VEGETATION OF WOODLAND CLEARINGS IN THE CHIRUNDU/CHIAWA AREA

of the

ZAMBEZI VALLEY, ZAMBIA

by

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A dissertation submitted to the University of Zambia in partial fulfilment of the requirements for the

Degree of Master of Science in Ecology

THE UNIVERSITY OF ZAMBIA

LUSAKA

1989

DECLARATION

It is hereby declared that this dissertation is my own work and that it has not been previously submitted for degree purposes at this or another university.

Signed........................ Date..................

SUMMARY

A vegetation survey was carried out within a 300 km^2 area around Gwabi on the Zambian side of the Middle Zambezi Valley, with emphasis on regenerating fields abandoned after clearing. Information was collected on the previous and present status of such fields. The Braun-Blanquet phytosociological method was used for describing the vegetation and other parameters of the study plots. Data was processed using computer routines for manipulating phytosociological tables and also multivariate analysis.

The floristic data is presented as an association table with communities arranged along a gradient from mesic to xeric moisture conditions. A provisional alliance, the **Combretion eleagnoidis**, was proposed to cover the woodland and thicket communities of the drier ground in the valley. * Four associations were named: the mopane woodland and scrub were diagnosed as: **Fockeo-Colophospermetum mopanis**. A community occurring in thickets with Pterocarpus lucens ssp. antunesii as an emergent was named as **Pterocarpo antunesii-Combretetum eleagnoidis**. In the more moist conditions a community of Acacia robusta ssp clavigera was named as the third association **Acacietum (robustae) clavigerae**, and the fourth occurring on the flood plain was named as the **Abutilo angulati-Acacietum tortilis**.

A number of numerical clustering techniques were applied to the data. WPGMA clustering on a matrix of Sørensens coefficients of similarity gave a classification which was very close to the communities recognised in the phytosociological table, with very few exceptions.

There were significant differences between means for potassium, phosphorus and calcium in the upper soil of the five communities examined (including the Eriochloa nubica grassland community not named because of few relevés sampled). Potassium and calcium were highest in the grassland community and lowest in the **Pterocarpo** community. Phosphorus was

highest in **Acacietum (robustae) clavigerae** community and lowest in the grassland community.

Thirty seven sites could be aged since last cultivation and ordered in increasing fallow period. No clear pattern emerged, but there was a general trend for weeds to fall in the early successional stage and woody species, especially shrubs to increase in the later stages.

ACKNOWLEDGMENTS

I am most indebted to Professor J. J. Moore. S. J. who so tirelessly supervised me to the end of this dissertation. His computer knowledge was invaluable in the treatment of the results. I have benefited from the criticisms and suggestions of Mr Katanekwa V. Katanekwa who always spared me time for discussion.

I also wish to express my gratitude to Mr A. Wardle of Gwabi for the hospitality. Miss Josephine Muwowo for the material support. Staff of the Department of Biology especially the technical wing and the River Basin Research Committee for the services rendered too numerous to mention. and all persons who assissted me in one way or another.

Unpublished results of a vegetation survey carried out by the RBRC in the Middle Zambezi Valley in 1988 were analysed by Prof. J. J. Moore and made available to me for comparative purposes, and they have been included in this dissertation.

Finally. I am grateful to my family for the patience endured during my absence from home.

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Chapter 1

INTRODUCTION

Background

The history of vegetation science has been characterised by the existence of many opposed schools of thought. The core of the argument has centered on two contradictory concepts or models of vegetation structure, the first one dwelling on classification of the vegetation into 'types' and the second looking on vegetation as exhibiting a continously variable pattern over time without any obvious so-called 'types'.

Up to about 1950 there was a definite emphasis on classification of vegetation types based on units which were classifiable. *This period which started with the work done by* Clements(1916 1928) portrayed vegetation as an organism which grew in structure and organisation with time. All the components cooperated in a complex relationship leading eventually to a climax vegetation type, under the influence of environmental conditions. Vegetation was thus viewed as a dynamic entity showing a progressive trend known as succession. This approach, later upheld in a less extreme way by Tansley(1939), stressed integration of community interactions within the vegetation.

Synthetic classification of plant communities recieved special impetus through the work of Braun-Blanquet(1928 1932). His system of 'phytosociology' found favourable acceptance throughout the world, and influenced the development of European vegetation science for decades. The hierarchy of systematic units worked almost exclusively on floristic criteria relating to character or differential species. The Braun-Blanquet approach recognised heterogeneity of species distributions and emphasised interactions between plants in the community.

Much of the work leading to this approach was centered at Zürich (Switzerland) and Montpellier (France), later on at

Stolzenau (West Germany) and, in a basically similar approach, in the Scandinavian countries (Du Rietz 1921). The key idea in the Braun-Blanquet system was that community classification was based on a fundamental unit, the association, which was defined by its possession of character-species (species of relative restriction to a given association: this was known as fidelity). An association consisted of units based on the description of samples of vegetation stands in the field (relevés: Aufnahmen). Classification of associations to higher levels was based mainly on floristic composition with relatively little emphasis on physiognomy. The hierarchical sequence used in this classification and the endings added was as follows: (the ending is added to the name-giving species of each category)

Rank	Ending
CLASS	-etea
ORDER	-etalia
ALLIANCE	-ion
ASSOCIATION	-etum
SUB-ASSOCIATION	-etosum

Opposition to this approach mainly came from the "Anglo-Saxon" vegetation scientists, mainly in UK and USA who emphasised classification of communities into types based on dominant species or dominant species groups (Whittaker 1962).

The diametrically opposed view in vegetation science was that vegetation was not made of classifiable units but formed a continuum and it was first explored independently by the early papers of Gleason(1926), LeNoble(1927) and Ramensky(1924) appearing at almost the same time. The authors differed strongly from Clements' monoclimax, organismal theories. The central concept in thier work was the species-environment complex which they focussed on as a determinant of the individual species distributions. They held that communities occurred along environmental gradients exhibiting gradual changes in species populations and interactions. These theories did not recieve much attention at that time except to be strongly opposed. In the early 1950's this continuum concept was taken up and developed notably by Whittaker(1951) and Curtis(1959) in the U.S.A.

The differences between schools in their approaches to vegetation science could well appear to have been nationalistic rather than scientific. Cultural differences contributed to the broad spectrum of terminologies which may, in fact, have differed little in their meanings. The period after 1965 saw an intergration of the two approaches (McIntosh 1967b, Whittaker 1967, Whittaker & Woodwell 1973, Gauch 1982). Most vegetation scientists began to realise that the best method of study largely depended on the problem, and they selected the appropriate techniques according to their stated objectives.

One consistent trend in vegetation science has been the progression towards increasingly quantitative methods (Whittaker 1962, Greig-Smith 1964, Daubenmire 1968, Moore et al 1970). This trend has been acccelerated by the increasing access to computers. A typical example is drawn from the study by Moore & O'Sullivan(1978) who were able to analyse a phytosociological table of 650 relevés and 260 species at one time on an IBM 360/50 computer, a task which would take a considerably long time if it were done manually.

In recent years the proliferation of numerical techniques has resulted in many an ecologist bieng faced with the problem of trying to choose the appropriate method for analysing his vegetation data (Gauch 1982), since there is a wide range of classification or ordination techniques and of similarity coefficients.

The present study aims at analysing a portion of .the vegetation of the Middle Zambezi Valley, Zambia using the Braun-Blanquet method supplemented by numerical techniques. The study concentrates on regenerating stands of vegetation and will try to propose a tentative successional trend in communities proposed. It forms part of an ongoing research project by the River Basin Research Committee (RBRC).

