.erioloba dominant along drainage lines.	Soil with either compact layer or high clay content	23	G	Baikiaea - Combretum woodland thicket on fossil sand dune crests
9	Woodland of T.prunioides & A.tortilis with Commiphora africana & C. pyracanthoides shrubs.	very hard soil layers	?		Not differentiated in this survey

second gradient was edaphic; that is, from "vegetation on deep sandy soils to vegetation on clays". In their analysis this latter group was characterised by the presence of *Lonchocarpus nelsii*. It is interesting

to note that in the present study *L. nelsii* was one of the differential species for Groups 6, 7 and 8 which varies from open bushed grassland to bushland, thicket and woodland.

Childes and Walker were cautious in explaining the catena "from open scrubby stands dominated by *Terminalia sericea* and *Burkea africana*, through to dense, well developed stands of *Baikiaea* " in terms of either an edaphic or a successional gradient, but postulated that a combination of the two were influential. According to this survey it is surmised that their types 1 and 2 are equivalent to types 25 and 24 of Group H respectively (Table 10).

Childes and Walker's type 3 is probably a mixture of this survey's type 21 and type 26. Type 21 *Acacia - Combretum - Ochna pulchra* bushland is usually found adjacent to type 26 *Baikiaea - Combretum celastroides* woodland. For example, it is found quite extensively in the Makona to Kennedy area in the Mitswiri - Shakwanki area and along the extension of the Linkwasha fossil vlei line to Makona and Libuti Pan areas.

Childes and Walker's type 9 (*T. prunioides* and *A. tortilis*) was not differentiated in this survey. West of Verney's Pan is an extensive calcrete area, which was not sampled (but mapped by extrapolation using the aerial photographs). The road which comes from Jupanda and Jesse Bush going to Manga 1 Pan, passes just north of an apparently extensive area of *Terminalia prunioides* woodland. It is not clear whether this woodland is associated with the calcrete area or with *Acacia - Mundulea sericea* bushland.

Evaluation of the sampling method used in this survey

The sampling method of recording presence and absence only and not cover abundance is seen here as an adequate technique for this vegetation survey for several reasons.

In the TWINSPAN classification the primary function of the programme is the arrangement of the samples or stands whereby the most similar stands (in terms of species composition) are placed next to each other to produce a phytosociological table. Thus stands with the most similar species composition are placed next to each other regardless of the cover abundance of each species within that type. Only if there are many samples of the same type (ie. with the same species composition) would one begin to see the separation of a sub-type or new type on the

basis of cover abundance. Thus theoretically, only the order of the stands within a type or community will be changed according to the cover abundance of a species. If there are not enough stands representing a type the cover abundance value will not have any effect on the arrangement of the stands within it.

At this scale (1:80 000) and sampling intensity (10 samples per vegetation type, where a type may cover thousands of hectares) the continuous variation of cover abundances of different species cannot be defined. For example, within *Baikiaea* woodland there are sometimes "pockets" of species such as *Guibourtia coleosperma* where one would measure a high cover abundance of that particular species. Within a short distance from that "pocket" one could just as easily find woodland dominated by *Baikiaea*. But in both the *G. coleosperma* and *B. plurijuga* dominated samples one would be likely to find each of the mentioned species present, at least as a shrub or a seedling.

With intensive sampling it would be possible to differentiate these variations as vegetation sub-types or types based on the variations in cover abundance of the two species. With few samples one would not be able to differentiate what could be two vegetation types above, even if one had the information of cover abundance. It would be the consistent presence of the two main species which would lead to the classification of one type ie. *Baikiaea - Guibourtia coleosperma* woodland.

Two different classifications were run by TWINSPAN. The first was the presence or absence of species in each sample, and the second was the weighting of species by height class (see Methods). Thus if a species occurred as a tree it was scored as 3, if as a shrub as 2 and if a sub-shrub as 1. The results in Appendix 2 show the similarity of the results using these two classifications. The first two columns are the numbers of the type in which the sample was classified. The first column is the classification based on the scoring of species using their height class index (which was used in this report), and the second is the classification based on the presence or absence of each species. Most types were composed of about 90% of the same stands in each type.

Thus in terms of the classification of stands by TWINSPAN, cover-abundance values, too, should not change the overall order. Indeed, when comparing the presence-absence and cover-abundance weighted species classification of the vegetation stands in Chirisa, a similar

result was obtained (Craig, Martin and Mahlangu, 1984). The ordering of the vegetation stands was little altered by the use of cover-abundance values in the TWINSPAN classification.

However, in the subsequent description of each type, it would have been useful to have a simple estimate of the relative abundance of each species for each sample. Thus, if this survey were to be conducted again, it is suggested that a three point measure of abundance be given for each species in each height class: dominant or co-dominant, common and rare. Thus, rare would be only a few individuals seen in one hectare, common would be many individuals present in one hectare and dominant or co-dominant would be the most abundant species in a sample. This would have helped later in the description of the vegetation types. The overall percent cover in each of the three height strata was useful.

This is a descriptive, reconnaissance vegetation survey. Kuchler (1967) describes reconnaissance mapping as "mostly a preliminary step to more intensive mapping". Thus our techniques were to be fast, with only the most important data being recorded. Up to fifteen minutes extra or double the sampling time per sample may be spent (especially in mixed communities or those without clear dominant species) estimating the cover abundance of each species at each physiognomic height.

CONCLUSIONS AND RECOMMENDATIONS.

There are three parts to this section: a critique of the study, the implications of this study for management, and for further research.

Critique of the study.

This work has taken a very long time to come to completion. It was intended as a preliminary descriptive survey, using quick field sampling techniques. However, the study became "bogged down" in the analysis phase once the TWINSPAN classification had been completed, the results of which were extremely difficult to interpret; almost as difficult as interpreting the vegetation patterns based on limited field experience.

Sampling was the least time-consuming part of this vegetation survey. Instead it was the stages between the collation of the data, to the final write-up, which contributed the most to the delay.

The time taken in the collation, analysis and then interpretation of the data was approximately 18 months, by the end of which field knowledge gained during sampling was hazy. At this point a short field trip, to assess the preliminary interpretation of the TWINSPAN classification, would have been useful. Without this, the description of the types was slowed considerably. The lengthiness of this period (ie. for collation, analysis and interpretation) may have been speeded up if the Ecologist concerned had been based in Harare, near the Biometrics computer (at the Department of Research and Specialist Services) on which the analyses were done.

Much time was also spent actually preparing the vegetation map which is very large, and covers an office wall. Most of the equipment used to transfer data from the aerial photographs to the base maps, was situated in Harare, which meant a doubling of the time (in travel and organisation) required to complete the work.

The scale of the map caused problems in other ways too. Not only was it necessary to scale the data down from 1:80 000 to 1:100 000, but it was also necessary to change the scale of the base maps obtained from the Surveyor General. The maps of Hwange National Park are obtainable at the 1:50 000 or 1:250 000 scales. Thus, thirty-one 1: 50 000 topographic maps were photographically reduced to 1:100 000 on transparent mylar sheets. These were then photocopied and the copies used as base maps. Since photocopies are always distorted to some

extent, this meant that the encoding and editing of digitized maps was problematic later on, where more time has been wasted. Three months of editing and map-joining were lost when it was discovered that the six original mylar vegetation maps (derived directly from the photocopied base maps) could not be registered with the map-joined composite map of the six vegetation maps. Each of the six vegetation maps must be edited to be line-perfect, before they are joined, projected and transformed to UTM coordinates.

The establishment of the GIS, on which the vegetation map is now completed, slowed the completion of the final report. Time was spent, not only in the acquisition and setting up of the hardware and software, but also in planning data bases and studying established Geographic Information Systems in other National Parks (eg. Berchtesgaden National Park in Germany). It is well known that 90% of the time and money required to establish a working GIS is spent in data capture. The vegetation map is likely to be the most detailed "layer" in the system and would thus account for a large percentage of the total time to be spent establishing a working GIS.

The main benefits of the work are that this map and report provide baseline data and background information on the vegetation of the whole Park, as a basis for more detailed vegetation research. The proportions and actual areas of each vegetation type are now known. The map, now in digital form, will be easy to update and manipulate in analyses combining information on the distribution of environmental and biotic factors. The map will be useful in the habitat studies of various mammals, such as the endangered wild dog, and also in the study of the detrimental effects of over-populations of herbivores within the National Park.

Implications for Management.

This vegetation map would be of limited use to management as a wall or paper map. It will be of far greater use to both field managers and Park management research as a digital map on the Hwange National Park Geographic Information System (GIS) for many of the aspects of management which require background research of this kind:

1. The area of each vegetation type, each group of types and each structural or physiognomic category (ie. woodland, bushland etc.) is automatically given by the computer (the area of each polygon is given in the PAT (polygon attribute table) file as the map is digitized into the computer).

2. The areas of factors, such as fire frequency, geology and distance from permanent water, coincident with vegetation types can be obtained from the computer.
3. New maps showing areas of interest can be derived. For example, one could produce a map showing where there were woodland types which had burned once every two years, which occurred over 1km from permanent water with an average dry season elephant density of over 5 elephants per square kilometre. This would be done by overlaying the modified vegetation map showing woodland types only, with maps of fire frequency, areas beyond 1km from water, and the appropriate elephant distribution. Although the maps of fire frequency and pumped pans are not in the computer yet, they are simple and can be quickly and easily digitized. The maps of elephant distribution and density are presently being derived from aerial survey data collected annually since 1980.
4. Another way the map can be used is in the placement of scenic tourist roads. Game is more easily viewed in open vegetation such as bushed grassland. The current road network can be overlaid with the vegetation map and new routes planned based on the distribution of open vegetation types.
5. The map can be used when planning economic fire control measures, so that emphasis can be placed on the protection of woodland types by special vigilance in those areas and priority fire guard clearing. By clearing fire guards only in areas where woodlands need special protection, managers can cut annual costs. In these days of minimum budgets, managers can also use the map to decide where to let wild fires burn without any fire control.
6. In conjunction with A. M. Conybeare's results on the percent occupancy of elephant in various vegetation types, the vegetation map could be used to predict where the greatest damage by elephant might occur and in which vegetation types.

Further Research.

Some useful information has been gathered, and some preliminary hypotheses regarding communities and associated environmental factors have been generated (see Discussion). The distribution of woodland communities and bushland is now mapped, and their relationship with environmental factors, such as geology, topography, rainfall and altitude, is beginning to emerge.

The vegetation map should be regarded as a first hypothesis of the distribution of woody vegetation types. Since the map is to be maintained on a computer, the matter of updating the information on it will be simplified and speeded up. Thus it will be easy to change, for example, the label of a stratum wrongly identified, or to add and delete boundary lines between vegetation types. However, to avoid corruption of the data, a copy of the original map should always be maintained as a back-up.

The next step in this work on vegetation, is to focus on woodlands and grasslands, in order to determine the changes in canopy cover of trees, and bush encroachment respectively. By comparing the 1959/60 aerial photography with the most recent data (photographs taken in 1983/4), the percent change in canopy cover (of trees and bushes) can be determined. Such information would have direct applicability to management problems, such as the discernment of the effects of fire and expanding elephant populations. Rates of vegetation change could be ascertained by measuring canopy cover in the intervening aerial photography from the years between 1960 and 1983/4. In the project proposal (Rogers, in prep.) for this study, it is suggested that low altitude photography of permanent sample sites be flown at regular intervals to monitor environmental and biotic effects on the vegetation.

A soil survey of the Kalahari sand areas was started in August 1991 by the Chemistry and Soil Research Institute. The results of this may help to differentiate between edaphic and successional bushland in Hwange National Park. These data on the depth (and possibly the extent) of the hard pan layer in Kalahari sand areas should be mapped on the Hwange National Park Geographic Information System for overlay with the vegetation map. The combination of maps will help in the preliminary definition of edaphic bushlands.

Elephant distribution and density over the years is of major interest. The patterns of elephant density and distribution and vegetation type and structure can be considered in relation to the previous year's rainfall, fire regime, culling disturbance (in years when culling has taken place), poaching disturbance (based on reports of poached animals), and any other factors which can be mapped, using the GIS. Three dimensional maps can be created using point data derived from aerial surveys in the SEM module of ARC/INFO, and vegetation 'draped over' this 'landscape' to show in which vegetation types elephant density is greatest during a dry season survey. Two dimensional maps

of elephant density and distribution can also be created for use in the ways described above. Maps created using large mammal survey data since 1980 can be combined to show which areas of the Park are consistently utilized by large mammals.

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Appendix 1.
The sample data sheet, page 1.

Sample No. _____ Date: _____
Loc. Stat. _____
Location:

Geology

Soil texture _____

clay bedrock
1 2 3 4 5 6 7 8 9

Soil colour

Topography

% Cover of community sampled
<1m 1-3m >3m

Physiognomic description and dominant species

Sample data sheet, page 2

Sample No._____

	Height stratum		
Species	<1m	1-3m	>3m
Colo mopa	√	√	√
Acac nilo	√		
Dich cine	√	√	

Appendix 2.

Summary of sample data in the order of the TWINSPAN classification

Abbreviations

i) The first two columns in Appendix 2 show the number of the type to which that sample was assigned in two TWINSPAN classifications:

1st column. TWINSPAN classification based on the weighted classification of species in three height classes 1. <1m, 2. 1-3m and 3. >3m.

2nd column. TWINSPAN classification based only on the presence and absence of species.

ii) The fifth and sixth columns

soil texture classes		soil colour classes	
1	clay	L	Black
2	sandy clay	B	Brown
3	shallow sand (non-Kalahari)	G	Grey
4	gravel	W	White
5	shallow sand (Kalahari)	P	Pink
6	deep sand	R	Red
7	gravel		
8	rock		
9	bedrock		

iii) geological formations

Basement Complex formations

GNSS	Granitic gneiss
GNS?	Granitic gneiss?
INYA	Inyantue formation
SIJQ	Sijarira quartzites
TSHO	Tshontanda formation
ECOG	ecotone of granitic gneisses

Basalt

BASL	Basalt
BAS?	Basalt?

Karoo formations

LOKR	Lower Karoo
LHSS	Lower Hwange sandstone
UHSS	Upper Hwange sandstone
HWFC	Hwange fireclay
MUDS	Madumabisa mudstones
ESCG	Escarpment grits
UPKR	Upper Karoo
RIPM	Ripple-marked flags (Upper Karoo)

Ecotone

ECOT	Ecotone (on the boundaries of different geological formations)

Kalahari sands

KALS	Kalahari sands
CALC	Calcrete
CAL?	Calcrete?

iv) Woody plant cover is summarised in Appendix 1 as percent cover of each height stratum (<1m, 1-3m and >3m) as estimated in the field and recorded on the data sheets.

v) Physiognomic description codes are as follows usually according to the classification by Pratt, Greenway and Gwynne (1966), see Table 1:

OPNSCRUB	open scrub (eg. type 1)
BUSHLAND	bushland
MIXDBUSH	mixed bushland
OPENBUSH	open bushland
THIKBUSH	thick bushland (almost thicket)
THICKET	thicket
WOODLAND	woodland
MIXDWOOD	mixed species woodland (eg type 3)
OPENWOOD	open woodland
WOODTHIK	woodland thicket or wooded thicket
WOODBUSH	wooded bushland
BUSHWOOD	bushed woodland (same as above)
BUSHGRAS	bushed grassland
GRASBUSH	bushed grassland

In the field descriptions some terms were used which were not defined as above, as follows. The field physiognomic descriptions were based on a first impression of the vegetation and are thus not always as accurate as the estimates of percent cover. I always used the estimated percent cover of the three heights of woody plants where they differed from the physiognomic descriptions.

RIVERINE	riverine vegetation
VLEI	vlei line vegetation
SIDAGA	sidaga, Mopane vegetation on black, self-churning clays
STUNTMOP	stunted mopane

COIMFLATS	*Combretum imberbe* flats
COIMGRAS	*Combretum imberbe* trees scattered in grassland (same as above)
BUSHTHIK	bushland thicket (almost thicket)
VLEIBUSH	vlei bushland
PANVEGE	pan vegetation
WOODVLEI	wooded vlei
CLMPBUSH	clumped vegetation (usually in calcrete areas)
PALMFLAT	Palm (*Hyphaene petersiana*) flats or *H. petersiana* trees scattered in grassland)

vi) <u>woody species used in this report in the order that they appear in the phytosociological table (Table 2)</u> They appear in Appendix 1 as eight letter codes in capital letters. In the first column there is a list of the dominant or most common woody species (usually a tree in woodland and a shrub in bushland), followed in the second column by the co-dominant or second most common species in the community being assessed.

Julb glob	*Julbernardia globiflora* (Benth.) Troupin
Afze quan	*Afzelia quanzensis* Welw.
Brid moll	*Bridelia mollis* Hutch.
Schr tric	*Schrebera trichoclada* Welw.
Stry mada	*Strychnos madagascariensis* Poir.
Cant fran	*Canthium glaucum* Hiern subsp. *frangula* (S. Moore) Bridson
Comb elae	*Combretum elaeagnoides* Klotzsch
Dios quil	*Diospyros quiloensis* (Hiern) F. White
Ster afri	*Sterculia africana* (Lour.) Fiori
Stry pota	*Strychnos potatorum* L.f.
Xero stuh	*Xeroderris stuhlmannii* (Taub.) Mendonça & E.C. Sousa
Abru schi	*Abrus schimperi* Baker subsp. *africanus* (Vatke) Verde.
Bosc an.co.	*Boscia angustifolia* A. Rich. var. *corymbosa* (Gilg) DeWolf
Cant burt	*Canthium burtii* sensu auct. = *Canthium pseudorandii* Bridson
Comm kari	*Commiphora karibensis* Wild
Comm marl	*Commiphora marlothii* Engl.

Lonc erio	*Lonchocarpus eriocalyx* Harms subsp. *wankieensis* Mendoça & E.C. Sousa
Pter luce	*Pterocarpus lucens* Guill. & Perr. subsp. *antunesii* (Taub.) Rojo
Comb moss	*Combretum mossambicense* (Klotzsch) Engl.
Term prun	*Terminalia prunioides* C. Lawson
Gard resi	*Gardenia resiniflua* Hiern
Mark zanz	*Markhamia zanzibarica* (DC.) K. Schum.
Brac boeh	*Brachystegia boehmii* Taub.
Carp pube	*Carphalea pubescens* (Klotzsch) Verdc.
Comm moll	*Commiphora mollis* (Oliv.) Engl.
Elep goet	*Elephantorrhiza goetzei* (Harms) Harms
Eryt zamb	*Erythroxylum zambesiacum* N.Robson
Kirk acum	*Kirkia acuminata* Oliv.
Lann disc	*Lannea discolor* (Sond.) Engl.
Cass abbr	*Cassia abbreviata* Oliv.
Ciss corn	*Cissus cornifolia* (Baker) Planch.
Scle birr	*Sclerocarya birrea* (A. Rich.) Hochst. subsp. *caffra* (Sond.) Kokwaro
Vite pete	*Vitex petersiana* Klotzsch
Acac robu	*Acacia robusta* Burch. subsp. *clavigera* (E. Mey.) Brenan
Berc disc	*Berchemia discolor* (Klotzsch) Hemsl.
Vepr zamb	*Vepris zambesiaca* S. Moore
Comb aden	*Combretum adenogonium* A. Rich.
Term rand	*Terminalia randii* Baker f.
Term stuh	*Terminalia stuhlmannii* Engl.
Acac nigr	*Acacia nigrescens* Oliv.
Pter rotu	*Pterocarpus rotundifolia* (Sond.) Druce
Comm moss	*Commiphora mossambicensis* (Oliv.) Engl.
Term sten	*Terminalia stenostachya* Engl. & Diels
Allo afri	*Allophylus africanus* Beauv.
Colo mopa	*Colophospermum mopane* (Benth.) J. Léonard
Comb apic	*Combretum apiculatum* Sond.
Cross febr	*Crossopteryx febrifuga* (Afzel. ex Don) Benth.
Dalb mela	*Dalbergia melanoxylon* Guill. & Perr.
Eucl divi	*Euclea divinorum* Hiern
Catu spin	*Catunaregam spinosa* (Thunb.)
Acac tort	*Acacia tortilis* (Forssk.) Hayne
Albi harv	*Albizia harveyi* Fourn.
Bolu spec	*Bolusanthus speciosus* (Bolus) Harms
Lonc capa	*Lonchocarpus capassa* Rolfe
Flue viro	*Flueggea virosa* (Willd.) Voigt

Comb imbe	*Combretum imberbe* Wawra
Dios mesp	*Diospyros mespiliformis* A. DC.
Comb cela	*Combretum celastroides* C. Lawson
Comm afri	*Commiphora africana* (A. Rich.) Engl.
Comm pyra	*Commiphora pyracanthoides* Engl.
Grew mont	*Grewia monticola* L.
Dipl cond	*Diplorhynchus condylocarpon* (Muell. Arg.) Pichon
Comb here	*Combretum hereroense* Schinz
Hyph pete	*Hyphaene petersiana* Klotzsch
Mayt sene	*Maytenus senegalensis* (Lam.) Exell
Term brac	*Terminalia brachystemma* Welw.
Acac erub	*Acacia erubescens* Oliv.
Dich cine	*Dichrostachys cinerea* (L.) Wight & Arn.
Pelt afri	*Peltophorum africanum* Sond.
Zizi mucr	*Ziziphus mucronata* Willd.
Vang infa	*Vangueria infausta* Burch.
Acac atax	*Acacia ataxacantha* DC.
Comm ango	*Commiphora angolensis* Engl.
Crot grat	*Croton gratissimus* Burch.
Hipp indi	*Hippocratea indica* Willd.
Comb albo	*Combretum albopunctatum* Suesseng.
Grew fl.fl.	*Grewia flavescens* var. *flavescens* Juss.
Mund seri	*Mundulea sericea* (Willd.) Chev.
Acac lued	*Acacia luederitzii* Engl.
Dios lyci	*Diospyros lycioides* Desf.
Acac erio	*Acacia erioloba* E. Mey.
Acac flec	*Acacia fleckii* Schinz
Rhus tenu	*Rhus tenuinervis* Engl.
Lonc nels	*Lonchocarpus nelsii* (Schinz) Heering & Grimme
Ochn cinn	*Ochna cinnabarina* Engl. & Gilg
Bosc albi	*Boscia albitrunca* (Burch.) Gilg & Benedict
Grew flav	*Grewia flava* DC.
Pave lasi	*Pavetta lasiopeplus* K. Schum.
Bauh pete	*Bauhinia petersiana* Bolle
Comb coll	*Combretum collinum* Fresen.
Comb zeyh	*Combretum zeyheri* Sond.
Term seri	*Terminalia sericea* DC.
Pseu mapr	*Pseudolachnostylis maprouneifolia* Pax
Stry spin	*Strychnos spinosa* Lam.
Vite payo	*Vitex payos* (Lour.)Merr.
Baph mass	*Baphia massaiensis* Taub. subsp. *obovata* (Schinz) Brummitt
Crot pseu	*Croton pseudopulchellus* Pax

Grew avel	*Grewia avellana* Hiern
Baik plur	*Baikiaea plurijuga* Harms
Ochn pulc	*Ochna pulchra* Hook.
Comb psid	*Combretum psidioides* Welw.
Dich rhod	*Dichapetalum rhodesicum* Sprague & Hutch.
Burk afri	*Burkea africana* Hook.
Eryt afri	*Erythrophleum africanum* (Benth.) Harms
Guib cole	*Guibourtia coleosperma* (Benth.) J. Léonard
Pter ango	*Pterocarpus angolensis* DC.