Definition of Terms

The following key words have been used in this paper:

Relevé: The list of species and of environmental factors recorded as a description of the stand.

Stand: The concrete area of vegetation in the field which has been described.

Community: An abstract unit of classification of any standing (alliance, association, nodum etc).

Succession: The orderly and directional process of community change.

Sere: An entire successional trajectory.

Regeneration: Community development on sites previously occupied by well developed communities.

Phytosociology: Study of all phenomena and effects regarding the "social life" of plants.

Vegetation Dynamics: Any change in plant communities, including seasonal, successional or post-glacial. Emphasis is on the process rather than the end point.

Source: Moore(1962), Odum(1975), Pickett & McDonnel(1989), Werger(1979).

Literature Review

The following outline is a review of some of the studies in which studies on the vegetation of Zambia have been described. Included are the broad descriptions covering the continent of Africa, regional studies in East Central and Southern Africa and finally studies within the Zambian territory, ultimately focussing on the Middle Zambezi Valley.

White(1983) has made a comprehensive review of the vegetation types of Africa. Sixteen structural types of vegetation have been described based on physiognomy and structure. These were described from 80 mapping units of the different vegetation types. The description is largely based on the one suggested at Yangambi for African vegetation types (Anon 1956). But due to the emphasis it places on West African types White modified the scheme to reflect the African situation as a whole and, in so doing, has omitted the term "savanna vegetation" as a structural category. The regional classification of East African vegetation (Greenway 1943 1973) recognises seven structural types which have also been included by White.

The vegetation map for the Flora Zambesiaca (Wild & Barbosa 1967) has outlined 74 mapping units which have been incorporated into seven structural types: closed forest, closed forest-woodland mosaic, thickets, woodland & savanna woodland, tree savanna, shrub savanna, and grassland. Werger(1978) had earlier reviewed work on the vegetation of the Zambezian Domain. This work placed emphasis on the phytosociological approach and outlined phytogeographical distribution of vegetation formations of all areas drained by the Zambezi River and its tributaries.

In Zambia, some of the early studies on the description of vegetation were done by Michelmore(1939), and Burt(1942). Michelmore concentrated his work on the grasslands of South Central and East Africa. He outlined the factors which led to the formation of open grasslands and portrayed them as climatic or physiographic in nature, and emphasised that these grasslands were not seral stages to savanna, bush or forest. Burt worked on some East African vegetation types and in part described the miombo vegetation of Northern Zambia. Studies which have attempted to relate vegetation to soils are Trapnell(1950 1953) and Trapnell & Clothier(1957). Their vegetation-soil survey was largely concerned with woody vegetation for which they mapped the different types. Analysis of the effect of fire on miombo woodlands based on experimental plots near Ndola were carried out by Trapnell (1959), and later on by Lawton(1964 1978). Lists of species were compiled for those affected by fire (fire tender species) and those which were not affected (fire tolerant species). Vesey-Fitzgerald(1963) carried out a survey of the grasslands of Central Africa (covering North of Zambia) for which a classification was suggested. A survey of the grassland and wooded grassland types of Western Province have been described by Verboom and Brunt(1970) with emphasis on exploiting these areas as fodder resources: the main vegetation types are cross referenced to Trapnell's(1950) soil-vegetation groups. The woodlands and grasslands of the Kafue flats were described in some detail by van Rensburg(1968) and a vegetation map produced. He identified 46 structural types, but a detailed vegetation description for the Lochinvar National Park, situated in the same area was later carried out by Douthwaite & van Lavieren(1977).

A major contributing source of literature on the description of the vegetation of Zambia is from the unpublished District Forestry Reports of Fanshawe (1961 1962 1963 1964 1969) for Senanga, Mongu, Sesheke, Kabompo, and Gwembe Districts. These reports contributed to form the basis to Fanshawe's (1969) treatise on the vegetation of Zambia. He describes the vegetation types under the headings: closed forest, open forest, woodland, termitaria, and grassland. Chidumayo (1987) has given an account of the different types of miombo woodlands in Zambia and their species structure.

Regeneration of vegetation in Zambia has been described by Strogaard (1986) with reference to miombo woodland. Three phases of regrowth were observed in this study and the turnover between different succession stages varied significantly. Chidumayo(1988) has described the development of fallow sample sites dominated by Acacia polyacantha, while Chidumayo(1989) has described some aspects of regeneration in plots of felled Marquesia woodland subjected to early and late burning. These and studies from other African countries tend to lay emphasis on regeneration of vegetation in abandoned fields which were previously cultivated. Boaler & Sciwale(1966) have outlined a probable course of changes in regenerating miombo woodlands of Western Tanzania. Effects of local cultivation practices on the vegetation have been described by Strang(1974). These were focussed on effects recorded several years after cutting the forest on the high veld in Zimbabwe (then Rhodesia). Campbell et al (1988) have described succession of a tropical evergreen forest in Mozambique. The study also showed that there was no evidence to support the facilitation model. Tietema(1989) has presented an assessment of mopane trees in a woodland at Dukwe, Botswana. This study has also outlined some management options for Colophospermum mopane.

The Middle Zambezi and Luangwa Valleys of Zambia form part of the rift valley system which stretches from North to South, parallel to the coast of Africa. Some of the richest wildlife santuaries in the world are situated within the Rift Valley (e.g. Luangwa National Park & International Game park in Zambia, the Serengeti National Park in Tanzania). Work in the valleys of Zambia has been concentrated in the Luangwa valley with emphasis on flora-fauna relationships. Astle(1969) has attempted a description of the land classification system so as to provide an ecological baseline for management planning for the Luangwa Valley. Studies on habitat destruction by elephants (Loxodonta africana) in the Luangwa have tied this aspect to the present status of vegetation. Caughley(1976) attributes destruction of vegetation to a stable limit cycle, which is determined by the population density of elephants. When the population density of elephants is high they destroy the vegetation to such an extent that the resources become critically scarce, after which a decline in their numbers follows. The cycle was estimated at two hundred years. Lewis(1986) on the other hand suggests that reduction of woodland habitats in South Luangwa is caused by elephants when they are compressed to limited range patterns arising from human disturbances.

Much of the work in the Middle Zambezi Valley has been concentrated on the Zimbabwean side of the international boundary. The vegetation of the area lying between Kariba and Mpata gorges, extending southwards to the escarpment was mapped by Guy (1977). Altogether seventeen vegetation types were recognised. However most of the smaller units of vegetation were fused into groups and referred to collectively by single names. Further studies were done on this area when a threat of inundation by a hydroelectric scheme was imminent. The results have been compiled into a report covering many aspects of the ecology of the valley (Du Toit 1982). Areas likely to be affected by the proposed Mpata and Batoka gorge dams along the Zambezi River were mapped and the possible impacts on biotic as well as abiotic factors outlined. A report on the vegetational studies is outlined by Muller & Pope(1982) from which 10 structural types were described based on 12 mapping units.

Apart from the broad vegetation descriptions covering large areas (Barbosa & Wild 1967, Werger 1978, White 1983), the Zambian side of the Middle Zambezi Valley has not experienced any detailed research. Most large-scale vegetation descriptions were based on aerial photography interpretations supplemented by a few ground studies. In keeping with the trend of events in the area work started recently (Howard et al 1987) by RBRC. So far a preliminary report has been compiled in which a list of species has been included.