There were 293 species which were used in the TWINSPAN classification of the 600 samples. They are listed below in alphabetical order. In the final tabulation (ie. the complete TWINSPAN phytosociological table) which was output by the programme, only 200 species were listed to try and keep the table to a manageable size.

The species used in the TWINSPAN classification are listed below in alphabetical order in which they were entered (ie. from species number 1 to species number 293). The sources for authorities were taken from "A list of Trees, Shrubs and Woody Climbers Indigenous and Naturalised in Rhodesia" by R.B. Drummond (1975) in Kirkia 10: 229 - 286. The authorities are abbreviated according to Brummitt, R.K., and Powell, C.E., Authors of plant names, Royal Botanic Gardens,Kew,1992 . Although Mr. R.B. Drummond also checked the species list and made updates where appropriate, I am responsible for any errors or omissions.

Abrus schimperi Baker subsp. *africanus* (Vatke) Verdc.
Acacia albida now *Faidherbia albida* (Delile) A. Chev.
Acacia ataxacantha DC.
Acacia eriocarpa Brenan
Acacia erioloba E. Mey.
Acacia erubescens Oliv.
Acacia fleckii Schinz
Acacia galpinii Burtt Davy
Acacia gerrardii Benth.
Acacia goetzei Harms subsp. goetzei
Acacia hebeclada DC.
Acacia karroo Hayne
Acacia kirkii Oliv.
Acacia luederitzii Engl.
Acacia mellifera (Vahl) Benth.
Acacia nigrescens Oliv.

Acacia nilotica (L.) Delile
Acacia polyacantha Willd. subsp. campylacantha (A. Rich) Brenan
Acacia robusta Burch. subsp. *clavigera* (E.Mey.) Brenan
Acacia sieberiana DC.
Acacia tortilis (Forssk.) Hayne
Adansonia digitata L.
Afzelia quanzensis Welw.
Albizia anthelmintica (A. Rich.) Brongn.
Albizia antunesiana Harms
Albizia brevifolia Schinz
Albizia harveyi Fourn.
Albizia tanganyicensis Baker f.
Allophylus africanus Beauv.
Amblygonocarpus andongensis (Oliv.) Exell & Torre
Ampelocissus africana (Lour.) Merr.
Ancylanthos bainesii Hiern
Annona stenophylla Engl & Diels subsp. *nana* (Exell) N. Robson
Artabotrys brachypetalus Benth
Azanza garckeana (F. Hoffm.) Exell & Hillc.
Baikiaea plurijuga Harms
Balanites aegyptiaca (L.) Delile
Baphia massaiensis Taub. subsp. obovata (Schinz) Brummitt
Bauhinia petersiana Bolle
Bauhinia thonningii now *Piliostigma thonningii* (Schumach.)Milne-Redh.
Bauhinia tomentosa L.
Berchemia discolor (Klotzsch) Hemsl.
Bolusanthus speciosus (Bolus) Harms
Boscia albitrunca (Burch.) Gilg & Gilg-Ben.
Boscia angustifolia A. Rich should be combined in the table with *Boscia* below
Boscia angustifolia A Rich. var. *corymbosa* (Gilg) DeWolf
Boscia matabelensis Pestal.
Boscia mossambicensis Klotzsch
Boscia salicifolia Oliv.
Brachystegia boehmii Taub.
Brachystegia spiciformis Benth.
Brackenridgea arenaria (De Wild & T.Durand) N.Robson
Bridelia cathartica G. Bertol.
Bridelia mollis Hutch.
Burkea africana Hook.
Cadaba kirkii Oliv.
Cadaba termitaria N.E. Br.
Canthium burttii Bullock now *Canthium pseudorandii* Bridson

Canthium frangula now *Canthium glaucum* Hiern subsp. *frangula* (S. Moore) Bridson
Canthium huillense now *Psydrax livida* (Hiern) Bridson
Capparis tomentosa Lam.
Carphalea pubescens (Klotzsch) Verdc.
Cassia abbreviata Oliv.
Cassia singueana now *Senna singueana* (Delile)Lock
Cassine transvaalensis now *Crocoxylon transvaalense* (Burtt Davy) N.Robson
Cephalocroton mollis Klotzsch
Cissus cornifolia (Baker) Planch.
Cissus welwitschii (Baker) Planch.
Clerodendrum glabrum E. Mey.
Clerodendrum wildii Moldenke
Cocculus hirsutus (L.) Diels
Colophospermum mopane (Benth.) J. Léonard
Combretum albopunctatum Suesseng.
Combretum apiculatum Sond.
Combretum celastroides C. Lawson
Combretum collinum Fresen.
Combretum elaeagnoides Klotzsch
Combretum fragrans now *Combretum adenogonium* A. Rich.
Combretum hereroense Schinz
Combretum imberbe Wawra
Combretum microphyllum Klotzsch
Combretum molle G. Don
Combretum mossambicense (Klotzsch) Engl.
Combretum paniculatum Vent.
Combretum psidioides Welw.
Combretum zeyheri Sond.
Commiphora africana (A. Rich.) Engl.
Commiphora angolensis Engl.
Commiphora caerulea B.D. Burtt
Commiphora edulis (Klotzsch) Engl.
Commiphora glandulosa Schinz.
Commiphora karibensis Wild
Commiphora marlothii Engl.
Commiphora mollis (Oliv.) Engl.
Commiphora mossambicensis (Oliv.) Engl.
Commiphora pyracanthoides Engl. should be combined with *C. glandulosa*
Commiphora ugogensis Engl.
Cordia pilosissima Baker
Courbonia glauca now *Maerua edulis* (Gilg & Ben.) DeWolf.

Crossopteryx febrifuga (G. Don) Benth.
Croton gratissimus Burch.
Croton megalobotrys Muell. Arg.
Croton menyharthii Pax
Croton pseudopulchellus Pax
Croton scheffleri now *Croton longipedicellatus* J.Léonard
Dalbergia martinii F. White
Dalbergia melanoxylon Guill. & Perr.
Dalbergia nitidula Baker
Dialium englerianum Henriq.
Dichapetalum rhodesicum Sprague & Hutch.
Dichrostachys cinerea (L.) Wight & Arn.
Dioscorea dumetorum (Kunth) Pax
Diospyros kirkii Hiern
Diospyros lycioides Desf. subsp. *lycioides*
Diospyros mespiliformis A. DC.
Diospyros quiloensis (Hiern) F. White
Diospyros senensis Klotzsch
Diplorhynchus condylocarpon (Muell. Arg.) Pichon
Dodonaea viscosa in the table but should be *Dodonaea angustifolia* L.f.
Dombeya rotundifolia (Hochst.) Planch.
Dovyalis caffra (Hook. f. & Harv.) Warb.
Dregea macrantha Klotzsch
Dyschoriste matopensis N.E. Br.
Ehretia amoena Klotzsch
Ehretia obtusifolia DC.
Ehretia rigida (Thunb.) Druce
Elephantorrhiza elephantina (Burch.) Skeels
Elephantorrhiza goetzei (Harms) Harms
Entada nana in the table but should be *Entada arenaria* subsp. *arenaria*
Entandrophragma caudatum (Sprague) Sprague
Erythrococca menyharthii (Pax) Prain
Erythrophleum africanum (Benth.) Harms
Erythroxylum zambesiacum N.Robson
Euclea divinorum Hiern
Euphorbia cooperi A. Berger
Euphorbia espinosa Pax
Euphorbia fortissima L.C. Leach.
Euphorbia griseola Pax
Euphorbia ingens Boiss.
Euphorbia malevola L.C. Leach.
Euphorbia matabelensis Pax
Excoecaria bussei (Pax) Pax

Fagara chalybdea now *Zanthoxylum chalybeum* Engl.
Feretia aeruginescens Stapf
Ficus capensis now *Ficus sur* Forssk.)
Ficus ingens (Miq.) Miq.
Ficus nigropunctata Mildbr. & Burret
Ficus obtusifolia ? misidentified
Ficus soldanella now *Ficus abutilifolia* Miq.
Ficus sycomorus L.
Flacourtia indica (Borm. f) Merr.
Fockea multiflora K.Schum.
Friesodielsia obovata (Benth.) Verdc.
Gardenia jovis-tonatis now *Gardenia ternifolia* Schumach. & Thonn.)
Gardenia resiniflua Hiern subsp. *resiniflua*
Gardenia volkensii K.Schum.
Grewia avellana Hiern
Grewia bicolor Juss.
Grewia flava DC.
Grewia flavescens Juss.*var flavescens*
Grewia flavescens Juss.*var olukondae* (Schinz) Wild
Grewia inaequilatera Garcke
Grewia monticola Sond.
Grewia retinervis Burret
Grewia schinzii K. Schum.
Grewia villosa Willd.
Guibourtia coleosperma (Benth.) J. Léonard
Gyrocarpus americanus Jacq.
Haplocoelum foliolosum (Hiern) Bullock
Hippocratea buchananii Loes.
Hippocratea indica Willd.
Hippocratea parviflora N.E.Br.
Hippocratea parvifolia Oliv.
Hyphaene benguellensis now *Hyphaene petersiana* Mart.
Ipomoea shirambensis Baker
Ipomoea shupangensis Baker
Jasminum fluminense Vell.
Jasminum stenolobum Rolfe
Julbernardia globiflora (Benth.) Troupin
Kigelia africana (Lam.) Benth.
Kirkia acuminata Oliv.
Lannea discolor (Sond.) Engl.
Lannea edulis (Sond.)Engl. var. edulis
Lannea edulis var *glabrescens* (Engl.) Burtt Davy
Lannea schweinfurthii (Engl.) Engl. var *stuhlmannii* (Engl.) Kokwaro

Lonchocarpus capassa Rolfe
Lonchocarpus nelsii (Schinz) Heering & Grimme
Lonchocarpus eriocalyx Harms subsp. *wankieensis* Mendonça & E.C. Sousa
Maerua angolensis DC.
Maerua juncea Pax
Maerua parvifolia Pax
Maerua prittwitzii Gilg. & Gilg-Ben.
Maerua salicifolia Wild
Manilkara mochisia (Baker) Dubard
Margaritaria discoidea (Baill.) G.L.Webster
Markhamia acuminata now *Markhamia zanzibarica* (DC.) K. Schum.
Markhamia obtusifolia (Baker) Sprague
Maytenus heterophylla (Eckl. & Zeyh) N.Robson
Maytenus putterlickioides (Loes.) Exell & Mendonça
Maytenus senegalensis (Lam.) Exell
Meiostemon tetrandrus (Exell) Exell & Stace
Monotes engleri Gilg.
Mundulea sericea (Willd.) A.Chev.
Ochna cinnabarina Engl. & Gilg
Ochna pulchra Hook.
Olax obtusifolia De Wild.
Parinari curatellifolia Benth.
Pavetta gardeniifolia A. Rich.
Pavetta lanciflora ? misidentified
Pavetta lasiopeplus K.Schum.
Pavetta schumanniana K. Schum.
Peltophorum africanum Sond.
Phyllanthus reticulatus Poir.
Pleurostylia africana Loes.
Pseudolachnostylis maprouneifolia Pax
Psilotricum scleranthum Thwaites
Pteleopsis anisoptera (C. Lawson) Engl. & Diels
Pteleopsis myrtifolia (C. Lawson) Engl. & Diels
Pterodiscus ngamicus Stapf
Pterocarpus angolensis DC.
Pterocarpus lucens auctt.=*P.antunesii* (Taub.)Harms
Pterocarpus rotundifolius (Sond.) Druce
Rhigozum brevispinosum Kuntze
Rhus tenuinervis Engl.
Ricinodendron rautanenii Schinz now *Schinziophyton rautanenii* (Schinz)Radcl.-Sm.
Schrebera trichoclada Welw.

Sclerocarya birrea (A. Rich.) Hochst. subsp. *caffra* (Sond.) Kokwaro
Securidaca longipedunculata Fresen.
Securinega virosa now *Flueggea virosa* (Willd.) Voigt
Steganotaenia araliacea Hochst.
Sterculia africana (Lour.) Fiori
Stereospermum kunthianum Cham
Stomatostemma monteroae (Oliv.)N.E.Br.
Strophanthus kombe Oliv.
Strophanthus nicolsonii Holmes
Strophanthus petersianus Klotzsch
Strychnos cocculoides Baker
Strychnos madagascariensis Poir.
Strychnos potatorum L.f.
Strychnos pungens Soler.
Strychnos spinosa Lam.
Swartzia madagascariensis Desv.
Tacazzea apiculata Oliv.
Tarenna luteola (Stapf) Bremek.
Tarenna neurophylla (S. Moore) Bremek.
Terminalia brachystemma Hiern
Terminalia mollis C. Lawson
Terminalia prunioides C. Lawson
Terminalia randii Baker f.
Terminalia sericea DC.
Terminalia stenostachya Engl. & Diels
Terminalia stuhlmannii Engl.
Terminalia trichopoda Diels
Tinnea vestita
Triaspis macranthus ? misidentified
Tricalysia allenii now *T. junodii* (Schinz) Brenan var. *kirkii* (Hook.f.) Robbrecht
Trichilia emetica Vahl
Triplochiton zambesiacus Milne-Redh.
Turraea nilotica Kotschy & Peyr.
Vangueria infausta Burch.
Vangueria randii S. Moore
Vangueria lanciflora (Hiern) Robyns
Vepris zambesiaca S. Moore
Vitex mombassae Vatke
Vitex payos (Lour.) Merr.
Vitex petersiana Klotzsch
Xeroderris stuhlmannii (Taub.) Mendonça & E.C. Sousa

Xeromphis obovata now *Catunaregam spinosa* (Thunb.) Tirvengadum subsp. *taylorii*
Xerophyta equisetoides
Ximenia americana L.
Ximenia caffra Sond.
Xylopia odoratissima Oliv.
Zanha africana (Radlk.) Exell
Ziziphus abyssinica A. Rich
Ziziphus mucronata Willd.
Allophyllus species
Capparis species
Dovyalis species
Ehretia species
Euphorbia species
Gardenia species
Grewia species
Hippocratea species
Olax species
Rhus species
Species 227
Species 228
Species one
Species two
Vitex species
Commiphora viminalis now *Commiphora merkeri* Engl.
Euphorbia transvaalensis Schltr.
Ficus thonningii Blume

Appendix 2 continued.

Summary of the sample data in the order of the TWINSPAN classification.

New Typ	Old Typ	Stand No.	UTM Loc. Stat.	Soil Tex	Soil Col	Geology	Wooc <1m	Plant Cove 1-3m	>3m	Physiognomic Description	1st common woody sp.	2nd commor woody sp.
1	1	469	MK243385	4		HWFC	26	48	9	OPNSCRUB	COMBELAE	LONCERIO
1	1	506	MK201468	8		LHSS	35	33	13	OPNSCRUB	COMBAPIC	LONCERIO
1	1	585	MK202465	2	W	LOKR	5	15	1	OPNSCRUB	COMBRESP	COLOMOPA
1	1	490	MK204526	4		HWFC	15	32	22	THICKET	COMBCELA	CROTSCHE
1	1	511	MK228450	4		UHSS	21	79	31	THICKET	COMBCELA	COMBELAE
1	1	470	MK239383	4		HWFC	57	78	16	THICKET	COMBELAE	COMBCELA
1	1	471	MK231433	4		HWFC	34	27	10	OPNSCRUB	LONCERIO	COMBELAE
1	1	489	MK204526	4		HWFC	18	17	23	OPNSCRUB	COMBCELA	COMBELAE
1	1	491	MK201525	8		LHSS	18	16	27	OPNSCRUB	COMBELAE	COMBCOLL
1	1	495	MK205525	4		UHSS	30	40	35	THICKET	COMBCELA	COMBELAE
1	1	496	MK198525	8		LHSS	11	11	28	OPNSCRUB	COMBELAE	LONCERIO
1	1	510	MK228451	4		UHSS	25	33	78	THICKET	COMBCELA	COMBELAE
1	1	534	MK228442	3	G	LHSS	23	98	12	THICKET	COMBCOLL	DIOSQUIL
1	1	535	MK230444	4		LHSS	12	40	13	OPNSCRUB	COMBAPIC	COMBELAE
2	2	459	MK248438	1	G	MUDS	22	73	42	MIXDWOOD	SECUVIRO	COMBHERE
2	2	467	MK238365	1	G	MUDS	0	55	2	RIVERINE	CROTGRAT	FRIEOBOV
2	5	478	MK400433	1	G	MUDS	42	44	88	WOODLAND	COLOMOPA	ACACROBU
2	2	595	MK446420	2	B		10	15	10	OPENBUSH	COMBELAE	DIOSQUIL
2	2	453	MK301416	1	G	MUDS	65	38	88	WOODLAND	COLOMOPA	GREWIASP
3	2	462	MK275049	8		ESCG	12	31	63	MIXDWOOD	COMMEDUL	GREWMONT
3	2	463	MK339471	8		ESCG	61	21	16	MIXDWOOD	GREWIASP	DIOSQUIL
3	2	479	MK429429	8		ESCG	16	10	44	MIXDWOOD	TERMPRUN	DIOSQUIL
3	2	499	MK475414	8		GNSS	12	13	40	MIXDWOOD	MARKACUM	STRYPOTA
3	2	504	MK525419	4	R	INYA	41	52	61	WOODTHIK	COMBELAE	COLOMOPA
3	2	530	MK202405	4	B	GNSS?	64	38	63	WOODLAND	COLOMOPA	DIOSQUIL
3	2	540	MK280452	8		ESCG	63	34	93	WOODTHIK	PTERLUCE	MARKACUM
4	5	474	MK240258			GNSS	16	30	57	RIVERINE	SECUVIRO	STRYPOTA
4	2	527	MK233433	4		LHSS	23	105	3	WOODBUSH	COLOMOPA	COMBELAE
4	13	586	MK189478	8	B		10	20	50	MIXDWOOD	ERYTZAMB	
4	9	592	MK201453	8		LOKR	5	80	1	THICKET	COMELAE	COMBAPIC
4	12	137	MK663350	8		GNSS	35	45	15	BUSHLAND	COLOMOPA	COMBAPIC
4	12	138	MK255240	8		GNSS	15	20	30	BUSHWOOD	COLOMOPA	COMBMOSS
4	12	140	MK733486	9		GNSS	2	10	25	BUSHLAND	COLOMOPA	PTERANGO
4	12	451	MK256486	9		GNSS	31	43	26	WOODLAND	KIRKACUM	CARPPUBE
4	2	481	MK422340	8		GNSS	27	9	56	MIXDWOOD	COMBELAE	MARKACUM
4	12	482	MK435327	2	R	INYA	27	52	58	MIXDWOOD	COMBAPIC	COLOMOPA
4	12	488	MK257498	8		GNSS	39	43	36	MIXDWOOD	COLOMOPA	COMBAPIC
4	2	493	MK187524	8		SIJQ	55	16	31	THICKET	COMBELAE	COMBAPIC
4	12	497	MK454417	5	R	TSHO	45	13	19	MIXDWOOD	COMBAPIC	COMBELAE
4	12	500	MK493420	8	R	TSHO	42	32	19	MIXDWOOD	COMBAPIC	COLOMOPA
4	12	507	MK179445	5	P	SIJQ	44	39	56	THICKET	COMBAPIC	COMBCOLL
4	12	518	MK121332	5	R	GNSS	28	92	32	MIXDWOOD	COLOMOPA	COMBAPIC
4	2	542	MK251239	8		INYA	51	124	106	MIXDWOOD	COLOMOPA	CANTBURT
4	12	584	MK153530	9		UPKR	5	30	20	MIXDBUSH	KIRKACUM	XEROSTUH
4	12	589	MK213488	9	B	SIJQ	3	25	20	WOODLAND	COLOMOPA	COMBAPIC

Appendix 2 continued.
Summary of the sample data in the order of the TWINSPAN classification.