Objectives and Rationale

The main aim of this study was to carry out a survey of the different vegetation types in the study area. Emphasis was placed on regenerating fields from which data on aspects of their past history of utilization and present status were collected. It was hoped to provide data to support and guide management policies in the study area which is at present undergoing extensive agricultural development. The study would also provide a baseline for future research undertaken in view of the anticipated changes.

Organisation of Work

An outline of the study area is given in chapter two. This chapter highlights the environmental setting of Gwabi camp site and its surrounding communities and includes a map showing the various infrastructures as well as the sampling sites. Farming systems (traditional and commercial) are also described. Chapter three focusses on three main aspects of research methods: field methods of data collection, laboratory methods dealing with soil extraction and nutrient analyses, and the various procedures followed in the analysis of data. The results of the study are given in chapter four. they are discussed in five sections: vegetation types, phytosociological units, numerical classificatin, ordering of relevés according to age (or fallow period) and soil nutrient analysis. Association tables for Gwabi area and woodland communities of the Middle Zambezi Valley are attached at the back cover. The last chapter (five) is the discussion. A list of appendices and references are also presented at the end.

Chapter 2

STUDY AREA

General Description

The River Basin Research Committee has outlined their study area (MZV) as that lying between 28x 50' to 30x 20' East and 15x 20' to 16x 30' South. It includes the whole area occurring below the 500m contour (see Howrad et al 1987) which lies at the base of the Escarpment. This contour forms the northern boundary from the Luangwa River in the east to Kariba Gorge Dam in the west. The southern boundary follows the international boundary with Zimbabwe from Lake Kariba to Luangwa town and river. This definition of the MZV was also adopted in the present study.

The present study area is that lying within a 10 Km radius around Gwabi camp on the Kafue River (fig 1). The Kafue River forms the boundary between two chiefdoms and two administrative areas (Lusaka and Southern Provinces). To the east is Chief Chiawa and Chief Sikongo is to the West of the river. Gobas are the main ethnic group in the Chiawa area but westwards they blend with the Tonga of Southern Province.

The general land surface slopes towards the Kafue and Zambezi Rivers. Hilly ground is noticeable particularly to the west and northwest of Gwabi. Ephemeral streams are common and they meander through Karoo sedimentary rocks which form the main geological strata in this area. The ground south of Gwabi is generally flat and terminates in a grassland towards the confluence of the Kafue with the Zambezi River. The soils here are clayey and poorly drained. Numerous cracks are noticeable over most of the grassland during the dry season. Most low lying parts of the grassland are usually flooded during the rain season. This probably accounts for the rarity of trees in this area. Termite mounds are common in the grassland though they are also present in woodland and thicket.

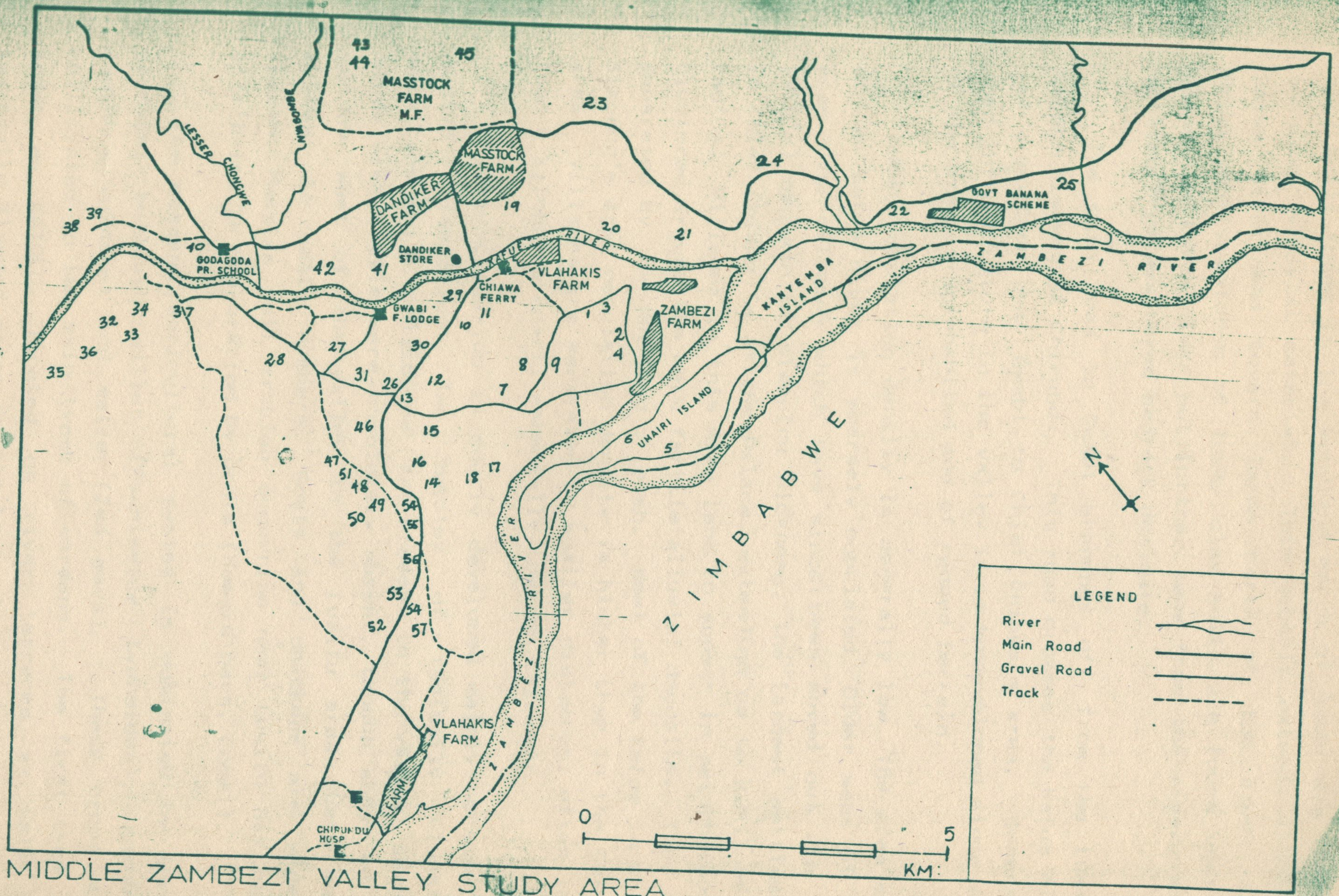


Fig. 1. MIDDLE ZAMBEZI VALLEY STUDY AREA

Soils found in the woodland north of Gwabi are composed of sandy alluvial material. This deposit extends along the Kafue River and covers large parts of the study area. Occasionally patches of loamy clay soils are found upstream along the Kafue River but further away from the river. soils derived from weathered bedrock dominate.

*The main road to Gwabi branches off from the Lusaka-*Harare highway at Chirundu. This road crosses the Kafue River via a pontoon near Gwabi to Chief Chiawa's area. Generally road infrastructure in the valley is underdeveloped since much of the area is uninhabited and of rugged terrain.

Human population density is generally low. The area east of the Kafue River is sparsely populated. Older maps of the area show villages which have since been moved out (in the 1930's) becuase of sleeping sickness. The largest settlement in Chief Chiawa is at the Palace. extending up to a kilometre radius. Villages in this area tend to appear in neighborhoods clustered around the more fertile alluvial deposits. They are separated by garden land or bush. West of the Kafue in Chief Sikongo's area population density is higher than in the Chiawa area. Villages are separated by smaller distances. often less than a kilometre apart. especially towards Chirundu.

Livestock rearing is poorly developed mainly because of tsetse infestation. Two species of tsetsefly Glossina morsitans and G. pallidipes are present in the valley. In our study area cattle were completely absent. though about 40 Km to the West of the valley in the Lusitu area these were present in small numbers. Goats and chickens are widely reared. Massive soil erosion occurring near Lusitu has been attributed to overgrazing by goats (Howard pers. comm.).

The peasant agricultural system is dominated by three cereals: bullrush millet (Pennisetum typhoides). sorghum (Sorghum vulgare) and maize (Zea mays). These crops are cultiivated in two main types of gardens. The first type is known as MATOLO. located on river terraces as well as seasonally flooded areas on the bank of the river. Maize is the common cereal in these gardens, but there are cases of sorghum and millet being grown here also. The second type is known as MINDA. These are inland gardens, sometimes several kilometres away from the Zambezi or Kafue Rivers. Sorghum is the main crop in these gardens and cotton to a lesser extent. The short rainy season and high temperatures have an influence on the choice of crops grown in these gardens. Similar garden types were reported among the Gwembe Tonga (Scudder 1962 1971). These included permanently cultivated gardens along the bank of the Zambezi River (JELELE) used primarily during the dry season and the floodplain garden (KUTI) which supported both dry and rainy season cultivation. The UNDA garden was located on rarely inundated riverine alluvia and on adjacent colluvial soils or Karroo sediments. These were periodically fallowed depending on soil fertility. The last type was the TEMWA gardens located on Karroo sediments several kilometres inland from the Zambezi and its major tributaries.

Cotton is grown by peasant farmers in the Gwabi area mostly for sell. Few are involved in this undertaking due to the high input costs involved, as well as the climatic risks. The other cash crop is banana. The plantation at Zambezi Training Farm is largely owned by peasant farmers who are allocated plots under the supervison of Italian volunteer workers. The location of this farm on the Zambezi River facilitates irrigation, so that it depends less on rain. Chiawa Banana Plantation is about 5km east of the Kafue along the Zambezi River. This plantation was implemented a year before the Zambezi Training Farm in 1969. This is also a commercial undertaking administered by the Department of Agriculture. The original plan was to resettle farmers from Zambezi Training Farm on this project after completing their course. But this never took place. The most recent commercial agriculture project is the cotton and wheat field at Masstock (Chiawa) Farm commissioned in May 1989. The field is irrigated with Kafue water pumped from the bank about 3km to the north east. This project will cover thousands of hectares on cleared woodland towards and beyond Chiawa's Palace.

The success of rainfed agriculture in the Middle Zambezi Valley is very dependent on climatic conditions. The number of rainy days averages at 40 out of 90 during the wet season. This aspect has led to the introduction of a short season sorghum variety (Siyunyi pers. comm.), although the new crop has not been very popular with the local people. It was noted also that weaver birds harvested a large proportion of sorghum. The Indian farmer (Dandiker) near the pontoon on the Kafue river has grown this variety successfully together with sunflower.

Study Sites

The location of study sites followed the pattern of occurence of regenerating fields in the study area. Although sampling was principally carried out in regenerating fields, some old vegetation communities were described as well. Prelocation of sites was achieved with the help of air photographs (1982, 1:30,000) supplemented by a ground survey. In remote, unoccupied parts of the study area, evidence of regeneration was sought from comparison with the adjacent stands of vegetation. Tree stumps, old cereal stalks attached to the ground, pottery, and patches of cleared vegetation were good indicators of regenerating fields. These included areas previously felled for reasons ranging from cultivation, construction work, settlements, woodfuel, to natural causes, such as effects of rain, wind,etc. Most study sites were located on inland gardens (MINDA) either left fallow or abandoned due to infertility, or because of excessive distance from home.

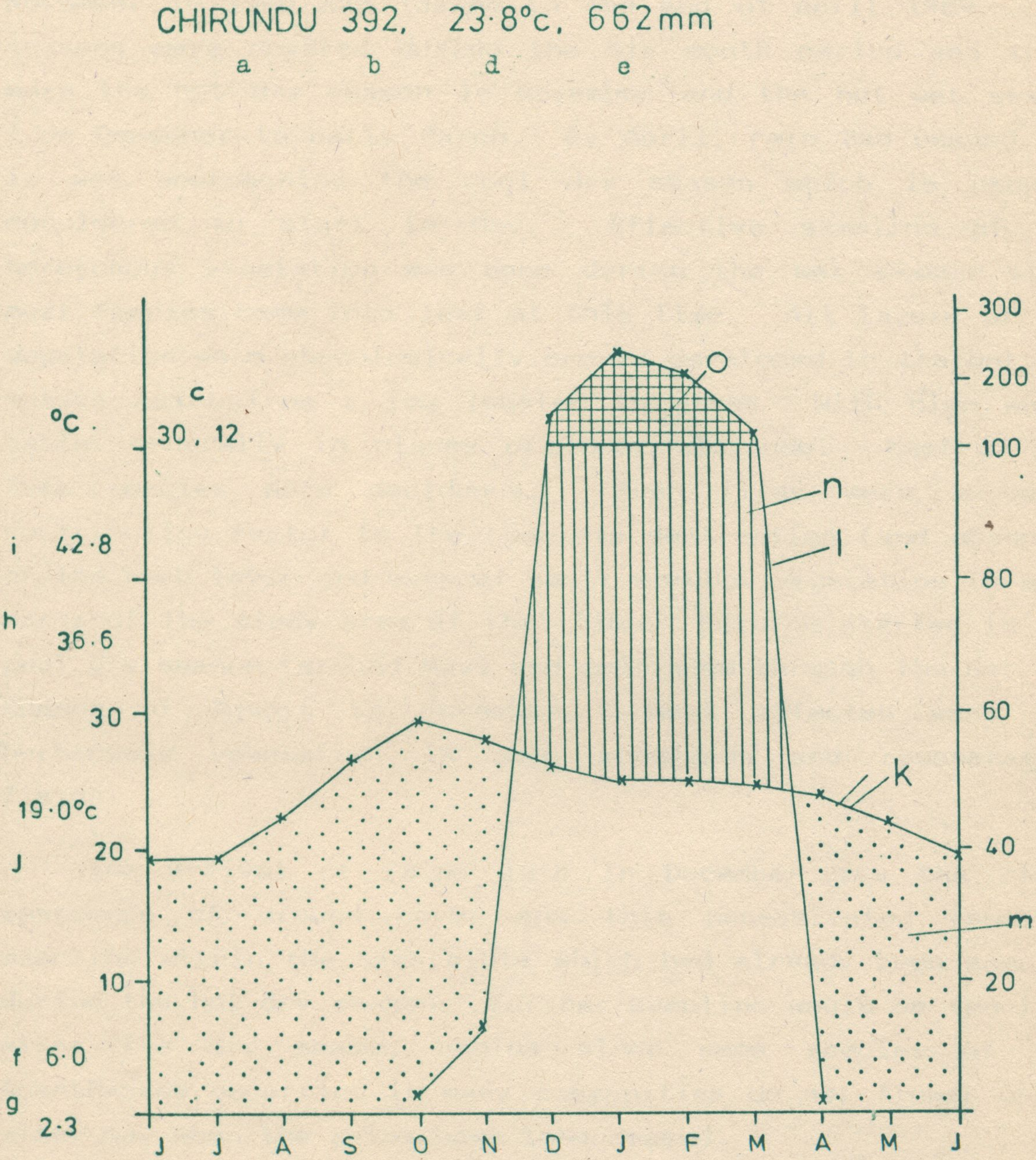
Lower river terrace gardens (Matolo) are often heavily utilised for cultivation and hence were not suitable for long term data accumulation over a 6 month period, because for almost half a year the fields were under cultivation. Replication of sampling in these fields was not possible.