New Typ	Old Typ	Stand No.	UTM Loc. Stat.	Soil Tex	Soil Col	Geology	Wooc <1m	Plant Cove 1-3m	>3m	Physiognomic Description	1st common woody sp.	2nd commor woody sp.
5	12	136	MK653339	9		GNSS	15	75	20	MIXDBUSH	TERMSTEN	COLOMOPA
5	12	141	MK731428	8		GNSS	10	10	10	BUSHLAND	COMBZEYH	COLOMOPA
5	12	142	MK742407	9		GNSS	20	15	5	BUSHWOOD		
5	12	143	MK697367	9		GNSS	20	35	10	BUSHWOOD	COLOMOPA	COMBZEYH
5	12	145	MK624319	9		GNSS	5	45	20	BUSHLAND	COMBAPIC	TERMSERI
5	12	153	MK726491	8		GNSS	10	15	5	MIXDBUSH	TERMSERI	COLOMOPA
5	12	154	MK753453	9		GNSS	10	10	15	BUSHLAND	COMBZEYH	COLOMOPA
5	12	155	MK697380	9		GNSS	5	10	10	MIXDBUSH	COMBZEYH	COLOMOPA
5	12	159	MK061356	2	B		10	40	15	WOODBUSH	COLOMOPA	COMBAPIC
5	13	449	MK288473	5			32	73	19	THICKET	COMBAPIC	COMBZEYH
5	1	454	MK193460			SIJQ	54	84	15	WOODSCRUI	COLOMOPA	JULBGLOB
5	12	487	MK252494	2	R	GNSS	18	44	15	MIXDWOOD	COLOMOPA	COMBAPIC
5	12	501	MK500422	8		TSHO	35	48	19	MIXDWOOD	COLOMOPA	COMBAPIC
5	12	590	MK211479	8		LOKR	5	65	2	BUSHLAND	COMBAPIC	COMBELAE
5	12	597	MK535420	9		GNSS	10	35	50	WOODLAND	COLOMOPA	COMBAPIC
5	12	598	MK545415	9		GNSS	5	30	20	WOODBUSH	COMBAPIC	COLOMOPA
5	13	35	MK841402	2			5	5	1	OPENBUSH	COMBCOLL	COLOMOPA
5	13	64	MK606310	2			30	75	20	BUSHWOOD	COMBAPIC	JULBGLOB
5	13	66	MK822424	8	B	ECOT	10	25	2	MIXDBUSH	COLOMOPA	COMBSP
5	13	75	MK423239	2		ECOT	15	70	35	BUSHLAND	COMBAPIC	SHCRTRIC
5	13	132	MK390248	2			2	65	5	THICKET	COMBAPIC	ERYTZAMB
5	13	151	MK775450	7	P	GNSS	15	35	10	BUSHWOOD		
5	13	599	MK786446	2	R	ECOT	15	30	20	WOODBUSH	COLOMOPA	COMBAPIC
5	13	600	MK811431	2	R	ECOT	5	30	10	BUSHLAND	COMBCOLL	COMBAPIC
6	13	60	MK799397	2	R		40	55	10	MIXDBUSH	MARKACUM	SCHRTRIC
6	13	70	MK132164	2	R		25	60	1	BUSHLAND	COMBAPIC	COMBMOSS
6	13	74	MK583315	2	R		15	75	10	THICKET	COMBAPIC	COMBMOSS
6	13	180	MK170312	2	R		10	40	55	THICKET	COMBAPIC	COLOMOPA
6	13	209	MK049312	5	R		5	55	80	WOODLAND	BAIKPLUR	COMBAPIC
6	13	213	MK004258	5	R		15	35	85	WOODLAND	BAIKPLUR	COMBAPIC
6	12	294	MK068322	2	R		15	70	10	THICKET	COMBAPIC	ERYTZAMB
6	13	564	LK882205	6	R	KALS	60	75	65	WOODLAND	BAIKPLUR	COMBAPIC
6	13	565	LK821198	2	R	ECOT	2	45	5	BUSHLAND	COMBAPIC	COMBMOSS
6	13	62	MK441268	8						MIXDBUSH	COMBAPIC	COMBIMBE
6	13	484	MK501302	5			27	60	30	THICKET	COMBAPIC	LONCNELS
6	1	526	MK183447	4		SIJQ	22	115	37	THICKET	DIOSQUIL	COLOMOPA
6	13	587	MK183481	8			5	85	1	BUSHLAND	COMBELAE	COMBAPIC
6	9	593	MK343485	2	R	UPKR	5	95	35	THICKET	COMBAPIC	COMBELAE
6	13	594	MK310473	2	R	UPKR	1	80	15	THICKET	COMBELAE	DIOSQUIL
7	7	1	MK083430	2	B	BASL	5	15	15	OPENWOOD	COLOMOPA	TERMRAND
7	8	53	MK700132	2	G		15	55	10	BUSHWOOD	COLOMOPA	COMBAPIC
7	8	588	MK195476	7	W					BUSHLAND	COLOMOPA	COMBAPIC
7	8	591	MK209477	8		LOKR	2	60	10	BUSHLAND	COMBAPIC	COLOMOPA
7	9	76	MK593312	2			35	50	25	WOODBUSH	COLOMOPA	COMMMOLL
7	9	77	MK633381	2	R	GNSS	20	15	45	WOODBUSH	COLOMOPA	STRYPOTA

Appendix 2 continued.

Summary of the sample data in the order of the TWINSPAN classification.

New Typ	Old Typ	Stand No.	UTM Loc. Stat.	Soil Tex	Soil Col	Geology	Wooc Plant Cove <1m	1-3m	>3m	Physiognomic Description	1st common woody sp.	2nd commor woody sp.
7	9	144	MK454282	8			20	35	35	WOODLAND	COLOMOPA	ERYTZAMB
7	12	146	MK658368	9		GNSS	5	20	35	OPENWOOD	COLOMOPA	CISSCORN
7	9	160	MK576346	2	R	ECOG	10	25	10	BUSHWOOD	COMBELAE	COMBAPIC
7	12	161	MK584371	4		GNSS	25	20	65	WOODLAND	COLOMOPA	
7	9	162	MK590390	8	R	ECOG	20	25	45	WOODLAND	COLOMOPA	COMBELAE
7	9	165	MK242247	8	B		15	20	30	WOODLAND	COLOMOPA	COMBELAE
7	9	166	MK232287	7	B		2	5	25	WOODLAND	COLOMOPA	COMBELAE
7	9	476	MK356228			KALS	61	10	44	WOODLAND	COLOMOPA	COMBELAE
7	12	483	MK435313	2	R	INYA	26	28	26	MIXDWOOD	COLOMOPA	COMBAPIC
7	2	494	MK193524	4		SIJQ	53	34	30	THICKET	COMBAPIC	COMBELAE
7	2	503	MK575395	4	R	INYA	33	46	75	WOODBUSH	COMBELAE	COMMMOSS
7	9	531	MK225433	8		ECOG	37	73	66	MIXDWOOD	COLOMOPA	COMBELAE
7	2	532	MK230436	4		LHSS	81	38	15	OPENWOOD	COLOMOPA	COMBELAE
7	9	596	MK480413	9	L	GNSS	30	45	25	MIXDWOOD	COMBMOSS	STERAFRI
8	9	148	MK247309	1	B		5	30	15	WOODLAND	COLOMOPA	ERYTZAMB
8	9	157	MK022396	7	B		2	40	40	WOODLAND	COLOMOPA	CARPPUBE
8	6	169	MK093419	7	B		2	30	20	WOODLAND	COLOMOPA	ERYTZAMB
8	7	178	MK224327	8			5	15	20	WOODLAND	COLOMOPA	COMBAPIC
8	6	452	MK309458	7	G	MUDS	53	54	41	WOODLAND	COLOMOPA	COMMAFRI
8	6	458	MK253453	1	G	MUDS	53	10	63	WOODLAND	COLOMOPA	STRONICO
8	6	461	MK327496	2		RIPM	65	27	75	WOODLAND	COLOMOPA	GREWIASP
8	5	468	MK257368	1	G	MUDS	31	16	41	WOODLAND	COLOMOPA	TERMSTUH
8	9	480	MK427384	2	R		47	21	45	MIXDWOOD	COLOMOPA	COMBAPIC
8	7	512	MK149329	1	R	GNSS	49	77	78	WOODLAND	COLOMOPA	COMBAPIC
8	7	513	MK117530	8	B	BASL	25	52	44	WOODLAND	COLOMOPA	COMBAPIC
8	7	516	MK109503	1	B	BASL	40	29	62	WOODLAND	COLOMOPA	CROTGRAT
8	6	525	MK251460	1	G	MUDS	60	59	15	WOODBUSH	COLOMOPA	COMMAFRI
8	6	450	MK286491	2			28	57	70	WOODLAND	COLOMOPA	ERYTZAMB
9	5	133	MK094387	8	B		25	75	20	THICKET	COMBELAE	COLOMOPA
9	2	150	MK097397	8	R		2	85	10	THICKET	COMBMOSS	COMBELAE
9	9	158	MK036356	7	B	GNS?	5	60	25	WOODLAND	COLONOPA	
9	5	173	MK024352	8	B		2	5	50	BUSHLAND	ACACROBU	TERMPRUN
9	9	177	MK090372	8	R		1	80	10	THICKET	COMBMOSS	COMBELAE
9	5	181	MK086363	8	B		2	20	10	WOODBUSH	ACACIASP	COMBELAE
9	5	473	MK234275	7		GNS?	26	80	71	RIVERINE	COMBMOSS	ACACROBU
9	5	533	MK227442				9	20	2	VLEI	COMBIMBE	COMBCOLL
9	9	164	MK654474	1		GNSS	40	50	20	RIVERINE	COLOMOPA	KIRKACUM
9	9	524	MK245319			UPKR	57	34	98	THICKET	COMBELAE	COMBMOSS
9	9	134	MK071347	2	B		5	80	40	WOODBUSH	COMBAPIC	DIOSQUIL
9	9	176	MK097339	7	R		15	60	30	THICKET	COMBELAE	XEROSTUH
9	9	179	MK192323	2	R		10	45	80	THICKET	COMBAPIC	COMBCELA
9	2	455	MK342433	4	R	UHSS	67	35	127	THICKET	COMBELAE	COMBAPIC
9	9	583	MK138525	9	R	UPKR	10	80	5	THICKET	COMBELAE	DIOSQUIL
10	5	19	MK043453	1	G		2	50	20	RIVERINE	COMBHERE	COMBIMBE
10	5	456	MK366434	2	G		25	40	63	MIXDWOOD	COMBPANI	GREWINAE

Appendix 2 continued.
Summary of the sample data in the order of the TWINSPAN classification.

New Typ	Old Typ	Stand No.	UTM Loc. Stat.	Soil Tex	Soil Col	Geology	Wooc <1m	Plant Cove 1-3m	>3m	Physiognomic Description	1st common woody sp.	2nd commor woody sp.
10	5	464	MK295343	1	G		19	19	107	MIXDWOOD	COMBMOSS	CROTMEGA
10	5	492	MK134532	1	G	BAS?	36	21	58	MIXDWOOD	COMBMOSS	SECUVIRO
10	5	505	MK398432			MUDS	26	50	17	RIVERINE	COMBMOSS	SECUVIRO
10	5	515	MK120528			BASL	55	34	21	MIXDWOOD	COMBHERE	COLOMOPA
10	5	523	MK168393			GNSS	10	20	35	RIVERINE	COMBMOSS	ACACROBU
10	9	168	MK264295			ECOT	2	5	2	RIVERINE		
10	11	460	MK325497			RIPM	25	70	49	MIXDWOOD	SECUVIRO	COMBHERE
10	5	498	MK475414			GNSS	35	29	22	RIVERINE	COMBMOSS	AZANGARC
10	11	502	MK559403			GNSS	32	54	22	RIVERINE	BAUHTHON	ZIZIABYS
10	11	522	MK107336			GNSS	31	50	40	RIVERINE	COMBHERE	COLOMOPA
10	5	539	MK254453			MUDS	19	56	49	RIVERINE	MAYTHETE	COMBIMBE
11	3	110	MJ717187	1	L		1	1	0	SIDAGA	ACACNILO	DICRCINE
11	5	174	LK973319	7	W	BASL	1	5	1	BUSHLAND	ACACLUDE	COLOMOPA
11	5	175	MK015326	7		BASL	1	5	75	WOODLAND	ACACLUDE	TERMPRUN
11	4	15	LK990370	1	L	BASL	25	35	2	STUNTMOP	COLOMOPA	COMBIMBE
11	4	54	MJ526145	1	G		2	15	35	WOODLAND	COLOMOPA	COMBIMBE
11	4	107	MK075337	1	L	BASL	15	5	1	STUNTMOP	COLOMOPA	COMBHERE
11	4	125	MJ539301	1	G		15	45	20	BUSHWOOD	COLOMOPA	COMBIMBE
11	4	129	MJ757324	1	G		5	35	40	WOODLAND	COLOMOPA	COMBAPIC
11	9	156	MK009368	7	B	BASL	2	25	25	WOODLAND	COLOMOPA	COMBIMBE
11	9	167	MK238301	8	B	BASL	2	90	1	THICKET	COMBELAE	COMBMOSS
11	5	457	MK279445	1	G	BASL	18	19	13	MIXDWOOD	ACACROBU	GREWASP
11	13	536	MK237434	5			12	14	2	GRASBUSH	COLOMOPA	DICHCINE
11	4	92	MJ627350	2	G		5	20		BUSHGRAS	COMBIMBE	COMBHERE
11	4	96	MJ590224	1	G		2	10		WOODLAND	COLOMOPA	COMBIMBE
11	3	98	MJ575168	1	G		2	20		WOODLAND	COLOMOPA	ACACSIEB
11	4	135	MJ537136	1	G		1	25		RIVERINE	ACACSIEB	COLOMOPA
11	4	413	NJ449897	5	W	CALC	1	1		COIMFLATS	COMBIMBE	HYPHBENG
11	4	544	LK920373	1	L	BASL	1	1		GRASBUSH	COMBIMBE	COMBAPIC
11	11	58	MK263174	1		ECOT	15	45	30	WOODLAND	COLOMOPA	COMBAPIC
11	4	265	NJ209955	5	W	CALC	1	1	5	COIMFLAT	COMBIMBE	GREWMONT
11	5	508	MK161425			BASL	29	17	4	RIVERINE	ZIZIMUCR	COMBHERE
11	4	521	MK082490			BASL	20	34	27	RIVERINE	COLOMOPA	COMBHERE
11	4	549	LK960355	1	L	BASL	5	10	1	GRASBUSH	COLOMOPA	COMBHERE
11	4	550	LK968370	1	L	BASL	10	35	5	BUSHLAND	COMBHERE	COMBIMBE
11	8	59	MK279187	2	G	ECOT	5	40	10	WOODBUSH	COLOMOPA	LONCCAPA
11	8	79	MK318208	2	W	CAL?	1	5	5	CLMPBUSH	COLOMOPA	ERYTZAMB
11	8	477	MK297215			KALS				WOODLAND	COLOMOPA	COMBHERE
11	8	547	LK929315	2	W	BASL	5	20	5	BUSHGRAS	BOLUSPEC	COMBHERE
11	8	548	LK944323	1	B	BASL	2	40	2	BUSHTHIK	COLOMOPA	TERMPRUN
11	13	48	MK633317	9		ECOT	3	30	20	WOODBUSH	COLOMOPA	
12	11	52	MK671333	2		KALS	25	40	10	MIXDBUSH	COLOMOPA	COMMAFRI
12	12	63	MK489295	2			5	50	3	BUSHLAND	COMBAPIC	COLOMOPA
12	13	65	MK684311	5		KALS	50	40	20	MIXDBUSH	TERMSERI	BURKAFRI
12	11	114	LK824269	2	W		10	30	5	BUSHLAND	COLOMOPA	ERYTZAMB

Appendix 2 continued.
Summary of the sample data in the order of the TWINSPAN classification.

New Typ	Old Typ	Stand No.	UTM Loc. Stat.	Soil Tex	Soil Col	Geology	Wooc <1m	Plant Cove 1-3m	>3m	Physiognomic Description	1st common woody sp.	2nd commor woody sp.
12	13	152	MK760477	2	W	GNSS	10	35	15	BUSHLAND	COMBAPIC	TERMSERI
12	11	541	MK343218			KALS	64	85	31	THICKET	COMBAPIC	TERMSERI
12	13	566	LK921205	2	G	ECOT	45	30	5	BUSHLAND	COLOMOPA	COMBAPIC
12	13	580	LK802394	8	B	GNS?	5	20	1	MIXDBUSH	BRACSPIC	BRACBOEH
12	11	7	LK773355	7		BASL	15	10	1	VLEIBUSH	COMBHERE	COLOMOPA
12	11	18	LK916466	1	B	BASL	2	1	1	VLEIBUSH	COMBIMBE	COLOMOPA
12	11	33	MK041174	1			5	20	2	MIXDBUSH	COLOMOPA	COMBELAE
12	12	81	MK116325	8	R		5	35	10	THICKET	COMBAPIC	COLOMOPA
12	11	111	LK750244	1	L		5	25	5	VLEIBUSH	COLOMOPA	COMBHERE
12	11	295	MJ043989	2		KALS	3	35	5	OPENBUSH	COLOMOPA	COMBIMBE
12	11	332	MK022190	2			2	10	1	OPENBUSH	COMBHERE	TERMSERI
12	11	485	MK324322	5		KALS	26	21	22	THICKET	COMBFRAG	DIPLCOND
12	11	546	LK921340	1	L	BASL	1	5	1	COIMGRAS	COMBIMBE	COMBHERE
12	11	556	MK000210	2	G	KALS	30	35	5	BUSHLAND	COLOMOPA	COMBHERE
12	11	558	MK003180	2	G	KALS	5	25	5	BUSHGRAS	TERMSERI	TERMBRAC
12	11	559	MK000163	2	W	KALS	20	15	5	BUSHLAND	COLOMOPA	COMBIMBE
12	11	561	MK008119	5		KALS	15	15	5	BUSHWOOD	COMBAPIC	COMBHERE
12	11	567	LK825221	1	G	ECOT	15	25	1	BUSHLAND	COLOMOPA	BOLUSPEC
12	11	570	LK771190	1	G		10	25	2	GRASBUSH	COLOMOPA	BOLUSPEC
12	11	573	LK838151	2	G	KALS	3	10	1	GRASBUSH	COMBHERE	BOLUSPEC
12	11	577	LK743347	1	L	BASL	5	5	0	GRASBUSH	BOLUSPEC	COLOMOPA
12	11	42	MK838385	1			8	8	10	OPENBUSH	COLOMOPA	ERYTZAMB
12	11	43	MK804347	1			5	15	20	OPENBUSH	COLOMOPA	COMBHERE
12	11	45	MK384152	2	B		15	50	20	BUSHWOOD	COLOMOPA	COMBAPIC
12	9	47	MK283217	2		BASL	5	35	45	WOODLAND	COLOMOPA	ERYTZAMB
12	8	55	MK191181	2	G		10	35	25	WOODLAND	COLOMOPA	ERYTZAMB
12	11	56	MK207181	2			20	50	30	MIXDBUSH	COLOMOPA	
12	11	80	MK309190	2			3	20	5	BUSHGRAS	COLOMOPA	COMBIMBE
12	8	90	MJ783411	5	W		15	45	2		COMBAPIC	COLOMOPA
12	11	118	MK012006	1		KALS	2	30	10	BUSHWOOD	COLOMOPA	
12	11	509	MK315206	5			42	30	6	PANVEGE	COLOMOPA	DIOSMESP
13	10	8	LK855374			BASL	2	10	2	BUSHVLEI	COMBHERE	COLOMOPA
13	10	10	LK900420	8		BASL	5	25	10	BUSHLAND	COLOMOPA	DALBMELA
13	10	12	LK934483	8		BASL	10	20	1	BUSHLAND	COMBAPIC	CARPPUBE
13	10	13	MK064468			BASL	5	25	10	WOODVLEI	COLOMOPA	ERYTZAMB
13	10	16	LK893376	8		BASL	1	10	5	WOODGRAS	COLOMOPA	COMBAPIC
13	10	24	MK032442	8		BASL	10	20	5	OPENWOOD	COLOMOPA	ERYTZAMB
13	11	31	MK157174	1			35	30	20	MIXDBUSH	COLOMOPA	TERMSTEN
13	11	57	MK217182	2	B		15	85	10	BUSHLAND	COMBAPIC	COLOMOPA
13	11	84	LK974291	1	B		15	30	2	BUSHLAND	COLOMOPA	DALBMELA
13	10	85	LK853247	1	B		10	40	15	BUSHLAND	COLOMOPA	COMBAPIC
13	13	147	MK643374	8		GNSS	25	35	25	WOODBUSH	COLOMOPA	SCLEBIRR
13	12	163	MK624441	8	R		30	15	35	WOODBUSH	COLOMOPA	COMBAPIC
13	11	475	MK321208	5		KALS	67	4	16	OPENWOOD	COLOMOPA	HYPHPETE
13	10	514	MK118529	8		BASL	36	28	34	MIXDWOOD	COMBAPIC	ACACNIGR

Appendix 2 continued.