Climate

Three main seasons have been identified in the valley: the hot wet season between the months of December and April, the cool dry season between May and July, and the hot dry season between August and November. Minimum and maximum temperatures range from 6°C in the coldest month to 39°C in the hottest month. This variation in temperature is also exhibited in a high range of daily temperature of about 19°C. Due to the low altitude (about 380 m.a.s.l.), the Middle Zambezi Valley is generally hotter and drier than most parts of Zambia. Temperatures above 40°C are common in the hot season. During the study period the highest temperature recorded was 42°C at midday in the shade on 5/11/88 (Relative humidity was 20%).

The humid period stretches from December to late February or early April in some years. Out of the 90 days of the wet season the valley experiences an average of 40 rainy days with annual totals generally less than 700mm but usually higher than 400mm. Relative humidity usually reaches well above 96% in January and February.

Fig: 4 CLIMATIC DIAGRAM FOR MIDDLE ZAMBEZI VALLEY



a. Station	i. Absolute maximum
b. Altitude	j. Mean daily range of temp.
c. No. of years of observation 1st Temp. 2nd Rainfall	k. Monthly mean temp.
d. Mean annual Temp.	l. Monthly mean rainfall
e. Mean annual rainfall (mm)	m. Arid period
f. Mean daily minimum coldest month	n. Humid period
g. Absolute minimum	o. Per humid period mean rainfall
h. Mean daily maximum hottest month.	

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Chapter 3

RESEARCH METHODS

Field and Laboratory Methods

Field work on this project started during the month of November in 1988 and lasted to the end of April 1989. Two seasons were covered during the six month period and these were the hot dry season in November and the hot wet season from December to early March. By April, rain had ceased and it was approaching the cool dry season which is usually considered to start in May. Effective sampling of the herbaceous vegetation was done during the wet season since most species came into leaf at this time. All layers of the vegetation were phenologically poorly developed in the hot dry season apart from a few located in areas with high water table, generally in places of lower altitude. Most of the tree species were deciduous. Bush fires were a major contributing factor to the complete destruction (and absence) of the herb layer and even of small shrubby vegetation in most parts of the study area at that time. Burning started in the cool dry season (around May) and continued through the hot dry season of August to November. Most affected were the herbaceous vegetation in open woodlands and regenerating fields.

The arrival of rains late in December saw the rapid emergence of ground cover and this necessitated repeated sampling within the same plots which had already been sampled during the hot dry season. Further sampling would be required after the dry season begins since some species of the Acanthaceae occurring in many communities do not flower until after May when the rains have long ceased.

An initial survey of the study area in early October and part of November facilitated the identification of sampling sites as well as field testing of the record card. Subsequent modifications resulted in a final and more detailed version of the card (fig 3).

MIDDLE ZAMBESI RESEARCH PROGRAMME

Area of Plot: Slope: No.
Map Grid: Aspect: Worker: Date:

Topography:

Microtopography:

Layers:

	Height m	Cover %	Phenology
1:			
2:			
3:			
4:			
Lianes:			

Soil:

	Depth	Colour	Texture	Structure
Surface				
Deeper:				

History of Regenerating Field:

Location	Last Cultiv/Cleared	Age of Plot	Purpose

Litter: Grazing: Dung: Footprints: Wood-cutting: Burning:

3	Acacia albida	88	Combretum imberbe	164	Grewia flavescens
4	Acacia ataxacantha	89	Combretum kirkii	174	Hippocratea indica
13	Acacia robusta clavigera	92	Combretum mossambicensis	176	Holmskioldia tettensis
16	Acacia tortilis	93	Combretum obovatum	185	Kirkia acuminata
26	Albizia anthelmintica	104	Commiphora edulis	166	Lannea schweinfurthii
36	Asparagus sp.	111	Commiphora pyracanthoides	189	Lonchcarpus capassa
47	Bauhinia tomentosa	116	Courbonia glauca	191	Lonchocarpus bussei
50	Boscia angustifolia	117	Crossopteryx febrifuga	204	Meistemon tetrandrus
51	Boscia matabelensis	120	Croton menyhartii	210	Olax dissitiflora
52	Boscia mossambicensis	124	Dalbergia martinii	228	Pteleopsis myrtifolia
55	Canthium frangula	125	Dalbergia melanoxylon	230	Pterocarpus antunesii
58	Capparis tomentosa	126	Dalbergiella nyasae	241	Securinega virosa
61	Cassia singueana	128	Dichrostachys cinerea	253	Stro[illegible]anthus kombe
62	Cassine schlechterana	129	Diospyros kirkii	324	Strychnos 3/88 #840
66	Cissus quadrangularis	132	Diospyros quiloensis	262	Tamarindus indica
77	Colophspermum mopane	140	Drypetes mossambicensis	268	Terminalia prunioides
79	Combretum apiculatum	158	Fockea multiflora	281	Vangueria infausta
80	Combretum celastroides	159	Friesodielsia obovata	81	Xanthocercis zambesiaca
83	Combretum eleagnoides	160	Garc[illegible]ia livingstonia	288	Ximenia americana

Fig. 3. Record card for field data collection. Sample species are shown together with their computer code numbers.

The choice of sampling sites depended on the availability of regenerating fields, distance from Gwabi camping site and the accessibility of these fields. Most cultivated fields were located near settlements or only a few kilometres away.

Historical data on regeneration were sought through interviews with the local people, and included estimates of fallow periods and land use patterns. Plots with fallow periods, mainly in the range of one to five years, were sampled. In remote parts of the study area few plots were sampled due to poor road infrastructure, while in some areas, such as to the east of the Kafue River, thickets of vegetation rendered them inaccessible.

The procedure for sampling relevės followed the Braun-Blanquet phytosociological approach for field methods. Application of this method has been reviewed by Poore(1955), Ellenberg(1956), Moore(1962), Shimwell(1971), Whittaker(1973), MÜller-Dombois & Ellenberg(1974), and Westhoff & van der Maarel(1978). An effort was made to sample relevės 20X20 metres with homogeneous plant cover and uniform habitats. The habitat factors described included: slope, aspect, topography, microtopography and a general overview of artificial ground marks. Layering and phenology of the vegetation was then described followed by a compilation of a species list including cover/abundance estimates for individual species (see Table 1). These estimates were based on the Braun-Blanquet scale (MÜller-Dombois & Ellenberg 1974) with one modification to include important species of plants growing close to the relevės but not recorded inside.

Table 1 : Braun-Blanquet Scale

5	Cover more than 75%
4	Cover between 50-75%
3	Cover between 25-50%
2	Cover between 5-25%
1	Cover up to 5%
+	Solitary or rare species with small cover
[+]	Species recorded outside but close to the relevė

Soil samples were extracted from the top 15cm of the soil. Three extracts were randomly selected in each relevé mixed and stored for analytical treatment. The depth range for soil samples was determined by the soil auger. Due to limited time spent in the field a complete soil profile could not be obtained for each relevé. Soil colour was determined on a Munsell Soil Colour Chart.

Most common weeds were identified in the field with the help of Vernon's(1983) excellent 'Field giude to important arable weeds of Zambia'. Doubtful specimens were collected and pressed for checking with the herbarium collection and more extensive taxonomic literature, namely Flora Zambesiaca, Flora of Tropical East Africa and other individual texts such as Hood(1967), Napper(1965), Chippindall(1955), Jackson & Wiëhe(1958). White's(1962) 'Forest Flora of Northern Rhodesia' was a very handy taxonomic text for woody vegetation both in the fied and laboratory. A total of 181 species was recorded from 57 relevės. The field records are filed at the Department of Biology, UNZA.

Soil analysis techniques as described by Chapman(1976) were employed, with minor alterations. The following chemical parameters were tested for in the soil extracts: pH, phosphorous, potassium and calcium.

A suspension in water was used when determining pH. 20ml water was added to 10g soil, shaken and allowed to settle. After 20 minutes the pH of the supernatant liquid was read on a Chemitrix (Type 60A) pH Meter. The meter was standardised with standard buffer solutions as outlined by West & Astle (1982), (pH 4.008, 6.85, 9.180). The temperature compensator was set at 22xC.

Ammonium acetate (1M, pH 7 (α0.1)) was used as extractant for the nutrients. 5g air-dried soil were added to 120ml ammonium acetate extractant in 250ml flasks. The flasks with their lids tightly closed were clamped on a Griffin Flask Shaker. The shaker had capacity for four flasks during each shaking session. Samples were shaken for one hour at a speed of 170 strokes per minute, after which the extracts were immediately filtered on number 44 Whatman Filter Paper.

A four figure precision balance was used when weighing chemicals for preparing standard solutions. Calibration curves were constructed from a range of secondary standard solutions diluted from primary standards.

Phosphorus determination was based on the molybdenum blue method, a reaction which estimates orthophosphate. This was read on a colorimeter (Bausch & Lombe Spectronic 20). Potassium and calcium were determined on a Flame Photometer (EEL Model 230) fitted with separate filters for the two cations. Both colorimetric and flame photometer measurements were made in duplicate, and recalibrated at intervals. Recalibration of the flame photometer was repeated at close intervals due to drift taking place after a short time of running the instrument.

The standard solutions used in the analysis are give in the appendix

Vegetation Analysis

Plant species recorded in the relevés were entered in a table, indicating their weighting in each relevé. This was done with the aid of a computer program in APL language (written by J.J. Moore). Relevés were entered in groups based on the area where sampling was carried out. Each sampling area was assigned a numeric code and a relevé number: these together with the code number of each species were entered in a storage file. The data set was assembled into a raw table (or data matrix). This raw table served as the basis of all subsequent manipulations for establishing plant communities using the Bruan-Blanquet table method. Technical aspects of differentiating the raw table through the use of differential species have been reviewed by Shimwell(1971), Moore(1962) and KÜchler(1967).

The computer aided Braun-Blanquet table work was run on an IBM-PC micro-computer. The main feature of this program was to allow easy rearranging of rows and columns of the matrix, either according to the wishes of the user, or using some objective criterion (e.g. arranging species in descending order of presence in the table).

Numerical Techniques

A numerical classification of communities was carried out. It was polythetic and agglmoerative. The data matrix was analysed by means of a computer program in APL for agglomerative classification (by J.J. Moore). Two inter-stand similarity coefficients were employed:

A. *Sørensens* similarity coefficient for presence/absence data between relevés. The index is:

$$\frac{2a}{2a+b+c}$$

where, a = number of species common to the two relevés concerned.

b = number of species in the first relevé only.

c = number of species in the second relevé only.

B. Euclidean distance is a dissimilarity coefficient between pairs of relevés (represented as data points in s-space), using quantitative weightings. It is defined as:

$$\sqrt{\sum(X_{ij}-Y_{ik})^2}$$

where X_i and Y_i are quantities of the i^{th} species in relevés j and k. The Braun-Blanquet symbols were transformed as follows (Moore et al 1970):

Braun-Blanquet:	[+]	+	1	2	3	4	5
Transformation:	0.5	0.2	1.0	4.0	6.0	8.5	10.5

This ensured that the weightings were more proportional to the cover value of the species.

Clustering. The inter-stand similarity coefficients were subjected to a number of clustering techniques (Sneath & Sokal 1963). The results of these calculations were plotted by computer as dendrograms showing the different clusters of relevés.

Chapter 4

RESULTS

Vegetation: General Description

The woody vegetation of the Middle Zambezi Valley is composed largely of dry deciduous types involving open woodlands and wooded grasslands but also some woodlands and thickets of varying densities. The vegetation types recorded on the Zimbabwean side of the valley by Muller & Pope(1982) were found to be reflected faithfully on the Zambian side, and can be recognised in parts of the present study area.

The main vegetation types recognised in the Gwabi region may be characterised in general as follows, following Muller & Pope's types:

1. **Mixed species layered dry forest ("Jesse bush"):** This is a tree/shrub vegetation with a thicket-like understory, found on deep sands around Gwabi camp to the west and east of the Kafue River and distributed widely in patches. Tree species common to jesse bush are Pterocarpus lucens ssp. antunesii (occurring as an emergent tree in most cases), Xerroderis stuhlmanii, Kirkia acuminata, Commiphora karibensis, Xylia torreana, Schrebera trichoclada, Pteleopsis myrtifolia, P. anisoptera, and Lonchocarpus bussei. Thicket forming species mainly include Combretum eleagnoides, C. celastroides, Dalbergia martinii, Friesodielsia obovata and Acacia ataxacantha. Combretum mossambicensis, Meiostemon tetrandus and Holmskioldia tettensis are shrub species which are common and sometimes dominant in certain types of jesse bush. The grass cover is poorly developed and rather sparse but in open areas Digitaria setivalva, D. milanjiana and Brachiaria brizantha are present together with less common herbaceous species. In most areas mature trees are absent and recent disturbance has led to the resurgence of derived thicket types sometimes dominated by Dichrostachys cinerea, Acacia tortilis, Albizia anthelmintica and Combretum eleagnoides.

2. Colophospermum mopane **woodland:** This is the most extensive single vegetation type within the present study area. The canopy species in this woodland is usually Colophospermum mopane. The structural composition varies from well-developed stands with a sparse shrub layer to a mixed species woodland with Colophospermum mopane occassionally appearing co-dominantly. Gradual changes from mopane woodland to the adjacent vegetation types are noticeable.

In well-grown mopane stands of our study area other trees which may be present incude Terminalia prunioides, Commiphora pyracanthoides, C. edulis, Olax dissitiflora and Combretum eleagnoides, while shrubs are Boscia mossambicensis, B. matabelensis, Maerua prittwitzii, Friesodielsia obovata and Grewia flavescens ssp. flavescens. Transitional types of mopane may be associated with the species Kirkia acuminata and Terminalia sericea adjacent to jesse vegetation. Close to the grassland on the edge of the Kafue alluvial system scrub mopane is present. It forms relatively dense patches of "trees" of mopane not more than two metres high.

Selective cutting of this woodland has created gaps which *form suitable habitats for understory growth. Common* herbaceous cover is characterised by the grasses, Pyrenacantha kaurabassana, a woody creeper and Fockea multiflora, a strangler reaching to the top of tall mopane trees, are species very closely associated with mopane woodland.

3. **Acacia woodland:** Much of the Acacia tortilis woodland in the present study area occurs on deep soils and in parts of the alluvial deposits. The tree layer is widely to closely spaced out with occassional appearances of Acacia nigrescens and Lonchocarpus capassa. The grass cover is poorly developed but dense patches are present where canopies are not closed. In the understorey Combretum spp. especially Combretum eleagnoides and C. mossambicense may be present together with clumps of Dichrostachys cinerea.