Summary of the sample data in the order of the TWINSPAN classification.

New Typ	Old Typ	Stand No.	UTM Loc. Stat.	Soil Tex	Soil Col	Geology	Wooc <1m	Plant Cove 1-3m	>3m	Physiognomic Description	1st common woody sp.	2nd commor woody sp.
13	10	2	LK893371			BASL	2	5	5	BUSHWOOD	COMBAPIC	COLOMOPA
13	10	3	LK869339	8		BASL	5	15	2	BUSHWOOD	COMMMOSS	COLOMOPA
13	7	4	LK840309	1	B	BASL	10	5	2	OPENWOOD	COLOMOPA	TERMSTUH
13	7	5	LK880357		B	BASL	5	15	5	BUSHWOOD	COLOMOPA	COMMMOSS
13	7	6	LK871349	1	B	BASL	2	15	15	BUSHWOOD	COLOMOPA	VITEPETE
13	10	9	LK887381			BASL	2	15	10	BUSHLAND	COLOMOPA	COMBAPIC
13	10	11	LK838434	8		BASL	5	15	10	BUSHLAND	COLOMOPA	COMBAPIC
13	10	17	LK842318	1	L	BASL	5	20	0	BUSHGRAS	DALBMELA	COLOMOPA
13	10	22	LK938443	8		BASL	5	10	2	BUSHLAND	COMBAPIC	COLOMOPA
13	10	26	MK051287	1	B		5	10	1	BUSHLAND	COLOMOPA	
13	10	27	LK948431	7	L	BASL	10	30	15	BUSHLAND	COLOMOPA	DALBMELA
13	7	29	MK014375			BASL	5	25	10	OPENWOOD	COLOMOPA	
13	10	30	MK074150	1	L		10	10	0	OPENBUSH	COLOMOPA	TERMINSP
13	7	86	LK949267	7			1	2	1	OPENBUSH	COMBAPIC	COLOMOPA
13	10	139	LK759358	8		GNSS	5	15	1	BUSHLAND	COMBHERE	COMBAPIC
13	10	170	LK846444	8	L	BASL	10	45	10	BUSHLAND	COLOMOPA	DALBMELA
13	10	171	LK843447	8		BASL	2	30	5	OPENBUSH	COMBAPIC	DALBMELA
13	10	172	LK821405	8		BASL	2	5	5	OPENBUSH	COLOMOPA	TERMSERI
13	10	520	MK088492	8		BASL	43	29	12	MIXDWOOD	COMBAPIC	COLOMOPA
13	10	553	LK948305	1	L	BASL	2	20	1	SIDAGA	COMBIMBE	COMBHERE
13	10	575	LK745300	8		BASL	10	25	2	GRASBUSH	COLOMOPA	COMBHERE
13	10	576	LK740323			BASL	15	25	2	BUSHLAND	COLOMOPA	COMBAPIC
13	10	578	LK745337			BASL	5	10	2	OPENBUSH	COLOMOPA	COMMPYRA
13	10	579	LK765385	8	B	BASL	2	15	5	WOODBUSH	COLOMOPA	COMMPYRA
13	10	581	LK952409	8			5	35	5	BUSHWOOD	COLOMOPA	COMMMOSS
14	7	14	MK075480	7		BASL	2	10	15	OPENWOOD	COLOMOPA	MUNDSERI
14	7	20	LK846232	1	G		10	35	5	BUSHLAND	COLOMOPA	TERMSTUH
14	10	21	MK022408	8	G		10	60	35	BUSHWOOD	COLOMOPA	COMBAPIC
14	7	23	MK011427	8	B	BASL	2	2	5	BUSHLAND	COMBAPIC	COLOMOPA
14	7	25	MK041460	8	B	BASL	2	10	2	BUSHWOOD	COLOMOPA	COMBAPIC
14	7	32	MK046155	1	L		1	20	1	BUSHGRAS	COLOMOPA	COMBHERE
14	7	78	MK154324	8	B	BASL	2	10	10	OPENWOOD	COLOMOPA	DIOSQUIL
14	7	82	MK068330	1	B		10	20	5	OPENBUSH	COLOMOPA	COMBAPIC
14	7	83	LK994289	1	B		5	10	10	WOODBUSH	COLOMOPA	ERYTZAMB
14	7	149	MK207333	7	G		5	10	45	WOODLAND	COLOMOPA	EUCLDIVI
14	7	486	MK584347	2	G	KALS	46	22	25	THICKET	COLOMOPA	COMBADEN
14	7	519	MK098497	8	B	BASL	22	41	31	THICKET	COMBAPIC	COLOMOPA
14	7	543	LK971401			BASL	5	25	25	BUSHWOOD	COLOMOPA	COMBHERE
14	7	545	LK905350	8	B	BASL	5	20	5	OPENBUSH	COLOMOPA	COMMIPSP
14	7	552	LK975353	1	B	BASL	20	40	20	BUSHLAND	COLOMOPA	
14	7	554	LK943278	8	B	BASL	10	25	1	OPENBUSH	COMBAPIC	COLOMOPA
14	7	555	LK949264	8		BASL	10	50	2	MIXDBUSH	COMBAPIC	COLOMOPA
14	7	582	MK088505	8	B	BASL	2	35	30	WOODLAND	COLOMOPA	ERYTZAMB
14	7	28	MK050444	1	L	BASL	40	10	5	BUSHLAND	COLOMOPA	COMBHERE
14	8	46	MK374179	2	G		3	15	45	WOODLAND	COLOMOPA	ERYTZAMB

Appendix 2 continued.

Summary of the sample data in the order of the TWINSPAN classification.

New Typ	Old Typ	Stand No.	UTM Loc. Stat.	Soil Tex	Soil Col	Geology	Wooc <1m	Plant Cove 1-3m	>3m	Physiognomic Description	1st common woody sp.	2nd commor woody sp.
14	8	87	MJ171767	2			15	40	5	CLMPBUSH	COLOMOPA	COMBIMBE
14	8	399	MJ607363	2			2	80	5	BUSHLAND	COLOMOPA	COMBAPIC
14	4	551	LK999385	1	L	BASL	10	40	2	BUSHLAND	COLOMOPA	COMBIMBE
15	7	108	LK742317	1	L	BASL	5	10	1	STUNTMOP	COLOMOPA	TERMSTUH
15	6	182	MK236326	7			1	10	50	WOODLAND	COLOMOPA	COMMAFRI
15	3	472	MK223405	1	G	MUDS	40	15	88	WOODLAND	COLOMOPA	DALBMELA
15	6	529	MK244432	1	G	MUDS	52	21	38	WOODLAND	COLOMOPA	COMMPYRA
15	6	537	MK237437	2	G	MUDS	57	41	38	WOODLAND	COLOMOPA	DIOSQUIL
15	6	538	MK248442	1	G	MUDS	57	38	63	WOODLAND	COLOMOPA	DALBMELA
15	3	100	MJ612085	1	G		15	40	25	WOODLAND	COLOMOPA	GREWBICO
16	3	101	MJ629073	1	G		10	70	35	WOODLAND	COLOMOPA	ACACSIEB
16	3	103	MJ649055	2	G		30	70	10	BUSHLAND	COLOMOPA	ACACROBU
16	8	124	MJ690348	1			20	70	5	BUSHLAND	COLOMOPA	GREWMONT
16	3	127	MJ732219	1	G		1	40	35	WOODLAND	COLOMOPA	GREWBICO
16	8	130	MJ767359	1			10	60	5	BUSHWOOD	COLOMOPA	COMBAPIC
16	3	97	MJ581202	1	G		5	75	2	STUNTMOP	COLOMOPA	XIMEAMER
16	3	99	MJ576113	1	G		1	80	20	BUSHWOOD	COLOMOPA	ACACNILO
16	3	102	MJ638064	1	G		20	75	1	STUNTMOP	COLOMOPA	ACACNILO
16	3	104	MJ674036	1	L		20	5	1	STUNTMOP	COLOMOPA	ACACNILO
16	3	105	MJ691080	1	G		5	40	20	WOODLAND	COLOMOPA	ACACROBU
16	3	106	MJ700132	1	G		5	55	35	WOODLAND	COLOMOPA	ACACSIEB
16	3	109	MJ687050	1	L		1	30	1	SIDAGA	COLOMOPA	
16	3	126	MJ713173	1	L		1	10	60	WOODLAND		
16	3	128	MJ744264	1	G		1	10	40	WOODLAND	COLOMOPA	ACACSIEB
17	17	61	MK403145	2		ECOT	10	35	30	BUSHWOOD	COLOMOPA	COMBAPIC
17	15	67	MJ586253	2		KALS	10	50	1	BUSHLAND	TERMSERI	COMBCOLL
17	14	89	MJ583253	2			25	35	5	BUSHLAND	COLOMOPA	COMBAPIC
17	15	123	MJ714377	1		KALS	10	35	5	GRASBUSH	COLOMOPA	COMBHERE
17	15	131	MJ414246	2		KALS	10	30	15	BUSHLAND	COLOMOPA	COMBCOLL
17	17	261	MK760300	2			15	5	20	GRASBUSH	COMBHERE	COLOMOPA
17	15	298	MK413106	2			3	35	5	BUSHLAND	COLOMOPA	
17	15	383	MK445117	2		KALS	8	10	10	GRASBUSH	COLOMOPA	COMBCOLL
17	14	428	MJ494176	1		KALS	2	25	35	BUSHWOOD	COLOMOPA	COMBAPIC
18	14	50	MJ160913	1		KALS	2	30	15	BUSHLAND	COLOMOPA	COMBHERE
18	14	93	MJ632341	1			2	10	1	BUSHLAND	COLOMOPA	COMBALBO
18	14	115	MJ825592	5		KALS	3	25	5	GRASBUSH	ACACIASP	CROTGRAT
18	14	296	LJ987981	1		KALS	20	55	15	BUSHWOOD	COLOMOPA	COMBHERE
18	14	300	MK295016	2		KALS	5	25	1	GRASBUSH	ACACERUB	BOSCANGU
18	14	316	MJ328755	2		KALS	5	20	8	OPENBUSH	COLOMOPA	LONCNELS
18	14	320	MJ834610	2		KALS	15	35	5	OPENBUSH	COLOMOPA	COMBHERE
18	14	429	MJ384269	2		KALS	40	25	1	BUSHLAND	COLOMOPA	GREWASP
18	14	49	MJ050768	2		KALS	2	20	5	GRASBUSH	BOSCALBI	ACACLUDE
18	14	305	MJ177717	2		KALS	5	20	5	OPENBUSH	ACACERUB	BOSCALBI
18	14	309	MJ104797	1		KALS	5	20	25	OPENBUSH	ACACIASP	BOSCALBI
18	14	310	MK004258	2		KALS	5	25	5	OPENBUSH	ACACIASP	LONCNELS

Appendix 2 continued.

Summary of the sample data in the order of the TWINSPAN classification.

New Typ	Old Typ	Stand No.	UTM Loc. Stat.	Soil Tex	Soil Col	Geology	Wood <1m	Plant Cove 1-3m	>3m	Physiognomic Description	1st common woody sp.	2nd commor woody sp.
18	14	329	MJ440527	1			5	50	5	GRASBUSH	BOSCALBI	ACACLUDE
18	14	422	MJ324829	2		KALS	10	20	5	GRASBUSH	BOSCALBI	MUNDSERI
18	14	431	MJ243382	1		KALS	2	20	15	BUSHWOOD	ACACIASP	GREWIASP
18	16	88	MJ587299	2			1	5	1	GRASBUSH	GREWIASP	BOSCALBI
18	16	91	MJ792444	2			5	50	1	GRASBUSH	COMBAPIC	COMBHERE
18	15	121	MJ794454	2		KALS	3	20	15	GRASBUSH	COMBHERE	ACACIASP
18	14	275	MJ861506	5		KALS	2	10	10	GRASBUSH	LONCNELS	COMBHERE
18	15	304	MJ182814	2		KALS	10	20	4	OPENBUSH	TERMSERI	BOSCALBI
18	14	319	MJ687567	2		KALS	10	35	2	OPENBUSH	COLOMOPA	ACACERIO
18	15	331	LJ941959	1		KALS	1	25	2	GRASBUSH	COLOMOPA	COMBIMBE
18	15	341	MJ864524	5		KALS	2	25	20	GRASBUSH	COMBHERE	ACACERIO
18	15	376	MJ933950	2		KALS	10	20	0	GRASBUSH	COMBHERE	GREWIASP
18	15	397	MJ575415	1		KALS	25	65	1	BUSHLAND	COMBAPIC	COLOMOPA
18	14	398	MJ589391	2		KALS	5	20	5	BUSHLAND	COMBHERE	TERMSERI
18	14	425	MJ758507	2		KALS	3	10	4	GRASBUSH	ACACERIO	COMBAPIC
18	14	426	MJ460507	2		KALS	15	10	5	GRASBUSH	BOSCALBI	LONCNELS
18	14	427	MJ534469	2		KALS	15	25	2	BUSHLAND	LONCNELS	COLOMOPA
18	14	433	MJ119456	2		KALS	1	60	1	BUSHLAND	COLOMOPA	COMBIMBE
18	15	255	MK878242	2	W	KALS	2	8	4	GRASBUSH	DIOSLYCI	ACACLUDE
18	15	302	MK315024	1		KALS	1	25	3	GRASBUSH	COMBHERE	MUNDSERI
18	14	313	MJ476929	1		KALS	5	10	10	GRASBUSH	ACACERIO	COMBHERE
18	15	318	MJ428647	1		KALS	5	15	10	OPENBUSH	TERMPRUN	ACACLUDE
18	16	358	NK101059	1			2	5	20	GRASBUSH	ACACERIO	DIOSLYCI
18	14	369	NJ112808	2		KALS	2	5	70	GRASWOOD	ACACERIO	TERMSERI
18	16	371	NJ049933	5			25	45	65	WOODBUSH	ACACERIO	DICRCINE
18	14	396	MJ880626	2		KALS	2	10	3	GRASBUSH	LONCNELS	COMBHERE
19	15	94	MJ842479	5		KALS	20	55	20	BUSHLAND	TERMSERI	ACACIASP
19	16	264	LK943483	2		CALC	10	30	15	BUSHLAND	ACACERIO	DICRCINE
19	24	353	NJ060762	2		KALS	5	20	10	GRASBUSH	TERMSERI	ZIZIMUCR
19	15	368	NK026022	2		KALS	2	30	5	GRASBUSH	ACACERIO	COMBHERE
19	16	372	NJ435899	2		KALS	1	10	85	BUSHLAND	ACACERIO	COMBIMBE
19	16	112	MJ799469	2			5	20	15	GRASBUSH	COMBIMBE	COMBHERE
19	16	253	MK924293	2		CALC	40	40	20	BUSHLAND	COMBHERE	DIOSLYCI
19	16	254	MK914276	5		CALC	5	30	5	BUSHGRAS	COMBHERE	DIOSLYCI
19	16	258	NK049226	2		CALC	2	10	5	GRASBUSH	DIOSLYCI	COMBHERE
19	16	263	NK156147	2		CALC	2	10	5	COIMFLAT	COMBIMBE	ACACERIO
19	14	324	NJ058717	2		KALS	2	15	10	GRASBUSH	COMBHERE	ZIZIMUCR
19	16	327	NJ359781	1	G		2	25	1	BUSHLAND	COLOMOPA	COMBHERE
19	16	328	NJ420806	1		KALS	1	10	5	GRASBUSH	COMBIMBE	DICRCINE
19	16	424	MJ556543	2		KALS	10	30	20	BUSHLAND	COLOMOPA	COMBHERE
19	16	259	NJ118963	2		CALC	2	5	6	GRASBUSH	DIOSLYCI	COMBHERE
19	16	322	NJ208947	2		CALC	1	1	10	GRASBUSH	COMBIMBE	
19	16	323	NJ282944	2		CALC	5	25	20	GRASBUSH	HYPHPETE	BURKAFRI
19	16	408	NJ344937	5	W	KALS	5	30	2	BUSHLAND	BURKAFRI	TERMSERI
19	22	410	NK263048	5		KALS	1	1	2	PALMFLAT	HYPHPETE	

Appendix 2 continued.
Summary of the sample data in the order of the TWINSPAN classification.

New Typ	Old Typ	Stand No.	UTM Loc. Stat.	Soil Tex	Soil Col	Geology	Wooc <1m	Plant Cove 1-3m	>3m	Physiognomic Description	1st common woody sp.	2nd commor woody sp.
19	16	412	NJ359914			CALC	10	25	15	MIXDBUSH	COMBIMBE	HYPHPETE
19	16	414	NJ473893			CALC	1	1	5	PALMFLAT	COMBIMBE	ZIZIMUCR
19	16	40	MK582160	1		ECOT	10	25	20	OPENBUSH	COLOMOPA	PELTAFRI
19	11	71	MK614150	1		ECOB	5	10	5	OPENBUSH	COMBHERE	PTERROTU
19	16	72	MK572155	1		ECOT	5	20	15	BUSHLAND	COLOMOPA	COMBHERE
19	17	260	MK876356	2		KALS	25	20	3	GRASBUSH	COLOMOPA	COMBHERE
19	22	317	MJ378724				5	35	15	BUSHLAND	COMBAPIC	COLOMOPA
19	16	325	NK268045	2			10	40	1	BUSHLAND	COMBHERE	COMBAPIC
19	16	326	NJ236726	2		CALC	5	25	1	GRASBUSH	COLOMOPA	COMBHERE
19	21	466	MK278327	6		KALS	43	37	108	THICKET	COMBAPIC	TERMSERI
19	11	574	LK754237	1	G	KALS	5	10	1	GRASBUSH	TERMBRAC	BOLUSPEC
20	14	119	MJ179879	1		KALS	1	20	3	GRASBUSH	ACACERUB	LONCNELS
20	19	224	NJ377805	5		KALS	10	35	50	WOODBUSH	BAIKPLUR	COMBCOLL
20	19	307	MJ083632	2		KALS	15	35	10	OPENBUSH	MUNDSERI	BOSCALBI
20	18	321	MJ771567	2		KALS	15	20	2	BUSHLAND	COLOMOPA	COMBHERE
20	14	350	LJ999774	2		KALS	25	65	1	BUSHLAND	COLOMOPA	COMBCOLL
20	19	367	MK992069	5		KALS	15	25	50	WOODLAND	LONCNELS	ACACLUDE
20	18	388	MJ179891	2		KALS	3	20	15	GRASBUSH	BOSCALBI	MUNDSERI
20	18	51	MJ255871			KALS	15	35	10	BUSHLAND	ACACLUDE	BOSCALBI
20	18	116	MK581136	2		KALS	25	50	20	BUSHLAND	TERMSERI	COMBZEYH
20	19	120	MK568045	2		KALS	55	50	4	BUSHLAND	DICRCINE	ACACATAX
20	19	122	MK791146	2		KALS	45	30	2	BUSHLAND	RHIGBREV	TERMSERI
20	18	297	MJ282832	2		KALS	50	15	10	BUSHLAND	COLOMOPA	BOSCALBI
20	18	301	MJ271973	5		KALS	40	55	20	BUSHLAND	TERMSERI	MUNDSERI
20	18	308	MJ039691	5	P	KALS	25	55	15	BUSHLAND	LONCNELS	DICRCINE
20	18	311	MJ295904	2		KALS	5	25	10	BUSHLAND	ACACLUDE	BOSCALBI
20	18	314	MJ420899	2		KALS	25	25	8	BUSHLAND	ACACIASP	COMBRESP
20	19	338	MK566069	2		KALS	50	35	3	BUSHLAND	ACACATAX	DICRCINE
20	18	339	MJ330765	2		KALS	20	40	10	BUSHLAND	LONCNELS	MUNDSERI
20	19	351	MK720175	2		KALS	8	18	3	GRASBUSH	ACACLUDE	MUNDSERI
20	18	380	MJ383498	2		KALS	20	35	2	OPENBUSH	LONCNELS	BOSCALBI
20	19	387	MJ170899	2		KALS	15	55	2	BUSHLAND	ACACIASP	MUNDSERI
20	18	423	MJ445563	2		KALS	5	15	8	OPENBUSH	BOSCALBI	LONCNELS
20	18	430	MJ298340	5		KALS	5	35	2	BUSHLAND	LONCNELS	DICRCINE
20	18	435	MJ417656	2		KALS	20	55	5	BUSHLAND	COMBZEYH	COMBCOLL
20	19	441	MJ043679	5	B	KALS	25	40	20	BUSHLAND	ACACLUDE	COMMANGC
21	19	117	MK772180	5		KALS	60	70	5	THIKBUSH	TERMSERI	ACACATAX
21	24	256	MK863239	6		KALS	50	45	2	BUSHLAND	TERMSERI	COMBRESP
21	19	257	MK861230	5		KALS	15	25	2	BUSHLAND	DIOSLYCI	TERMSERI
21	19	266	MK812229	5		KALS	50	60	20	WOODLAND	COMBCOLL	CROTGRAT
21	19	267	NK057218	5		KALS	60	30	20	WOODLAND	COMBZEYH	DICRCINE
21	19	286	MK786181	2		KALS	60	45	0	BUSHLAND	TERMSERI	ACACATAX
21	19	352	MK879004	2		KALS	2	10	1	GRASBUSH	COMBHERE	DICRCINE
21	19	356	NK060204	5		KALS	20	15	20	WOODLAND	ACACERIO	BAIKPLUR
21	19	357	NK112157	5		KALS	35	55	20	WOODLAND	DICRCINE	ACACERIO

Appendix 2 continued.
Summary of the sample data in the order of the TWINSPAN classification.

New Typ	Old Typ	Stand No.	UTM Loc. Stat.	Soil Tex	Soil Col	Geology	Wood <1m	Plant Cove 1-3m	>3m	Physiognomic Description	1st common woody sp.	2nd commor woody sp.
21	18	370	NJ027719	5		KALS	30	70	30	THIKWOOD	ACACLUDE	CROTGRAT
21	19	436	MJ955664	2		KALS	5	60	15	BUSHLAND	DICRCINE	ACACERIO
21	18	445	NJ409818	1		KALS	5	40	2	THICKET	DICRCINE	ACACERIO
21	18	68	MJ766342	5			1	35	5	BUSHLAND	COMBAPIC	GREWIASP
21	19	69	MJ513159	5		KALS	5	55	5	BUSHLAND	COMBCOLL	TERMSERI
21	19	73	MK451141	2		KALS	20	55	3	BUSHLAND	COMBCOLL	COMBZEYH
21	25	79	MK849044	2		KALS	45	25	5	BUSHLAND	ACACATAX	COMBRESP
21	24	306	MJ131636	1		KALS	10	5	0	GRASBUSH	OCHNPULC	LONCNELS
21	20	342	MJ877617	5		KALS	55	40	10	BUSHLAND	TERMSERI	COMBCOLL
21	19	345	MJ379488	5		KALS	50	30	1	BUSHLAND	TERMSERI	COMBCOLL
21	19	355	MK846038	2		KALS	5	15	5	GRASBUSH	ACACERIO	DICRCINE
21	19	361	NJ029751	2		KALS	5	20	45	BUSHLAND	ACACERIO	LONCNELS
21	25	362	NJ009798	5		KALS	40	35	15	BUSHLAND	ACACERIO	TERMSERI
21	25	364	MK927145	2	G	KALS	20	60	25	THICKET	DICRCINE	ACACATAX
21	19	389	MJ171767	5		KALS	10	40	35	WOODLAND	BURKAFRI	ACACIASP
21	25	393	MJ313856	2		KALS	20	45	60	THIKBUSH	DICRCINE	TERMSERI
21	19	404	MJ027743	2	G	KALS	25	75	25	BUSHLAND	DICRCINE	TERMSERI
21	19	420	MJ342296	6	W	KALS	5	15	25	BUSHLAND	LONCNELS	DICRCINE
21	25	421	MJ322319	6	W	KALS	2	5	85	WOODBUSH	TERMSERI	BURKAFRI
21	19	432	MJ198388	2	G	KALS	50	35	1	BUSHLAND	ACACERIO	TERMSERI
21	19	442	MJ939648	2		KALS	2	50	5	BUSHLAND	LONCNELS	TERMSERI
21	19	443	MJ993698	2		KALS	10	35	20	OPENBUSH	TERMSERI	ACACERIO
22	17	36	MK891367	2		KALS	70	65	10	BUSHTHIK	DICRCINE	BAIKPLUR
22	24	44	MK710289	2		KALS	25	70	50	THIKBUSH	DICRCINE	ACACFLEC
22	17	299	MK359078	2	W		25	50	10	BUSHLAND	COLOMOPA	COMBAPIC
22	18	312	MJ503932	1		KALS	25	50	25	WOODTHIK	TERMPRUN	CROTGRAT
22	19	330	LJ939871	2		KALS	40	45	1	BUSHLAND	COLOMOPA	TERMSERI
22	17	359	MK742302	5		KALS	30	70	25	WOODBUSH	BAIKPLUR	COMBELAE
22	18	437	LJ938993	2		KALS	10	75	15	BUSHLAND	COLOMOPA	BOSCSALI
22	18	444	MJ755407	2		KALS	5	45	1	MIXDBUSH	COMBAPIC	TERMSERI
23	25	196	MK961208	6		KALS	5	10	60	WOODLAND	BAIKPLUR	ACACERIO
23	20	204	NJ103754	6		KALS	15	20	55	WOODLAND	BAIKPLUR	LONCNELS
23	20	205	NJ091719	5	R	KALS	5	15	70	WOODLAND	BAIKPLUR	LONCNELS
23	20	347	MJ537456	6	W	KALS	5	55	2	BUSHLAND	BAIKPLUR	TERMSERI
23	20	374	NJ423799	1		KALS	10	95	80	THICKET	DICRCINE	ACACERIO
23	20	375	NJ434886	6	W	KALS	1	50	30	WOODLAND	ACACERIO	BAIKPLUR
23	20	197	MK894007	6		KALS	5	35	85	WOODLAND	BAIKPLUR	ACACERIO
23	20	208	MK833031	6		KALS	10	55	50	WOODLAND	BAIKPLUR	ACACERIO
23	20	363	MJ987889	6		KALS	5	25	70	WOODLAND	BAIKPLUR	ACACERIO
23	20	365	MK973127	6		KALS	10	30	20	BUSHLAND	ACACLUDE	DICRCINE
23	20	366	MK971080	6		KALS	25	35	40	WOODLAND	ACACLUDE	ACACATAX
23	20	191	MJ533960	6		KALS	15	25	60	WOODLAND	BAIKPLUR	CROTGRAT
23	20	360	MK273007	5		KALS	5	35	60	WOODLAND	BAIKPLUR	DICRCINE
23	20	415	MJ504920	6		KALS	20	40	35	WOODTHIK	BAIKPLUR	COMBCELS
23	20	417	MJ743558	6	R	KALS	15	45	70	WOODLAND	BAIKPLUR	COMBCELA

Appendix 2 continued.

Summary of the sample data in the order of the TWINSPAN classification.

New Typ	Old Typ	Stand No.	UTM Loc. Stat.	Soil Tex	Soil Col	Geology	Wooc <1m	Plant Cove 1-3m	>3m	Physiognomic Description	1st common woody sp.	2nd commor woody sp.
23	20	418	NJ088713	6		KALS	15	55	60	WOODLAND	BAIKPLUR	COMBCELA
23	20	187	MK018066	6		KALS	1	90	85	WOODTHIK	BAIKPLUR	COMBCELA
23	20	192	MJ355765	6	P	KALS	3	20	80	WOODLAND	BAIKPLUR	CROTGRAT
23	20	194	MJ432603	6	R	KALS	1	85	70	WOODLAND	BAIKPLUR	COMBCELA
23	20	225	MJ501478	6	W	KALS	5	35	15	THIKBUSH	BAIKPLUR	
23	20	416	MJ516542	6		KALS	10	30	65	WOODLAND	BAIKPLUR	CROTGRAT
23	20	419	MJ421519	6	W	KALS	5	50	85	WOODLAND	BAIKPLUR	CROTGRAT
24	24	390	MJ792444	5		KALS	15	25	10	OPENBUSH	TERMSERI	OCHNPULC
24	25	392	MJ149820	5		KALS	30	25	55	WOODLAND	TERMSERI	BURKAFRI
24	24	234	NK029039	2		KALS	30	25	15	BUSHWOOD	BURKAFRI	TERMSERI
24	25	276	MJ752567	2		KALS	40	25	2	BUSHLAND	TERMSERI	COMBZEYH
24	24	303	MJ188860	5		KALS	1	15	1	GRASBUSH	TERMSERI	
24	24	343	NJ078768	6		KALS	20	35	5	BUSHLAND	TERMSERI	ACACFLEC
24	22	354	NJ288749	2		KALS	20	30	1	BUSHLAND	TERMSERI	
24	24	377	MK941116	2		KALS	5	20	0	BUSHLAND	TERMSERI	COMBPSID
24	24	378	NK007068	2		KALS	50	40	2	BUSHLAND	TERMSERI	OCHNPULC
24	25	379	MK836057	2		KALS	25	25	0	BUSHLAND	COMBCOLL	DICRCINE
24	19	403	LJ941981	5		KALS	10	95	1	THICKET	COMBCOLL	TERMSERI
24	25	438	NJ131818			KALS	5	70	1	BUSHLAND	TERMSERI	COMBPSID
25	25	227	LJ987793	6	W	KALS	70	20	1	BUSHLAND	BAIKPLUR	BAPHMASS
25	25	251	MJ285354	6	W	KALS	15	15	45	WOODLAND	TERMSERI	BURKAFRI
25	25	271	MK753207	6		KALS	45	20	2	BUSHLAND	BAIKPLUR	COMBCOLL
25	25	278	MK899115	6		KALS	80	60	10	BUSHLAND	TERMSERI	OCHNPULC
25	25	282	MK962125	6		KALS	55	55	2	BUSHLAND	TERMSERI	COMBRESP
25	25	285	MK803113	2		KALS	60	45	0	BUSHLAND	CROTPSEU	COMBCOLL
25	25	315	MJ335794	5		KALS	30	45	20	WOODLAND	TERMSERI	COMBCOLL
25	25	340	MJ458546	6		KALS	60	40	2	BUSHLAND	BAIKPLUR	TERMSERI
25	25	346	MJ473503	6	P	KALS	10	15	35	WOODLAND	COMBCOLL	LONCNELS
25	25	349	MJ084569	6	B	KALS	70	35	1	BUSHLAND	TERMSERI	COMBCOLL
25	25	382	MK013031	5		KALS	30	60	2	BUSHLAND	TERMSERI	OCHNPULC
25	25	384	MK384088			KALS	25	25	8	BUSHLAND	TERMSERI	COMBCOLL
25	25	385	MK338039	6	W	KALS	70	65	10	BUSHLAND	TERMSERI	OCHNPULC
25	25	401	MJ265374	6	W	KALS	45	30	20	WOODLAND	COMBCOLL	CROTPSEU
25	25	402	MJ134394	6	W	KALS	10	25	40	WOODLAND	TERMSERI	COMBRESP
25	25	440	MJ150638	6	R	KALS	10	20	5	BUSHLAND	OCHNPULC	BAPHMASS
25	25	195	MJ960770			KALS	15	10	65	WOODLAND	BAIKPLUR	CROTGRAT
25	26	199	MK941204	6		KALS	5	30	40	WOODLAND	BAIKPLUR	CROTGRAT
25	25	207	NJ035920	6		KALS	15	20	50	WOODLAND	BAIKPLUR	COMBMOLL
25	27	226	MJ117467	6	R	KALS	10	45	15	BUSHWOOD	BAIKPLUR	BAPHMASS
25	25	237	NJ000909	6		KALS	25	35	5	BUSHWOOD	BURKAFRI	TERMSERI
25	25	238	MK821096	6		KALS	20	25	15	BUSHWOOD	BURJAFRI	TERMSERI
25	26	270	MK774217	6		KALS	55	60	10	BUSHLAND	BAIKPLUR	TERMSERI
25	25	280	MJ934959	6		KALS	50	35	1	BUSHLAND	BAIKPLUR	ERYTAFRI
25	25	284	NJ120732	6		KALS	45	30	2	BUSHLAND	TERMSERI	BAIKPLUR
25	25	289	NJ374789	2		KALS	50	40	5	BUSHWOOD	BAPHMASS	PTERANGO

Appendix 2 continued.

Summary of the sample data in the order of the TWINSPAN classification.

New Typ	Old Typ	Stand No.	UTM Loc. Stat.	Soil Tex	Soil Col	Geology	Wood <1m	Plant Cove 1-3m	>3m	Physiognomic Description	1st common woody sp.	2nd common woody sp.
25	26	290	NJ333766	2		KALS	45	40	1	BUSHLAND	BAIKPLUR	COMBCOLL
25	26	291	NJ288749	5		KALS	60	60	1	BUSHLAND	BAIKPLUR	BAPHMASS
25	25	337	MJ460209	5		KALS	60	20	20	BUSHLAND	PTERANGO	TERMSERI
25	26	348	MJ114479	6	W	KALS	55	30	1	BUSHLAND	BAIKPLUR	TERMSERI
25	25	394	MJ501937	2		KALS	35	50	20	WOODLAND	TERMSERI	BAIKPLUR
25	25	395	MJ426635	6		KALS	50	35	3	BUSHLAND	BAIKPLUR	TERMSERI
25	25	400	MJ489180	6		KALS	35	20	5	BUSHLAND	TERMSERI	COMBCOLL
26	24	184	NJ093951	6		KALS	15	20	15	BUSHWOOD	ERYTAFRI	GUIBCOLE
26	26	229	LK914083	6	W	KALS	10	65	25	WOODLAND	BAIKPLUR	CROTGRAT
26	26	230	NJ014806	6		KALS	35	15	2	BUSHLAND	TERMSERI	BAPHMASS
26	26	231	NJ012843	6		KALS	40	25	5	BUSHLAND	TERMSERI	BURKAFRI
26	26	232	MK892091	6		KALS	60	45	25	BUSHLAND	BAIKPLUR	ERYTAFRI
26	26	233	MK953119	6		KALS	15	45	10	BUSHWOOD	BYRKAFRI	COMBRESP
26	26	235	NJ241890	6		KALS	25	40	8	WOODLAND	BURKAFRI	TERMSERI
26	26	236	NJ212834	6		KALS	5	20	10	BUSHWOOD	BURKAFRI	TERMSERI
26	23	239	MK902261	6	W	KALS	5	60	25	WOODLAND	TERMSERI	BURKAFRI
26	26	268	NJ072996	5		KALS	20	35	8	BUSHLAND	COMBCOLL	TERMSERI
26	26	269	NJ076944	5		KALS	25	15	12	BUSHLAND	OCHNPULC	TERMSERI
26	26	272	MJ143959	6		KALS	65	5	1	BUSHLAND	BAIKPLUR	GUIBCOLE
26	26	273	MK565115	2		KALS	40	25	3	BUSHLAND	BAIKPLUR	TERMSERI
26	26	277	MJ950770	6		KALS	60	30	1	BUSHLAND	TERMSERI	OCHNPULC
26	23	281	MK980229	6		KALS	25	45	20	WOODLAND	OCHNPULC	BURKAFRI
26	23	283	NJ264938	6		KALS	15	15	10	BUSHWOOD	BURKAFRI	ERYTAFRI
26	26	293	LK935024	5	W	KALS	35	45	1	BUSHLAND	BAIKPLUR	TERMSERI
26	26	333	MJ129983	5		KALS	60	10	5	BUSHLAND	BAIKPLUR	PTERANGO
26	26	335	NJ201795	6		KALS	30	60	20	WOODLAND	PTERANGO	BAIKPLUR
26	26	386	MJ290946	6	W	KALS	40	55	20	WOODLAND	BURKAFRI	TERMSERI
26	25	391	MJ054648	6	W	KALS	5	40	25	WOODBUSH	BURKAFRI	OCHNPULC
26	23	439	NJ210827	2		KALS	2	20	0	BUSHLAND	TERMSERI	BURKAFRI
26	26	446	MK983282	6	W	KALS	12	36	16	WOODBUSH	BAIKPLUR	CROTPSEU
26	26	448	MK909314	6	W	KALS	70	28	3	BUSHLAND	BAIKPLUR	BAUHPETE
27	26	37	MK821353	6		KALS	15	35	65	WOODLAND	BRACSPEC	BAIKPLUR
27	26	183	NK000230			KALS	50	40	55	WOODLAND	BAIKPLUR	CROTPSEU
27	23	198	NJ156961	6		KALS	35	40	15	WOODLAND	BAIKPLUR	GUIBCOLE
27	23	200	NJ300942	6		KALS	25	30	20	WOODLAND	BURKAFRI	ERYTAFRI
27	26	202	NJ234895	6		KALS	10	20	55	WOODLAND	BAIKPLUR	GUIBCOLE
27	26	214	NK213099	6	W	KALS	15	30	65	WOODLAND	BAIKPLUR	GUIBCOLE
27	26	215	NK206078	6	W	KALS	30	20	20	WOODLAND	BAIKPLUR	GUIBCOLE
27	23	217	NJ111983	6	W	KALS	15	35	40	WOODLAND	GUIBCOLE	BAIKPLUR
27	26	218	NJ390912	6	W	KALS	1	5	70	WOODLAND	BAIKPLUR	
27	23	220	NK310005	6	W	KALS	5	30	55	WOODLAND	BAIKPLUR	GUIBCOLE
27	26	222	NJ363875	6	W	KALS	30	20	60	WOODLAND	BAIKPLUR	PTERANGO
27	23	223	NJ379849	6	W	KALS	5	15	85	WOODLAND	BAIKPLUR	ERYTAFRI
27	23	241	NK190129	6	W	KALS	5	10	20	WOODLAND	BURKAFRI	ERYTAFRI
27	23	242	NK207113	6	W	KALS	10	30	25	WOODLAND	BURKAFRI	ERYTAFRI

Appendix 2 continued.

Summary of the sample data in the order of the TWINSPAN classification.