The Acacia robusta woodland consists of two main variants. The first type is characterised by clumps of trees in incipient pans with a dense shrub layer: Grewia flavescens ssp. flavescens. Olax dissitiflora and Acacia ataxacantha may be present. The second type is a stretch of woodland comprising spaced-out trees. sometimes occurring with Euphorbia ingens. Olax dissitiflora. Boscia matabelensis and Albizia anthelmintica. Grass cover is poorly developed due to prolonged waterlogging during the wet season.

4. **Grassland:** These are fairly extensive areas. devoid of woody vegetation (except for a few scattered ones). found near to the confluence of the Kafue with the Zambezi River. Digitaria setivalva. D. milajiana and a Kyllinga sp. are present in this area. The grassland is located on clays which form cracks after the wet season. In certain places the grassland is dominated by species of the family Acanthaceae which seem to form localised patches on heavy clays.

Depressions which appear to have an impervious substratum remain flooded for most part of the wet season and only dry out early in the dry season. These places support a different set of species. some of which are Nymhpaea sp.. Scirpus sp. and Echinocloa spp.

5. **Riparian vegetation:** This vegetation consists of well-grown trees often with an almost continuous canopy in places where it is not much disturbed. Typical of this vegetation type are the tall Acacia albida woodlands fringing the Zambezi River near the Chongwe and Munyemeshi confluences. Pure stands of Acacia albida were not recorded in our study area but isolated regenerating trees were recorded. Presumably this woodland existed at one time and has since been cut down. The tree is highly favored by the villagers for constructing canoes.

Riparian vegetation is found mainly on recently deposited alluvial soils close to the river. Trees that are found in the alluvial deposits include Kigelia africana. Lonchocarpus capassa. Trichilia emetica. Tamarindus indica. Garcinia livingstonei and Grewia flavescens ssp. olukondae. The herb layer consists mainly of annual grass species such as Panicum maximum, Rottboellia exaltata, Echinocloa colonum, and Setaria sphacelata.

Phytosociological Units

Relevės sampled from different parts of the study area are placed in groups which show close similarity in species composition and are thus considered to form a community. Each community is characterised by a set of species which seem to be fairly closely restricted to it (differential species), while some of its species seem to occur frequently in all the communities.

The final rearrangement of relevės into communities is shown in Table 2. Four main vegetation units were arrived at after careful manipulation of the raw table; they are arranged on a trend from communities on the flood plain to those above the river terrace.

The following is a floristic description of the communities. Each community will be given a tentative name and rank within the Braun-Blanquet system (Barkman et al 1976). Since this is the first attempt to apply the system to the vegetation of Zambia, the names should be taken as very tentative at this stage.

1. Abutilon-Acacia community

This community occurs within and on the periphery of the flood plain but more on the alluvial deposits and extends as far as the terrace.

The dominant tree species in this community is Acacia tortilis and the scrambler Combretum obovatum is very common. Other species common in this community are Albizia anthelmintica, Dichrostachys cinerea, Solanum spp. and

Asparagus sp. while grasses. Brachiaria serrata. Panicum maximum and forbs are present.

The Abutilon-Acacia community can tentatively be subdivided into two sub-groups:

I. Relevé 5. 6. and 20 characterised by seven differential species. Taccazea apiculata. Boerhavia diffusa. Amaranthus spinosa. Acacia albida. Piliostigma thorningii. Ziziphus mauritiana and Sorghastrum bipennatum.

This community was common on low lying alluvial deposits. especially on Umairi island (in the Zambezi River)

II. Relevés between no. 36 and 40 are characterised by five differential species: Courbonia glauca. Capparis sepiaria. Maerua juncea. Diospyros quiloensis and Balanites aegyptica. This community occurs on drier soil sometimes on the first terrace above the narrow flood plain fringing the Kafue River.

(Relevé 1 has no differential species)

This community is provisionally considered to be an association namely **Abutilo angulati-Acacietum tortilis**. and relevé 20 is cited as the typical relevé.

2. Acacia robusta community:

The community dominated by Acacia robusta ssp. clavigera occurs at the edge of the flood plain away from the river. as well as over the first river terrace but here it is characterised by its occurring in moist depressions and areas of poor drainage which remain flooded for most of the wet season.

No subdivision of this community is reasonable since only four relevés are recorded from it. Relevés between 38 and 39 consist mainly of shruby species belonging to the Capparaceae. These are Courbonia glauca. Capparis sepiaria and Maerua juncea and these serve to relate it with the previously described community. Common species include Acacia ataxacantha, Combretum obovatum and sometimes Strophanthus kombe. The stretch of Acacia robusta ssp. clavigera running parallel to the east bank of the Kafue has many termite mounds on which Euphorbia ingens grows well (relevés 39 & 41).

This community is provisionally designated as an association: **Acacietum (robustae) clavigerae**, and relevé 39 is cited as the typical relevé.

3. **Eriochloa nubica community:**

This is a grassland community characterised by the Eriochloa nubica grass. Although Sesbania sesban is not a grass, it was placed in this group owing to its relevance in delineating this community. The grassland occupies a large portion of the elevated terrace around Zambezi Training Farm lying at about 10m above the present river level. It appears to have been at one time a flood plain of the Kafue and Zambezi Rivers. The clayey soils are very hard in the dry season and when rain sets in, they become flooded and remain in that state for a long time after the rains. It is probably an edaphically determined grassland, and not due to human influence. However, there are at present isolated patches of cultivation though they are not very suitable due to the problems outlined above.

Several of the weedy differential species associated with the Colophospermum mopane community are present in relevés 1, 3, and 4 i.e. Chloris virgata, Phyllanthus leucanthus, Oldenlandia herbacea and Commelina benghalensis, and the grasses: Eragrostis viscosa and Echinocloa colonum.

The following grass and herb species occur fairly frequently in this community: Digitaria setivalva, Eragrostis aspera, Brachiaria spp., Setaria sp., Corchorus olitorius, Ipomoea dichroa, Tridax procumbens, an unidentified species of the Acanthacaeae, and the sedges: Kyllinga and Cyperus spp.

The community will not be given a syntaxonomic name due to the limited samples collected.

A number of transitional relevés are placed at this point in the table. Relevés 2 & 25 are grassland samples not fitting well into any of the units. Relevé 25 was from the edge of a flood plain near Chiawa, and Relevé 2 was in a previously cultivated field in the grassland close to Zambezi Training Farm. They both show absence of character species of the Eriochloa nubica community, probably due to cultivation. Relevés 7 & 42 are transitional between this community and the Abutilon-Acacia community of the first few relevés in the table).

4. Wooded community of Combretum eleagnoides:

This community (relevés between 37 and 52) is considered to include all the woodland and thicket not dominated by Acacia species. The woody species are mainly shrubs, Combretum eleagnoides, C. celastroides, Friesodielsia obovata, Holmskioldia tettensis, Dalbergia melanoxylon, all typical of jesse bush. Non woody species occurring mainly are Bidens schimperi, Spermacoce senensis and Triumfetta annua.

Since this combination of thicket species occurs in several types of vegetation, it is provisionally considered to characterise an alliance: **Combretion eleagnoidis**, and the typical relevé is cited as no. 46

4a. Colophospermum mopane community:

This community is usually represented on higher ground occasionally associated with irregular terrain. The soils are shallow and moisture hardly seeps into the ground. As a result, numerous seasonal water channels cut through this community providing very good drainage in some places.