New Typ	Old Typ	Stand No.	UTM Loc. Stat.	Soil Tex	Soil Col	Geology	Wooc <1m	Plant Cove 1-3m	>3m	Physiognomic Description	1st common woody sp.	2nd commor woody sp.
27	26	292	NJ397859	6		KALS	30	55	5	BUSHLAND	BAIKPLUR	ERYTAFRI
27	26	336	NJ413878	6		KALS	20	25	5	BUSHLAND	BAIKPLUR	PTERANGO
28	26	185	MK664171	6		KALS	45	55	20	BUSHWOOD	BAIKPLUR	CROTPSEU
28	27	188	MJ153937	6	W	KALS	10	25	50	WOODLAND	BAIKPLUR	CROTGRAT
28	27	193	MJ371731	6	G	KALS	10	20	55	WOODLAND	BAIKPLUR	COMBCOLL
28	26	201	NJ241920	6		KALS	5	5	70	WOODLAND	BAIKPLUR	GUIBCOLE
28	26	203	NJ222868			KALS	15	15	75	WOODLAND	BAIKPLUR	CROTGRAT
28	26	206	NJ190816	6		KALS	20	40	75	WOODLAND	BAIKPLUR	BAPHMASS
28	27	219	NK335008	6		KALS	15	35	75	WOODLAND	BAIKPLUR	CROTGRAT
28	26	228	LJ971819	6	W	KALS	10	65	40	WOODLAND	BAIKPLUR	CROTGRAT
28	26	274	MJ373744			KALS	50	35	2	BUSHLAND	BAIKPLUR	ERYTAFRI
28	26	447	MK915307	6	W	KALS	48	49	41	WOODBUSH	BAIKPLUR	CROTPSEU
28	26	560	MK004146	5		KALS	35	40	30	OPENWOOD	BAIKPLUR	BAPHMASS
28	26	39	MK645219	5		KALS	15	25	45	BUSHWOOD	BAPHMASS	BAIKPLUR
29	21	38	MK752322	6		KALS	60	40	20	BUSHLAND	BAPHMASS	BURKAFRI
29	21	41	MK664171	2	B	KALS	35	65	30	WOODBUSH	BAIKPLUR	CROTGRAT
29	21	186	MK300184	6	W	KALS	15	30	25	WOODLAND	BAIKPLUR	TERMSERI
29	21	190	MJ570128	2		KALS	15	5	20	BUSHLAND	BAIKPLUR	BAPHMASS
29	23	221	NJ306984	6	W	KALS	10	30	20	WOODLAND	BAIKPLUR	TERMSERI
29	21	517	MK273331	5	R	KALS	40	55	48	THICKET	BAIKPLUR	COMBAPIC
29	21	528	MK268336	5		KALS	41	68	36	THIKWOOD	COMBAPIC	BAIKPLUR
29	21	563	LK961226	6		KALS	50	60	20	BUSHLAND	BAIKPLUR	TERMSERI
29	27	189	MJ070994	6		KALS	20	15	70	WOODLAND	BAIKPLUR	CROTGRAT
29	27	211	LK750268	6	R	KALS	15	25	40	WOODLAND	BAIKPLUR	BAPHMASS
29	26	252	LK966113	2		KALS	5	35	25	WOODLAND	BAIKPLUR	BURKAFRI
29	27	557	MK000193	6		KALS	50	50	70	WOODLAND	BAIKPLUR	CROTGRAT
29	26	562	MK001132	5		KALS	45	65	20	BUSHLAND	BAIKPLUR	TERMSERI
29	26	569	LK758220	5		KALS	50	70	20	WOODBUSH	BAIKPLUR	ERYTAFRI
29	26	572	LK815165	6	R	KALS	40	45	20	OPENWOOD	BAIKPLUR	TERMSERI
29	21	95	LK744306	1	B	KALS	15	30	5	MIXDBUSH	BAIKPLUR	TERMSERI
29	21	113	MK259303	6	R	KALS	5	45	30	THICKET	COMBAPIC	COMMMOSS
29	27	210	MK043246	6	R	KALS	10	65	50	BUSHWOOD	BAIKPLUR	COMBRESP
29	17	212	LK835271	5	R	KALS	15	40	75	WOODLAND	BAIKPLUR	ERYTZAMB
29	21	571	LK792182	6	R	KALS	25	20	10	WOODBUSH	BAIKPLUR	COMBAPIC
29	21	34	MK859402	2	R	KALS	30	55	45	BUSHLAND	COMBAPIC	BRACSPEC
29	21	334	MK184009	2		KALS	25	45	30	WOODBUSH	BAIKPLUR	COLOMOPA
29	21	434	MK110001	2		KALS	15	30	10	BUSHLAND	COMBAPIC	BURKAFRI
29	21	568	LK800225	5		KALS	50	45	40	WOODLAND	BAIKPLUR	ERYTAFRI
30	23	216	NK249025	6		KALS	2	10	30	WOODLAND	GUIBCOLE	ERYTAFRI
30	23	243	NK301036	6		KALS	10	40	30	WOODLAND	BURKAFRI	GUIBCOLE
30	23	247	NJ375915	6	W	KALS	30	20	15	BUSHWOOD	BURKAFRI	GUIBCOLE
30	23	249	NJ369894	5		KALS	25	35	30	BUSHLAND	BURKAFRI	ERYTAFRI
30	23	287	NK210089	5		KALS	35	25	5	BUSHWOOD	ERYTAFRI	TERMSERI
30	23	344	NJ230995	6	W	KALS	1	5	1	BUSHLAND	TERMSERI	BURKAFRI
30	23	244	NJ231984	6		KALS	10	30	35	WOODLAND	BURKAFRI	GUIBCOLE

Appendix 2 continued.

Summary of the sample data in the order of the TWINSPAN classification.

New Typ	Old Typ	Stand No.	UTM Loc. Stat.	Soil Tex	Soil Col	Geology	Wooc <1m	Plant Cove 1-3m	>3m	Physiognomic Description	1st common woody sp.	2nd commor woody sp.
30	22	246	NJ322945	6		KALS	20	40	25	BUSHLAND	BURKAFRI	TERMBRAC
30	23	262	NJ188950	6		KALS	35	25	10	BUSHLAND	TERMSERI	COMBHERE
30	22	288	NJ427899	6		KALS	20	45	5	BUSHLAND	TERMSERI	ERYTAFRI
30	23	373	NJ481886	6	W	KALS	5	35	75	THIKWOOD	ACACERIO	DICRCINE
30	22	240	NK179139	6	W	KALS	15	14	35	BUSHWOOD	BURKAFRI	TERMSERI
30	22	245	NJ219968	6	G	KALS	5	15	2	BUSHGRAS	BURKAFRI	TERMSERI
30	22	248	NJ368981	6	W	KALS	25	30	45	BUSHLAND	TERMSERI	BURKAFRI
30	22	381	NJ113972	5		KALS	5	20	15	BUSHLAND	ERYTAFRI	COMBHERE
30	22	405	NK261069	2		KALS	10	30	5	BUSHLAND	HYPHPETE	TERMSERI
30	22	406	NK279054	6		KALS	5	15	55	BUSHLAND	BURKAFRI	TERMSERI
30	22	407	NK268045	5		KALS	10	15	2	BUSHWOOD	PARICURA	TERMSERI
30	22	409	NJ348924	6	W	KALS	2	35	2	BUSHLAND	BURKAFRI	TERMSERI
30	22	411	NK287047	6	W	KALS	1	10	1	BUSHLAND	TERMSERI	TERMBRAC
30	22	250	NJ383826	2		KALS	40	25	5	BUSHLAND	TERMSERI	BURKAFRI
30	21	465	MK292344	6		KALS	37	24	112	THICKET	COMBAPIC	ERYTAFRI

Appendix 3.

Species, areas and environmental factors associated with each vegetation type.

Vegetation Type	Indicator and Common Species	LOCATION topography	GEOL. TYPE topography	No std	SOIL texture	No std	SOIL colour	No std
TYPE 1	***Combretum coll.***	SINAMATELLA AREA	HWNG FIRECLAY	5	SH. SAND	9	WHITE	1
14 stands	***Abrus schimperi***	low, dome shaped,	LOWER KAROO	1	ROCK	3	GREY	1
80 species	***Canthium burtii***	round or long sstone	LWR. HW. SSTONE	3	SANDY CL.	2		
	Diospyros quiloensis	ridges	UPPR. HW. SSTONE	5				
	Colophospermum mo.							
TYPE 2	***Diopsyros quiloe.***	SINAMATELLA AREA	MADUMAB MUDST.	4	CLAY	4	GREY	4
5 stands	***Acacia robusta***	Adjacent to small			SANDY CL.	1	BROWN	1
60 species	*Erythroxylum zamb.*	water courses						
	Combretum mossam.							
TYPE 3	*Colophospermum mop.*	SINAMATELLA AREA	ESCARP. GRITS	4	ROCK	5	RED	1
7 stands	*Combretum elaeagn.*	Steep scarp slopes	GNSS/INYTUE FM.	4	SH. SAND	2	BROWN	1
81 species	*Commiphora karib.*							
	Sterculia africana							
	Markhamia acumin.							
TYPE 4	***Commiphora kar.***	SINAMATELLA AREA	GNEISS	8	ROCK	9	RED	4
19 stands	***Afzelia quanzen.***	DETE AREA	SIJARI QUARTZ.	3	BEDROCK	4	BROWN	2
156 species	***Bridelia mollis***	INYANTUE AREA	TSHONT FORMTN.	2	SH. SAND	4	PINK	1
	Sterculia africa.	SHUMBA AREA	INYNTUE FORMTN.	2	SANDY CL.	1		
	Elephantorrhiza	Castle kopjies with	KAROO	1				
		flat mopane areas		1				
TYPE 5	***Acacia nigrescens***		GNEISS	12	BEDROCK	8	BROWN	2
24 stands	***Diplorhynchus***	MTOA AREA	TSHONT FROMTN.	1	ROCK	4	RED	3
109 species	***Terminalia steno.***	INYANTUE AREA	SIJARI QUARTZ.	1	SH. SAND	1	PINK	1
	Julbernardia glob.	DETE AREA	LOWER KAROO	1	SANDY CL.	2		
	Catunaregam spinos.	SINAMATELLA AREA	ECOTONE	4				
	Carphalea pubescens	Flat to undulating						
	Erythroxylum zam.	with rocky outcrops						
TYPE 6	***Baphia massaien.***	DETE AREA	ECOTONE	1	SANDY CL.	6	RED	9
9 stands	*Kirkia acuminata*	INYANTUE AREA	KALAHARI SAND	1	SH. SAND	2		
130 species	*Vangueria infausta*	DETEEMA AREA			DE. SAND	1		
	Combretum collinum	Flat to undulating						
TYPE 6a	***Combretum elaeag.***	SHUMBA AREA	SIJARI QUARTZ.	1	ROCK	2	RED	2
6 stands	*Friesodielsia obov.*	SINAMATELLA AREA	UPPR. KAROO	2	SH. SAND	2		
	Diospyros quiloensis	Inselberg tops, hill			SANDY CL.	2		
		tops and sides						
TYPE 7	***Xeroderris stuhl.***	SINAMATELLA AREA	LOWR. KAROO	1	GRAVEL	2	WHITE	1
20 stands	*Kirkia acuminata*	INYANTUE AREA	GNEISS	4	ROCK	5	RED	5
119 species	*Sclerocarya birrea*	SHUMBA AREA	KAL. SAND/GNSS	4	BEDROCK	2	BROWN	2
	Grewia monitcola	Flat to undulating	SIJARI QUARTZ.	1	SANDY CL.	6	BLACK	1
	Xeroderris stuhlm.		INYANTUE	2	SH. SAND	4		
	Acacia nigrescens		LWR. HWNGE SST.	1				
TYPE 8	***Terminalia prun.***	SHUMBA AREA	MADUMAB MUDS.	4	CLAY	6	BROWN	5
14 stands	***Terminalia stuhl.***	SINAMATELLA AREA	BASALT?	2	GRAVEL	3	GREY	4
99 species	***Grewia flavescens***	DETEEMA AREA	RIPP MRKD FLAGS	1	ROCK	2	RED	2
	Combretum elaeagn.	Flat to undulating	GNEISS?	1	SANDY CL.	3		
	Vepris zambesiaca							

Appendix 3 continued.
Species, areas and environmental factors associated with each vegetation type.

Vegetation Type	Indicator and Common Species	LOCATION topography	GEOL. TYPE topography	No std	SOIL texture	No std	SOIL colour	No std
TYPE 9	***Diospyros quiloe.***	CHINGAHOBE AREA	GNEISS	3	ROCK	5	BROWN	5
15 stands	***Berchemia disc.***	MASUMA AREA	UPPER KAROO	2	GRAVEL	3	RED	6
104 species	*Canthium frangula*	DETEEMA AREA	UP. HWNG SSTONE	1	CLAY	1		
		INYANTUE RIVER			SANDY CL.	2		
		BUMBOOSIE AREA						
		River terraces						
TYPE 10	***Diospyros mesp.***	S'MATELLA RIVERS	MADUMAB MUDS	2	CLAY	3	GREY	4
13 stands	***Diospyros quil.***	River edges	GNEISS	4	SANDY CL.	1		
124 species	***Combretum moss.***		BASALT	2				
	Securinega virosa		RIPP MRKD FLAGS	1				
TYPE 11	*Colophospermum*	DZIVANINI	BASALT	10	CLAY	15	BLACK	6
	Combretum imberbe	SALT PANS AREA	ECOTONE	6	GRAVEL	3	WHITE	5
30 stands	*Combretum hereroense*	' TOMS AREA			ROCK	1	GREY	9
94 species	*Lonchocarpus capassa*	DETEEMA AREA			SH. SAND	3	BROWN	3
	Acacia nigrescens	SHUMBA			SANDY CL.	4		
	Dichrostachys cinerea	BUMBOOSIE			BEDROCK	1		
		Flat						
TYPE 12	***Crossopteryx febr.***	MTOA AREA	KALAHARI SANDS	11	SANDY CL.	16	GREY	7
35 stands	***Terminalia sericea***	TSHOMPANE AREA	BASALT	5	CLAY	10	WHITE	4
134 species	***Catunaregam spin.***	ROBINS SOUTH	GNEISS	2	SH. SAND	5	BROWN	3
	Diplorynchus condyl.	SHUMBA AREA	ECOTONE	2	ROCK	1	BLACK	3
	Terminalia sericea	NANTWICH AREA			GRAVEL	1	RED	1
	Colophospermum mo	DEKA AREA	Shallow depressions					
	Bolusanthus specio.	HENDRICkS AREA	on the watershed					
	Combretum imberbe	MANZIMBOMVU AREA						
	Combretum herer.	DANDARI						
		DETE AREA						
		LIBUTI AREA						
TYPE 13	***Sclerocarya birrea***	ROBINS AREA	BASALT	27	ROCK	18	BROWN	8
39 stands	***Diplorhynchus cond***	DEKA AREA	GNEISS	2	CLAY	9	BLACK	5
97 species	***Pterocarpus rotu.***	DANDARI	KALAHARI SAND	1	SANDY CL.	1	RED	1
	Peltophorum afric.	Low hills,			GRAVEL	2		
		undulating terrain			SH. SAND	1		
TYPE 14	***Vitex petersiana***	ROBINS AREA	BASALT	13	ROCK	9	GREY	5
23 stands	*Terminalia prunioi.*	ROBINS SOUTH	KALAHARI SAND	1	CLAY	7	BROWN	10
91 species	*Terminalia stuhlmann*	DANDARI	undulating terrain		SANDY CL.	4	BLACK	3
		LIBUTI AREA			GRAVEL	2		
TYPE 15	***Vepris zambesiac***	SINAMATELLA AREA	MADUMAB MUDS.	4	CLAY	5	BLACK	1
7 stands	***Colophospermum m***	S DEKA?	BASALT	1	SANDY CL.	1	GREY	5
53 species	*Dichrostachys cinerea*	Flat			GRAVEL	1		
TYPE 16	***Grewia bicolor***	DZIVANINI AREA			CLAY	13	GREY	9
14 stands	*Colophospermum mop*	Flat			SANDY CL.	1	BLACK	3
26 species	*Dichrostachys ciner*							
	Acacia erubescens							

Appendix 3 continued.
Species, areas and environmental factors associated with each vegetation type.

Vegetation Type	Indicator and Common Species	LOCATION topography	GEOL. TYPE topography	No std	SOIL texture	No std	SOIL colour	No std
TYPE 17	***Lonchocarpus cap.***	SHUMBA AREA	KALAHARI SAND	5	SANDY CL.	7		
9 stands	***Commiphora ed.***	DZIVANINI AREA	ECOTONE	1	CLAY	2		
76 species	***Vangueria infau.***	Flat						
	Acacia nigrescens							
	Combretum collin.							
TYPE 18	***Ziziphus mucron.***	TRIGA VLEI	KALAHARI SAND	31	CLAY	12	WHITE	1
38 stands	***Boscia albitrunca***	LIBUTI AREA	CALCRETE	1	SANDY CL.	22		
84 species	*Mundulea sericea*	JOSIVANINI AREA			SH. SAND	4		
	Acacia leuderitzii	JUPANDA VLEI	Inter-dune					
	Acacia fleckii	MANGA VLEI	troughs, fossil					
		KENNEDY VLEI	vlei lines					
		LINKWASHA VLEI						
TYPE 19	***Burkea africana***	TEN MILE DRIVE	KALAHARI SAND	12	SANDY CL.	16	GREY	2
30 stands	***Combretum imberb***	KENNEDY	CALCRETE	11	SH. SAND	4	WHITE	1
107 species	*Maytenus senegalensis*	MADUNDAMELLA	ECOTONE	3	CLAY	6		
	Peltophorum african.	UMKOWAZAAN			DEEP SAND	1		
	Diospyros lycioides	MBIZA - NGAMO	Flat					
	Combretum zeyheri	LIBUTI AREA						
TYPE 20	***Mundulea sericea***	TRIGA VLEI	KALAHARI SAND	24	SANDY CL.	17	PINK	1
25 stands	*Commiphora ango.*	WEXCAU AREA			SH. SAND	6	BROWN	1
74 species	*Combretum albo.*	JOSIVANINI AREA	Flat gently sloping		CLAY	1		
	Acacia erioloba	UMKOWAZAAN						
	Lonchocarpus nelsii	SHAPI AREA						
		GUVALALA AREA						
TYPE 21	***Ochna pulchra***	GUVALALA AREA	KALAHARI SAND	12	SANDY CL.	3		
31 stands	*Lonchocarpus nelsii*	NYAMANDHLOVU			SH. SAND	7		
66 species	*Acacia fleckii*	SINANGA AREA			DEEP SAND	1		
	Bauhinia petersiana	Flat			CLAY	1		
TYPE 22	***Dalbergia melan.***	MANGA TWO AREA	KALAHARI SAND	25	SANDY CL.	16	GREY	3
8 stands	***Colophospermum***	MAKONA AREA	Flat to undulating		SH. SAND	7	WHITE	2
74 species	*Combretum apiculat*	WEXCAU AREA			DEEP SAND	2		
	Combretum herero.	TRIGA VLEI						
	Peltophorum africa.	JOSIVANINI AREA						
TYPE 23	***Baikiaea plurijuga***	MANGA VLEI	KALAHARI SAND	22	DEEP SAND	19	WHITE	4
22 stands	***Combretum celas***	LINKWASHA AREA			SH. SAND	2	RED	3
57 species	***Grewia avellana***	JOSIVANINI	Dune crests		CLAY	1	PINK	1
	Croton pseudop.	NGAMO AREA						
	Croton gratiss.	SINANGA AREA						
		JUPANDA AREA						
TYPE 24	***Peltophorum afri.***	TRIGA VLEI	KALAHARI SAND	12	SH. SAND	4		
12 stands	***Ancylanthos baln.***	MANGA AREA			SANDY CL.	6		
53 species	***Acacia erioloba***	UMKOWAZAAN	Fossil vlei		DEEP SAND	1		
	Terminalia sericea	JOSIVANINI AREA	margins, flat					
		DOPI VLEI	to gently sloping					
		LINKWASHA						

Appendix 3 continued.

Species, areas and environmental factors associated with each vegetation type.

Vegetation Type	Indicator and Common Species	LOCATION topography	GEOL. TYPE topography	No std	SOIL texture	No std	SOIL colour	No std
TYPE 25	***Baikiaea plurijuga***	TRIGA VLEI	KALAHARI SAND	33	DEEP SAND	23	WHITE	6
53 stands	***Commiphora ango***	GUVALALA AREA			SH. SAND	4	PINK	1
60 species	***Pterocarpus ango.***	JAMBILE AREA	Flat terrain		SANDY CL.	4	BROWN	1
	Croton pseudop.	JOSIVANINI AREA					RED	2
	Lonchocarpus nelsii	NEHIMBA AREA						
TYPE 26	***Combretum colli.***	MAIN CAMP-NGAMO	KALAHARI SAND	24	DEEP SAND	18	WHITE	7
24 stands	*Ptercocarpus angol.*	TIBUKAI AREA			SH. SAND	4		
55 species	*Burkea africana*	BEAVA AREA	Flat terrain		SANDY CL.	2		
	Diplorhynchus co.	CATERPILLAR AREA						
		SINANGA AREA						
		NJEKWA AREA						
		SHAPI AREA						
TYPE 27	***Baikiaea plurijuga***	DETE AREA	KALAHARI SAND	16	DEEP SAND	15	WHITE	8
16 stands	***Guibourtia coleos***	MAIN CAMP-NGAMO					YELLOW	2
56 species	***Pseudolachnostylis***							
	Acacia erioloba	Flat terrain						
TYPE 28	***Vangueria infausta***	WHITE HILL AREA	KALAHARI SAND	12	DEEP SAND	8	WHITE	3
12 stands	***Croton gratissimus***	NJEKWA AREA			SH. SAND	2	GREY	1
59 species	*Commiphora mossam.*	MITSWIRI AREA	Flat terrain					
	Croton pseudopulch.	DETE AREA						
	Rhus tenuinervis	LINKWASHA AREA						
	Grewia avellana	INTUNDHLA AREA						
TYPE 29	***Commiphora moss.***	DETE AREA	KALAHARI SAND	22	DEEP SAND	11	RED	8
24 stands	***Catunaregam spin.***	SHAPI AREA			SH. SAND	6	WHITE	2
99 species	***Combretum apic.***	SHUMBA AREA	Flat to sloping,		SANDY CL.	6	BROWN	2
	Diplorynchus co.	KAPULA AREA	the edges of		CLAY	1		
	Pterocarpus angolen.	TIBUKAI AREA	Kalahari sand					
	Xeromphis obovata	DANDARI AREA	distribution					
		SOUTH ROBINS AREA						
TYPE 30	***Terminalia brac.***	MAKWA-NGAMO	KALAHARI SAND	22	DEEP SAND	16	WHITE	7
22 stands	***Annona stenoph.***	KAPULA AREA			SH. SAND	4	GREY	1
71 species	*Diplorynchus condy.*		Edges of calcrete		SANDY CL.	2		
	Combretum herer.	Flat terrain	areas, on the					
	Acacia erioloba		watershed					
	Pseudolachnostylis							

Appendix 4.

Presence of species in each height class in each type, where % presence > 20 to 25%.

Species height class		
<1 m	1-3m	>3m
> 25 % presence	> 25 % presence	> 20 % presence
Type 1		
Abrus schimperi 64	Combretum elaeagnoides 50	Diospyros quiloensis 71
Canthium burtii 50	Combretum collinum 42	Colophospermum mopane 42
Grewia flavescens var. flav. 42	Strychnos madagascariensis 42	Combretum collinum 42
Dalbergia nitidula 35	Combretum celastroides 35	Combetum celastroides 35
Hippocratea indica 35	Combretum zeyheri 35	Pteleopsis myrtifolia 35
Hippocratea parvifolia 28	Combretum mossambicense 35	Haplocoelum foliolosum 28
Mundulea sericea 28	Haplocoelum foliolosum 35	Lonchocarpus eriocalyx 28
Ipomoea schupangensis 28	Lonchocarpus eriocalyx 35	Combretum apiculatum 28
Canthium frangula 28	Margaritaria discoidea 35	Boscia angustifolia var. cory. 28
Boscia angustifolia var. cory. 28	Pteleopsis myrtifolia 35	Lannea schweinfurthii 28
	Pterocarpus lucens 28	
	Meiostemon tetrandus 28	
	Acacia ataxacantha 28	
Type 2		
Dichrostachys cinerea 60	Diospyros quiloensis 60	Colophospermum mopane 100
Fockea multiflora 40	Acacia ataxacantha 40	Acacia robusta 40
Ipomoea schupangensis 40	Canthium frangula 40	Vangueria randii 40
Grewia species 40	Combretum celastroides 40	Combretum mossambicense 40
Commiphora edulis 40	Dichrostachys cinerea 40	Erythroxylum zambesiacum 40
Lonchocarpus capassa 40	Gardenia resiniflua 40	Canthium frangula 20
Commiphora africana 40	Mundulea sericea 40	Diospyros quiloensis 20
Commiphora pyracanthoides 40	Strychnos potatorum 40	Allopyhlus africanus 20
Acacia ataxacantha 40		Adansonia digitata 20
Type 3		
Canthium frangula 57	Grewia flavescens var. flav. 42	Colophospermum mopane 85
Combretum elaeagnoides 57	Diopsyros quiloensis 42	Commiphora marlothii 57
Erythrococca menyharthii 42	Azanza garckeana 28	Sterculia africana 57
Grewia flavescens var. flav. 42	Elephantorrhiza goetzei 28	Commiphora mollis 42
Markhamia zanzibarica 42	Markhamia zanzibarica 28	Entandrophragma caudatum 42
Combretum mossambicense 42	Vitex petersiana 28	Gyrocarpus americanus 42
Acacia ataxacantha 42	Gardenia resiniflua 28	Kirkia acuminata 42
Cissus cornifolia 28	Combretum celastroides 28	Adansonia digitata 42
Commiphora karibensis 28		Lannea schweinfurthii 42
Commiphora mossambicensis 28		Albizia tanganyicensis 28
Courbonia glauca 28		Boscia angustifolia var. cory. 28
Steganotaenia araliacea 28		Commiphora karibensis 28
Stomatostemma monterioae 28		Euphorbia forbesii 28
Ipomoea schupangensis 28		Markhamia zanzibarica 28
Gardenia resiniflua 28		Steganotaenia araliacea 28
Acacia nigrescens 28		Stomatostemma monterioae 28
Grewia monticola 28		Bridelia mollis 28
		Diospyros quiloensis 28

Appendix 4 continued.

Presence of species in each height class in each type, where % presence > 20 to 25%.

Species height class		
<1m	1-3m	>3m
> 25 % presence	> 25 % presence	> 20 % presence
Type 4		
Catunaregam spinosa 68	Combretum elaeagnoides 57	Colophospermum mopane 94
Pterocarpus rotundifolius 52	Cissus cornifolia 47	Afzelia quanzensis 57
Commiphora mossambicensis 52	Combretum apiculatum 47	Combretum apiculatum 47
Dalbergia melanoxylon 47	Schrebera trichoclada 42	Sterculia africana 42
Dichrostachys cinerea 47	Diospyros quiloensis 42	Diospyros quiloensis 42
Jasminium stenolobum 42	Carphalea pubescens 42	Xeroderris stuhlmannii 42
Carphalea pubescens 36	Elephantorrhiza goetzei 36	Erythroxylum zambesiacum 42
Erythrococca menyharthii 31	Diplorhynchus condylocarpon 36	Strychnos madagascariensis 36
Markhamia zanzibarica 31	Hippocratea parvifolia 31	Kirkia acuminata 36
Canthium frangula 26	Acacia nigrescens 31	Strychnos potatorum 31
Commiphora karibensis 26	Grewia monticola 31	Acacia nigrescens 26
Steganotaenia araliaceae 26	Strychnos madagascariensis 26	Cassia abbreviata 26
Kirkia acuminata 26	Canthium frangula 26	Commiphora marlothii 26
Cassia abbreviata 26	Azanza garckeana 26	Commiphora mollis 26
Sclerocarya birrea 26	Bridelia mollis 26	Schrebera trichoclada 21
Grewia monticola 26	Erythroxylum zambesiacum 26	Steganotaenia araliaceae 21
Diplorhynchus condylocarpon 26	Commiphora mossambicense 26	
	Euclea divinorum 26	
	Combretum zeyheri 26	
Type 5		
Catunaregam spinosa 75	Commiphora mossambicensis 68	Colophospermum mopane 81
Pterocarpus rotundifolius 50	Diplorhynchus condylocarpon 62	Diospyros quiloensis 62
Lannea discolor 43	Carphalea pubescens 62	Combretum apiculatum 43
Sclerocarya birrea 37	Erythroxylum zambesiacum 62	Terminalia stenostachya 37
Cassia abbreviata 31	Cissus cornifolia 56	Afzelia quanzensis 31
Carphalea pubescens 31	Strychnos madagascariensis 56	Xeroderris stuhlmannii 31
Commiphora mossambicensis 31	Julbernardia globiflora 50	Terminalia sericea 31
Grewia monticola 31	Grewia monticola 50	Commiphora mollis 25
Jasminium stenolobum 31	Dichrostachys cinerea 43	Erythroxylum zambesiacum 25
Dalbergia melanoxylon 25	Acacia nigrescens 43	Kirkia acuminata 25
Kirkia acuminata 25	Combretum apiculatum 43	Combretum zeyheri 25
Dichrostachys cinerea 25	Combretum zeyheri 43	
Vangueria infausta 25	Pterocarpus rotundifolius 37	
Bauhinia peterisana 25	Peltophorum rotundifolia 37	
	Schrebera trichoclada 31	
	Bauhinia petersiana 31	
	Commiphora pyracanthoides 31	
	Commiphora mollis 25	
	Diospyros quiloensis 25	
	Crossopteryx febrifuga 25	
	Dalbergia melanoxylon 25	
	Pseudolachnostylis maproun. 25	
	Combretum elaeagnoides 25	

Appendix 4 continued.

Presence of species in each height class in each type, where % presence > 20 to 25%.

Species height class		
<1m	1-3m	>3m
> 25 % presence	> 25 % presence	> 20 % presence
Type 6		
Catunaregam spinosum 60	Vangueria infausta 56	Combretum apiculatum 56
Pterocarpus rotundifolius 56	Combretum collinum 52	Erythroxylum zambesiacum 47
Dalbergia melanoxylon 43	Strychnos madagascariensis 47	Colophospermum mopane 34
Dichrostachys cinerea 39	Commiphora mossambicensis 47	Kirkia acuminata 30
Diplorhynchus condylocarpon 39	Grewia monticola 47	Diospyros quiloensis 26
Grewia monticola 39	Carphalea pubescens 43	Catunaregam spinosum 21
Commiphora mossambicensis 34	Erythroxylum zambesiacum 43	
Jasminium stenolobum 30	Combretum apiculatum 43	
Bauhinia petersiana 30	Cissus cornifolia 39	
Cissus cornifolia 26	Schrebera trichoclada 39	
	Vitex payos 39	
	Combretum elaeagnoides 39	
	Allophylus africanus 39	
	Euclea divinorum 39	
	Commiphora pyracanthoides 39	
	Combretum zeyheri 39	
	Terminalia sericea 39	
	Baphia massaiensis 34	
	Friesodielsia obovata 34	
	Pterocarpus rotundifolius 34	
	Pseudolachnostylis maproun. 34	
	Combretum mossambicense 30	
	Diospyros quiloensis 30	
	Kirkia acuminata 30	
	Colophospermum mopane 30	
	Peltophorum africanum 30	
	Bauhinia petersiana 30	
	Lannea discolor 26	
	Canthium frangula 26	
	Strychnos potatorum 26	
	Markhamia zanzibarica 26	
	Commiphora mollis 26	
	Dichrostachys cinerea 26	

Appendix 4 continued.

Presence of species in each height class in each type, where % presence > 20 to 25%.

Species height class		
<1m	**1-3m**	**>3m**
> 25 % presence	**> 25 % presence**	**> 20 % presence**
Type 7		
Dichrostachys cinerea 60	Diospyros quiloensis 75	Colophospermum mopane 95
Dalbergia melanoxylon 55	Acacia nigrescens 65	Erythroxylum zambesiacum 35
Grewia monticola 55	Combretum elaeagnoides 60	Xeroderris stuhlmannii 30
Markhamia zanzibarica 50	Combretum apiculatum 55	Combretum apiculatum 20
Jasminium stenolobum 50	Commiphora mossambicensis 50	
Pterocarpus rotundifloius 50	Carphalea pubescens 40	
Commiphora africana 45	Cissus cornifolia 40	
Commiphora pyracanthoides 45	Erythroxylum zambesiacum 35	
Cassia abbreviata 35	Ximenia americana 35	
Cissus cornifolia 30	Grewia monticola 35	
Combretum mossambicense 30	Acacia robusta 30	
Kirkia acuminata 30	Cassia abbreviata 30	
Carphalea pubescens 25	Commiphora edulis 25	
Commiphora mossambicensis 25	Sclerocarya birrea 25	
Sclerocarya birrea 25	Euclea divinorum 25	
Allophylus africanus 25		
Type 8		
Grewia flavescens var. flav. 71	Terminalia prunioides 57	Colophospermum mopane 100
Dalbergia melanoxylon 57	Erythroxylum zambesiacum 50	Erythroxylum zambesiacum 35
Commiphora africana 57	Combretum elaeagnoides 50	Acacia nigrescens 21
Commiphora pyracanthoides 57	Diospyros quiloensis 50	Diospyros quiloensis 21
Vepris zambesiaca 50	Carphalea pubescens 42	
Grewia monticola 50	Acacia nigrescens 42	
Commiphora karibensis 42	Canthium frangula 35	
Markhamia zanzibarica 42	Commiphora africana 35	
Cissus cornifolia 42	Gardenia resiniflua 35	
Dichrostachys cinerea 42	Cissus cornifolia 35	
Cassia abbreviata 35	Commiphora mossambicensis 35	
Fagara chalybea 28	Vitex petersiana 35	
Grewia species 28	Combretum apiculatum 35	
Commiphora edulis 28	Commiphora africana 35	
Euphorbia espinosa 28	Terminalia stuhlmannii 28	
Lannea schweinfurthii 28	Ximenia americana 28	
Terminalia prunioides 28		
Pterocarpus rotundifolius 28		
Commiphora mossambicensis 28		

Appendix 4 continued.

Presence of species in each height class in each type, where % presence > 20 to 25%.

Species height class		
<1m	1-3m	>3m
> 25 % presence	> 25 % presence	> 20 % presence
Type 9		
Markhamia acuminata 53	Combretum elaeagnoides 66	Diospyros quiloensis 73
Grewia monticola 46	Combretum mossambicensis 46	Erythroxylum zambesiacum 53
Grewia flavescens var. flav. 46	Dichrostachys cinerea 46	Xeroderris stuhlmanni 46
Dichrostachys cinerea 40	Canthium frangula 40	Colophospermum mopane 46
Erythroxylum zambesiacum 33	Combretum zeyheri 40	Combretum apiculatum 40
Dalbergia melanoxylon 33	Securinega virosa 33	Berchemia discolor 33
Grewia flavescens var. oluk. 33	Strychnos madagascariensis 26	Sterculia africana 33
Boscia salicifolia 26	Acacia luederitzii 26	Acacia robusta 26
Carphalea pubescens 26		Combretum elaeagnoides 26
Cassia abbreviata 26		Terminalia prunioides 26
Allophylus africanus 26		Acacia nigrescens 20
Hippocratea indica 26		Adansonia digitata 20
Grewia bicolor 26		Combretum imberbe 20
Type 10		
Dichrostachys cinerea 46	Securinega virosa 92	Combretum hereroense 100
Lonchocarpus capassa 38	Combretum mossambicense 61	Combretum imberbe 84
Dalbergia melanoxylon 30	Peltophorum africanum 46	Diospyros mespiliformis 61
Jasminium stenolobum 30	Ziziphus mucronata 38	Kigelia africana 53
Allophylus africanus 30	Allophylus africanus 30	Colophospermum mopane 53
Grewia flavescens var. flav. 30	Grewia monticola 30	Croton megalobotrys 46
	Strychnos potatorum 30	Lonchocarpus capassa 46
	Colophospermum mopane 30	Acacia galpinii 38
	Dichrostachys cinerea 30	Diospyros quiloensis 38
		Erythroxylum zambesiacum 38
		Combretum mossambicense 30
		Terminalia prunioides 30
		Ziziphus mucronata 30

Appendix 4 continued.

Presence of species in each height class in each type, where % presence > 20 to 25%.

Species height class		
<1 m	**1-3m**	**>3 m**
> 25 % presence	**> 25 % presence**	**> 20 % presence**
Type 11		
Lonchocarpus capassa 86	Combretum imberbe 86	Colophospermum mopane 59
Combretum imberbe 86	Colophospermum mopane 76	Combretum imberbe 52
Colophospermum mopane 83	Combretum hereroense 62	Combretum hereroense 38
Dichrostachys cinerea 69	Acacia nigrescens 48	
Combretum hereroense 69	Ziziphus mucronata 45	
Acacia nigrescens 59	Lonchocarpus capassa 41	
Securinega virosa 41	Securinega virosa 34	
Combretum mossambicense 41	Dichrostachys cinerea 34	
Maytenus senegalensis 41	Combretum mossambicense 31	
Grewia flavescens v. oluk. 38	Acacia sieberiana 28	
Euclea divinorum 38		
Hyphenae petersiana 38		
Grewia monticola 34		
Dalbergia melanoxylon 34		
Grewia flavescens v. flav. 31		
Acacia sieberiana 28		
Cassia abbreviata 28		
Diospyros lycioides 28		
Peltophorum africanum 28		

Appendix 4 continued.

Presence of species in each height class in each type, where % presence > 20 to 25%.

Species height class		
<1m	1-3m	>3m
> 25 % presence	> 25 % presence	> 20 % presence
Type 12		
Catunaregam spinosum 77	Crossopteryx febrifuga 77	Erythroxylum zambesiacum 55
Pterocarpus rotundifolius 66	Dalbergia melanoxylon 66	Colophospermum mopane 55
Jasminium stenolobum 55	Bauhinia petersiana 55	Combretum apiculatum 33
Commiphora mossambicensis 55	Diplorhynchus condylocarpon 55	Combretum hereroense 33
Lannea discolor 44	Cissus cornifolia 55	Terminalia sericea 33
Diplorhynchus condylocarpon 44	Combretum collinum 55	
Lannea discolor 44	Grewia monticola 55	
Pavetta schumanniana 44	Combretum apiculatum 55	
Pterocarpus angolensis 33	Brachystegia boehmii 44	
Terminalia stenostachya 33	Acacia robusta 44	
Allophylus africanus 33	Burkea africana 44	
Euclea divinorum 33	Commiphora mossambicensis 44	
Commiphora africana 33	Terminalia sericea 44	
Grewia monticola 33	Erythroxylum zambesiacum 44	
Euphorbia matabelensis 33	Peltophorum africanum 44	
Kirkia acuminata 33	Euclea divinorum 44	
	Cassia abbreviata 33	
	Combretum hereroense 33	
	Combretum zeyheri 33	
	Commiphora africana 33	
	Commiphora mollis 33	
	Julbernardia globiflora 33	
	Kirkia acuminata 33	
	Lannea discolor 33	
	Pseudolachnostylis maproun. 33	
	Vitex payos 33	
	Ximenia americana 33	
	Sclerocarya birrea 33	
	Combretum adenogonium 33	
	Pterocarpus rotundifolius 33	
	Securinega virosa 33	

Appendix 4 continued.

Presence of species in each height class in each type, where % presence > 20 to 25%.

Species height class		
<1m	1-3m	>3m
> 25 % presence	> 25 % presence	> 20 % presence
Type 13		
Pterocarpus rotundifolius 41	Dalbergia melanoxylon 76	Colophospermum mopane 84
Jasminium stenolobum 38	Acacia nigrescens 71	Combretum apiculatum 30
Cissus cornifolia 35	Commiphora pyracanthoides 64	Combretum hereroense 30
Commiphora africana 35	Combretum apiculatum 58	
Diplorhynchus condylocarpon 33	Terminalia randii 56	
Cassia abbreviata 30	Pterocarpus rotundifolius 53	
Carphalea pubescens 28	Grewia monticola 51	
Sclerocarya birrea 28	Commiphora mossambicensis 43	
Commiphora mossambicensis 28	Combretum imberbe 41	
Catunaregam spinosum 28	Peltophorum africanum 41	
Allophylus africanus 25	Carphalea pubescens 38	
Grewia monticola 25	Commiphora africana 33	
	Cassia abbreviata 30	
	Sclerocarya birrea 30	
	Combretum hereroense 30	
	Cissus cornifolia 28	
	Combretum adenogonium 28	
	Rhus tenuinervis 25	
Type 14		
Grewia monticola 56	Combretum apiculatum 60	Colophospermum mopane 95
Pterocarpus rotundifolius 52	Acacia nigrescens 52	
Commiphora mossambicensis 47	Vitex petersiana 52	
Carphalea pubescens 43	Erythroxylum zambesiacum 47	
Cissus cornifolia 34	Commiphora pyracanthoides 47	
Jasminium stenolobum 34	Dalbergia melanoxylon 43	
Dalbergia melanoxylon 30	Terminalia randii 39	
Dichrostachys cinerea 30	Commiphora africana 34	
Commiphora pyracanthoides 30	Cissus cornifolia 30	
Cassia abbreviata 26	Combretum hereroense 30	
Ximenia americana 26	Terminalia stuhlmannii 26	
Commiphora africana 26	Combretum imberbe 26	
	Dichrostachys cinerea 26	

Appendix 4 continued.

Presence of species in each height class in each type, where % presence > 20 to 25%.

Species height class		
<1m	1-3m	>3m
> 25 % presence	> 25 % presence	> 20 % presence
Type 15		
Commiphora africana 83	Commiphora pyracanthoides 33	Colophospermum mopane 100
Vepris zambesiaca 66	Dalbergia melanoxylon 33	
Dichrostachys cinerea 66	Dichrostachys cinerea 33	
Dalbergia melanoxylon 50		
Terminaia prunioides 50		
Fagara chalybea 33		
Cissus cornifolia 33		
Cissus welwitschii 33		
Olax obtusifolia 33		
Terminalia stuhlmannii 33		
Commiphora mossambicensis 33		
Ximenia americana 33		
Boscia matabelensis 33		
Grewia monticola 33		
Maerua parvifolia 33		
Type 16		
Grewia bicolor 33	Acacia erubescens 40	Colophospermum mopane 100
Boscia matabelensis 33	Ximenia americana 40	
Dalbergia melanoxylon 26	Dichrostachys cinerea 33	
Commiphora africana 26	Acacia nilotica 26	
Commiphora pyracanthoides 26		
Grewia monticola 26		
Maerua parvifolia 26		
Dichrostachys cinerea 26		
Type 17		
Lonchocarpus capassa 77	Terminalia sericea 66	Colophospermum mopane 77
Commiphora africana 77	Combretum hereroense 55	Acacia nigrescens 22
Dalbergia melanoxylon 66	Dichrostachys cinerea 55	
Commiphora pyracanthoides 66	Lonchocarpus nelsii 55	
Grewia flavescens var. flav. 66	Combretum collinum 44	
Grewia monticola 44	Combretum apiculatum 33	
Maerua parvifolia 44	Combretum imberbe 33	
Dichrostachys cinerea 44	Peltophorum africanum 33	
Rhus tenuinervis 44	Vangueria infausta 33	
Commiphora edulis 33	Grewia bicolor 33	
Pterocarpus rotundifolius 33	Grewia flavescens var. flav. 33	
Euclea divinorum 33		
Vangueria infausta 33		
Acacia fleckii 33		
Lonchocarpus nelsii 33		
Grewia flava 33		

Appendix 4 continued.

Presence of species in each height class in each type, where % presence > 20 to 25%.

Species height class		
<1m	**1-3m**	**>3m**
> 25 % presence	**> 25 % presence**	**> 20 % presence**
Type 18		
Commiphora africana 81	Combretum hereroense 68	Acacia erioloba 47
Rhus tenuinervis 52	Ziziphus mucronata 57	Boscia albitrunca 39
Dichrostachys cinerea 50	Grewia flavescens var. flav. 55	Colophospermum mopane 26
Dalbergia melanoxylon 44	Mundulea sericea 52	
Commiphora pyracanthoides 44	Terminalia sericea 47	
Jasminium stenolobum 44	Dichrostachys cinerea 39	
Acacia fleckii 44	Grewia bicolor 39	
Grewia monticola 42	Lonchocarpus nelsii 36	
Grewia flava 31	Colophospermum mopane 36	
Grewia flavescens var. flav. 28	Peltophorum africanum 34	
Maerua parvifolia 26	Acacia erioloba 34	
Commiphora angolensis 26	Boscia albitrunca 34	
Pavetta lasiopeplus 26	Grewia flava 28	
	Combretum apiculatum 26	
	Diospyros lycioides 26	
Type 19		
Lonchocarpus capassa 46	Terminalia sericea 60	Combretum imberbe 63
Dalbergia melanoxylon 43	Maytenus senegalensis 46	Combretum hereroense 56
Grewia monticola 43	Peltophorum africanum 46	Colophospermum mopane 26
Dichrostachys cinerea 40	Diospyros lycioides 40	Acacia erioloba 26
Grewia flavescens var. flav 40	Dichrostachys cinerea 33	Terminalia sericea 20
Lannea edulis 40	Combretum hereroense 30	Burkea africana 20
Commiphora pyracanthoides 33	Rhus tenuinervis 30	
Rhus tenuinervis 33	Combretum apiculatum 26	
Diplorhynchus condylocarpon 30	Ziziphus mucronata 26	
Acacia erioloba 26	Acacia erioloba 26	
Acacia fleckii 26	Ochna pulchra 26	

Appendix 4 continued.

Presence of species in each height class in each type, where % presence > 20 to 25%.

Species height class		
<1m	1-3m	>3m
> 25 % presence	> 25 % presence	> 20 % presence
Type 20		
Commiphora africana 80	Mundulea sericea 92	Acacia erioloba 44
Commiphora pyracanthoides 76	Dichrostachys cinerea 80	Lonchocarpus nelsii 40
Hippocratea indica 72	Ochna cinnabarina 80	Acacia luederitzii 36
Rhus tenuinervis 64	Terminalia sericea 72	
Commiphora angolensis 52	Combretum collinum 72	
Combretum albopunctatum 48	Grewia flavescens var. flav. 64	
Bauhinia petersiana 44	Combretum hereroense 52	
Baphia massaiensis 44	Acacia fleckii 48	
Pavetta lasiopeplus 36	Lonchocarpus nelsii 48	
Grewia flavescens var. flav. 32	Boscia albitrunca 48	
Erythrococca menyharthii 28	Combretum zeyheri 48	
Vangueria infausta 28	Baphia massaiensis 48	
Grewia flava 28	Acacia luederitzii 44	
	Acacia ataxacantha 40	
	Grewia monticola 36	
	Commiphora angolensis 36	
	Grewia bicolor 36	
	Vangueria infausta 32	
	Croton gratissimus 32	
	Acacia erioloba 28	
	Rhus tenuinervis 28	
	Rhigozum brevispinosum 28	
Type 21		
Rhus tenuinervis 58	Dichrostachys cinerea 74	Lonchocarpus nelsii 35
Bauhinia petersiana 55	Acacia ataxacantha 65	Terminalia sericea 35
Commiphora africana 52	Acacia fleckii 58	Acacia erioloba 23
Hippocratea indica 52	Combretum collinum 58	Combretum collinum 23
Baphia massaiensis 52	Ochna pulchra 58	
Grewia flavescens var. flav. 45	Grewia flavescens var. flav. 55	
Commiphora angolensis 42	Combretum zeyheri 55	
Grewia flava 35	Lonchocarpus nelsii 52	
Acacia fleckii 32	Terminalia sericea 48	
Burkea africana 29	Baphia massaiensis 45	
Ochna cinnabarina 29	Ochna cinnabarina 42	
Combretum psidioides 26	Combretum hereroense 32	
Grewia bicolor 26	Peltophorum africanum 32	
Commiphora pyracanthoides 26	Commiphora angolensis 29	
	Croton gratissimus 29	
	Rhus tenuinervis 29	
	Ziziphus mucronata 26	
	Acacia erioloba 26	
	Pavetta lasiopeplus 26	

Appendix 4 continued.

Presence of species in each height class in each type, where % presence > 20 to 25%.

Species height class		
<1m	1-3m	>3m
> 25 % presence	> 25 % presence	> 20 % presence
Type 22		
Dalbergia melanoxylon 88	Lonchocarpus nelsii 88	Colophospermum mopane 63
Hippocratea indica 75	Combretum collinum 88	Combretum apiculatum 25
Commiphora africana 63	Baphia massaiensis 63	Acacia fleckii 25
Commiphora pyracanthoides 50	Peltophorum africanum 50	Boscia albitrunca 25
Grewia monticola 50	Ochna cinnabarina 50	Terminalia sericea 25
Pavetta lasiopeplus 50	Combretum hereroense 38	Baikiaea plurijuga 25
Bauhinia petersiana 50	Dichrostachys cinerea 38	
Pterocarpus rotundifolius 38	Vangueria infausta 38	
Ximenia americana 38	Commiphora angolensis 38	
Diplorhynchus condylocarpon 38	Rhus tenuinervis 38	
Maerua parvifolia 38	Combretum zeyheri 38	
Dichrostachys cinerea 38	Terminalia sericea 38	
Croton pseudopulchellus 38	Combretum mossambicense 25	
Pterocarpus angolensis 38	Markhamia zanzibarica 25	
Commiphora edulis 25	Erythroxylum zambesiacum 25	
Cassia abbreviata 25	Colophospermum mopane 25	
Jasminium stenolobum 25	Combretum apiculatum 25	
Combretum hereroense 25	Erythrococca menyharthii 25	
Acacia ataxacantha 25	Acacia ataxacantha 25	
Grewia flavescens var. flav. 25	Croton gratissimus 25	
Tinnea vestita 25	Grewia flavescens var. flav. 25	
Rhus tenuinervis 25		
Grewia flava 25		
Combretum zeyheri 25		
Dicapetalum rhodesicum 25		
Type 23		
Grewia avelana 77	Dichrostachys cinerea 81	Baikiaea plurijuga 100
Rhus tenuinervis 68	Ochna cinnabarina 81	Acacia erioloba 40
Hippocratea indica 54	Acacia ataxacantha 77	Lonchocarpus nelsii 27
Croton pseudopulchellus 54	Grewia flavescens var. flav. 72	Croton gratissimus 27
Jasminium stenolobum 45	Combretum celastroides 68	
Commiphora angolensis 40	Baphia massaiensis 68	
Vangueria infausta 31	Croton gratissimus 63	
Grewia flavescens var. flav. 27	Acacia fleckii 50	
Baphia massaiensis 27	Lonchocarpus nelsii 45	
	Vangueria infausta 40	
	Commiphora angolensis 40	
	Erythrococca menyharthii 36	
	Combretum collinum 31	
	Boscia albitrunca 27	

Appendix 4 continued.

Presence of species in each height class in each type, where % presence > 20 to 25%.

Species height class		
<1m	1-3m	>3m
> 25 % presence	> 25 % presence	> 20 % presence
Type 24		
Bauhinia petersiana 75	Ochna pulchra 100	Terminalia sericea 58
Ancylanthos bainesii 58	Combretum psidioides 83	Acacia erioloba 25
Acacia ataxacantha 50	Acacia fleckii 66	Burkea africana 25
Rhus tenuinervis 41	Baphia massaiensis 66	
Strychnos spinosa 41	Acacia erioloba 58	
Dicapetalum rhodesicum 41	Combretum collinum 58	
Annona stenophylla 41	Combretum zeyheri 58	
Burkea africana 41	Grewia flavescens var. flav. 50	
Commiphora africana 33	Dichrostachys cinerea 50	
Diplorhynchus condylocarpon 33	Terminalia sericea 41	
Hippocratea indica 33	Erythrophleum africanum 41	
Baphia massaiensis 33	Peltophorum africanum 33	
Brakenridgea arenaria 33	Vitex payos 33	
Grewia monticola 25	Burkea africana 33	
Combretum zeyheri 25	Combretum hereroense 25	
Lannea edulis 25	Lonchocarpus nelsii 25	
Erythrophleum africanum 25	Ochna cinnabarina 25	
Type 25		
Dicapetalum rhodesicum 87	Combretum collinum 84	Terminalia sericea 42
Bauhinia petersiana 69	Ochna pulchra 75	Baikiaea plurijuga 30
Grewia flavescens var. flav. 42	Baphia massaiensis 72	
Rhus tenuinervis 39	Terminalia sericea 57	
Combretum zeyheri 36	Dichrostachys cinerea 57	
Ximenia caffra 30	Acacia ataxacantha 57	
Commiphora angolensis 30	Combretum zeyheri 54	
Croton pseudopulchellus 30	Croton pseudopulchellus 54	
Combretum psidioides 30	Acacia fleckii 51	
Pterocarpus angolensis 30	Combretum psidioides 48	
Pseudolachnostylis maproun. 29	Lonchocarpus nelsii 42	
Dichrostachys cinerea 27	Grewia fleavescens var. flav. 33	
Acacia fleckii 27	Erythrophleum africanum 33	
Burkea africana 27	Pterocarpus angolensis 33	
Canthium huillense 25	Bauhinia petersiana 30	
	Ochna cinnabarina 27	
	Burkea africana 27	

Appendix 4 continued.

Presence of species in each height class in each type, where % presence > 20 to 25%.

Species height class		
<1m	1-3m	>3m
> 25 % presence	> 25 % presence	> 20 % presence
Type 26		
Dicapetalum rhodesicum 79	Combretum zeyheri 79	Burkea africana 75
Diplorhynchus condylocarpon 62	Baphia massaiensis 75	Terminalia sericea 45
Bauhinia petersiana 58	Combretum collinum 70	Erythrophleum africanum 29
Strychnos spinosa 50	Ochna pulchra 70	Baikiaea plurijuga 20
Guibortia coleosperma 50	Combretum psidioides 54	Guibortia coleosperma 20
Dichrostachys cinerea 45	Terminalia sericea 50	Pterocarpus angolensis 20
Croton psuedopulchellus 45	Vitex payos 50	
Ancylanthos bainesii 45	Pterocarpus angolensis 33	
Pterocarpus angolensis 41	Baikiaea plurijuga 29	
Strychnos pungens 41	Acacia ataxacantha 25	
Erythrophleum africanum 37	Bauhinia petersiana 25	
Vitex payos 33	Erythrophleum africanum 25	
Combretum psidioides 33		
Ximenia caffra 29		
Grewia flavescens var. flav. 29		
Rhus tenuinervis 29		
Pseudolachnostylis maproun. 29		
Annona stenophylla 29		
Lannea edulis 25		
Canthium huillense 25		
Type 27		
Diplorhynchus condylocarpon 68	Ochna pulchra 87	Baikiaea plurijuga 100
Strychnos spinosa 68	Terminalia sericea 68	Guibortia coleosperma 75
Vitex payos 62	Combretum zeyheri 62	Erythrophleum africanum 68
Pterocarpus angolensis 62	Pseudolachnostylis maproun. 56	Burkea africana 37
Ancylanthos bainesii 50	Dichrostachys cinerea 43	Terminalia sericea 31
Swartzia madagascariensis 50	Baphia massaiensis 37	
Croton pseudopulchellus 43	Combretum psidioides 37	
Dicapetalum rhodesicum 43	Burkea africana 37	
Strychnos pungens 43	Terminalia brachystemma 25	
Xylopia odorotissima 43	Acacia erioloba 25	
Ximenia caffra 37	Bauhinia petersiana 25	
Grewia flavescens var. flav. 37	Erythrophleum africanum 25	
Acacia erioloba 37		
Bauhinia peterisana 37		
Combretum zeyheri 37		
Grewia avelana 37		
Combretum psidioides 37		
Brakenridgea arenaria 37		
Dichrostachys cinerea 31		
Rhus tenuinervis 31		
Pseudolachnostylis maproun. 31		
Grewia monticola 25		
Baphia massaiensis 25		

Appendix 4 continued.

Presence of species in each height class in each type, where % presence > 20 to 25%.

Species height class		
<1m	1-3m	>3m
> 25 % presence	> 25 % presence	> 20 % presence
Type 28		
Dicapetalum rhodesicum 75	Baphia massaiensis 91	Baikiaea plurijuga 83
Dichrostachys cinerea 58	Combretum zeyheri 83	Guibortia coleosperma 58
Grewia avelana 58	Combretum collinum 75	Croton gratissimus 25
Bauhinia petersiana 50	Croton gratissimus 66	
Burkea africana 50	Ochna pulchra 66	
Grewia monticola 41	Terminalia sericea 58	
Vitex payos 41	Vangueria infausta 50	
Croton pseudopulchellus 41	Croton pseudopulchellus 50	
Commiphora mossambicensis 33	Combretum psidioides 50	
Commiphora angolensis 33	Bauhinia peterisana 41	
Grewia flavescens var. flav. 33	Acacia erioloba 33	
Erythrophleum africanum 33	Rhus tenuinervis 33	
Pavetta schumanniana 25	Vitex payos 33	
Vangueria infausta 25	Erythrophleum africanum 33	
Rhus tenuinervis 25	Acacia ataxacantha 25	
Combretum psidioides 25	Grewia flavescens var. flav. 25	
Pterocarpus angolensis 25	Canthium huillense 25	
	Pseudolachnostylis maproun. 25	
Type 29		
Catunaregam spinosa 70	Ochna pulchra 62	Baikiaea plurijuga 87
Diplorhynchus condylocarpon 70	Baphia massaiensis 58	Erythrophleum africanum 45
Grewia monticola 62	Combretum collinum 54	Combretum apiculatum 33
Dicapetalum rhodesicum 54	Bauhinia petersiana 50	Terminalia sericea 33
Commiphora mossambicensis 45	Terminalia sericea 50	Erythroxylum zambesiacum 29
Bauhinia petersiana 41	Commiphora mossambicensis 41	Burkea africana 25
Dalbergia melanoxylon 37	Croton gratissimus 41	
Pavetta schumanniana 37	Combretum zeyheri 41	
Lannea discolor 33	Vitex payos 41	
Rhus tenuinervis 33	Pterocarpus angolensis 37	
Combretum psidioides 33	Grewia monticola 33	
Pterocarpus angolensis 33	Peltophorum africanum 33	
Commiphora pyracanthoides 29	Vangueria infausta 33	
Vangueria infausta 29	Pseudolachnostylis maproun. 33	
Combretum zeyheri 29	Combretum psidioides 33	
Strychnos spinosa 25	Burkea africana 33	
Vitex payos 25	Kirkia acuminata 29	
Ochna pulchra 25	Pterocarpus rotundifolius 29	
Burkea africana 25	Combretum apiculatum 29	
	Rhus tenuinervis 29	
	Erythrophleum africanum 29	
	Cassia abbreviata 25	
	Diplorhynchus condylocarpon 25	

Appendix 4 continued.

Presence of species in each height class in each type, where % presence > 20 to 25%.

Species height class		
<1m	**1-3m**	**>3m**
> 25 % presence	**> 25 % presence**	**> 20 % presence**
Type 30		
Annona stenophylla 68	Ochna pulchra 63	Combretum imberbe 45
Diplorhynchus condylocarpon 59	Terminalia sericea 54	Combretum hereroense 40
Strychnos spinosa 50	Combretum psidioides 54	Terminalia sericea 36
Swartzia madagascariensis 50	Terminalia brachystemma 45	Terminalia brachystemma 27
Grewia monticola 40	Acacia erioloba 45	
Brakenridgea arenaria 40	Pseudolachnostylis maproun. 45	
Lonchocarpus capassa 31	Combretum zeyheri 40	
Hyphenae petersiana 27	Diplorhynchus condylocarpon 36	
Bauhinia peterisana 27	Burkea africana 36	
Lannea edulis 27	Euclea divinorum 31	
Ochna pulchra 27	Dichrostachys cinerea 31	
	Combretum apiculatum 27	

Appendix 5.

The classification of vegetation types into physiognomic classes. The numbers of each physiognomic class correspond with those used in the ARC/INFO item STRUCT which represents the physiognomy (as below) of each type.

1. Grassland.

2. Bushed grassland.

Type 18 *Acacia - Boscia albitrunca* - Mopane bushed grassland.
Type 19 *C. hereroense - Hyphaene* bushed grassland on calcrete.

3. Scrub.

Type 1 *Combretum - Boscia angustifolia* open scrub and thicket on Lower Karoo sandstones.

4. Bushland.

Type 13 Mopane - *Combretum* bushland on basalt.
Type 14 Mopane bushland on basalt.
Type 16 Mopane - *Acacia - Grewia bicolor* stunted woodland in the Dzivanini area.
Type 20 *Acacia - Mundulea sericea* bushland.
Type 21 *T. sericea - Lonchocarpus nelsii* bushland.
Type 22 Mopane - *C. apiculatum* bushland.
Type 24 *T. sericea - Acacia erioloba* bushland.
Type 25 *T. sericea - Baikiaea plurijuga* bushland.

5. Thicket.

Type 6 *Combretum - Baphia* thicket.
Type 9 Mopane - *Combretum elaeagnoides* thicket on Basement Complex.

6. Woodland.

Type 2 Mopane - *Acacia* woodland adjacent to riverine vegetation.
Type 3 Mopane - *Commiphora marlothii* mixed woodland on scree slopes.
Type 4 Castle kopje mixed woodland and thicket.
Type 7 Mopane - *Combretum* woodland.
Type 8 Mopane - *Terminalia prunioides* woodland.
Type 10 Riverine vegetation with *Diospyros mespiliformis* and *Combretum mossambicense.*
Type 15 Mopane - *Vepris zambesiaca* woodland on Madumabisa mudstones.

Type 27 *Baikiaea plurijuga - Guibourtia coleosperma* woodland.
Type 28 *Baikiaea plurijuga - Croton gratissimus* woodland.

7. Wooded bushland.

Type 5 Mopane - *Julbernardia - Combretum* wooded bushland.
Type 26 *Burkea africana - Pterocarpus angolensis* bushland and woodland.

8. Woodland - bushland - grassland mosaic.

Type 11 Mopane - *Acacia - Combretum* grassland to woodland in seasonally inundated areas.
Type 12 Mopane - *Combretum hereroense* bushed grassland to bushland on basalt.
Type 17 Mopane woodland - *Combretum* bushed grassland mosaic on ecotone Kalahari sands.
Type 30 *Burkea africana - Terminalia brachystemma* bushland.

9. Woodland thicket.

Type 23 *Baikiaea - Combretum* woodland thicket on fossil dune crests.
Type 29 Ecotone *Baikiaea - Commiphora mossambicensis* woodland and thicket.

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