Relevės between 9 and 37 are taken from mopane woodland (or derived communities) and are characterised by woody species such as Colophospermum mopane, Commiphora pyracanthoides, C. edulis, Kirkia acuminata, Terminalia prunioides, Pteleopsis anisoptera, Fockea multiflora and by an unidentified non-woody species of the Zingiberaceae.

Other woody species commonly occurring in this community are mainly shrubs and these are: Grewia flavescens ssp. olukonde, G. bicolor, Combretum mossambicense, Dichrostachys cinerea and the climber Asparagus sp. The herbaceous vegetation includes Amorphophalus abyssinicus, Digitaria setivalva, Brachiaria serrata, Dactyloctenium aegyptica and Fimbristylis sp.

An associated group of herbs (mainly weeds associated with recent cultivation) is present in relevės between 22 and 37. These are Oldenlandia herbacea, Corchorus olitorius, Hibiscus sp. and the grasses: Chloris virgata, Eragrostis viscosa, Panicum maximum, Digitaria milanjiana, and a sedge Kyllinga.

This community is provisionally erected to an association and the tentative name arrived at is: **Fockeo-Colophospermetum mopanis**. The typical relevė is no. 26

4b. **Jesse thicket community:**

This group comprises species forming closed canopies in scattered patches, usually on loose sandy to loamy soils. Relevės between no.23 and 29 are basically a jesse thicket community in which some of the common species include Acacia tortilis, Diospyros quiloensis, Strophanthus kombe, Boscia mossambicensis, Acacia ataxacantha and Grewia flavescens ssp olukonde. It is characterised by the emergent tree species Pterocarpus lucens ssp antunesii, and the thicket species: Pteleopsis myrtiflora, Schrebera trichoclada, Markhamia obtusifolia and Dalbergia martinii. In a few places

Pterocarpus is dominant and forms a broken canopy (relevé 23), but mostly it is only an emergent from the thicket. Relevés between no. 29 and 48 are characterised by the following differential species which are mainly weeds in the regenerating thicket after cultivation: Phyllanthus leucanthus, Ceratotheca sesamoides, Ocimum canum, Cleome hirta, Erlangea misera, Chloris virgata, Eragrostis viscosa, E. aspera and Leptocarydion vulpiastrum. Markhamia acuminata seems to be associated with these regenerating thickets, while Markhamia obtusifolia is more characteristic of mature thicket.

Dominant shruby species of this weedy community are Albizia anthelmintica, Combretum obovatum, C. mossambicense, Grewia bicolor and Dichrostachys cinerea which provide the canopy cover, while the ground cover is represented by other non woody species and weeds such as Corchorus olitorius, Dactyloctenium aegyptica, Kyllinga sp., Fimbristylis sp., and a species in the family Araceae.

Due to good drainage provided by the deep sands in most of the jesse thicket , upland (Minda) gardens are sometimes located on cleared patches of this vegetation type.

This community is provisionally given a phytosociological classification at association level and is named after the Pterocarpus and Combretum spp: **Pterocarpo antunesii-Combretetum eleagnoidis**. The typical relevé is no.51

5. The last four relevés on the table form an ill-defined group. They are characterised by the presence of the same group of weedy species, as in the cultivated jesse thicket but do not have any of the woody species characteristic of it. The relevés were sampled in some of the most recently cultivated fields on the terrace with fallow period less than three years. The regenerating vegetation is dominated by the more wide-spread shrubs and many grasses. They include: Combretum obovatum, C. mossambicense, Albizia anthelmintica

and Dregea macrantha (a creeping woody species). Common grasses are Digitaria setivalva, Brachiaria serrata, and Dactyloctenium aegyptica.

A rather similar floristic pattern is noticed from the communities described by Moore et al (pers. comm.) from more mature woodland around Gwabi and to the east of the Kafue River towards the escarpment (see Table 3). Presumably there is a basic natural vegetation pattern in the area, which is much influencend by human activity. This is reflected in the four main vegetation units represented in Table 2 in which this pattern is discernible, but the effects of the cultivation factor and other disturbances are superimposed on it. These effects are reflected mainly in the herbaceous weed species which were not recorded in the earlier study.

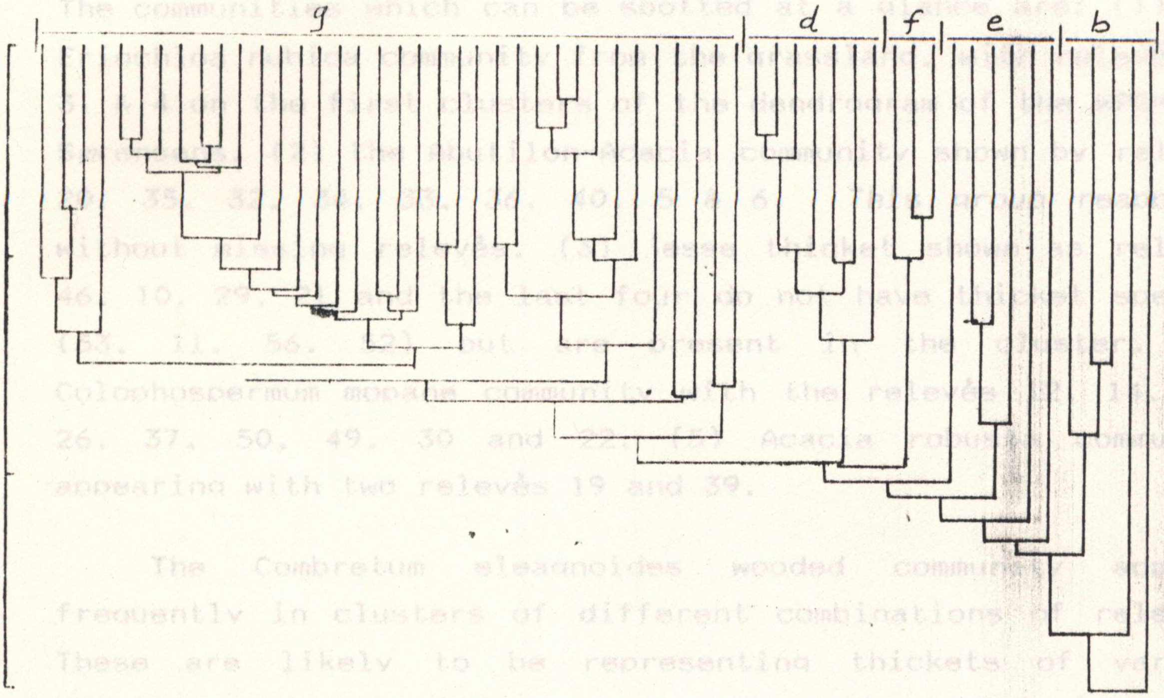
Numerical Classification of the Relevẻs

An alternative way to classify relevẻs shown in the Braun Blanquet table is by employing numerically based clustering methods. This approach considers relevẻs to be individuals to be classified while the individual species in each relevẻ are the attributes on which relevẻs are classified.

Several clustering techniques were tested and the weighted pair group method was found to yield clusters of relevẻs which matched very closely to those in the phytosociological table when applied on a matrix of Sørensen's coefficient of simmilarity. These methods bring together the mutually most similar relevẻs in the first cycle, so that in the dendrogram they lie side by side. This stage is useful in that it enables checking whether relevẻs with the same differential species have an overall similarity of species composition.

Results of the classification of relevẻs are shown in the dendrograms of fig 4. In fig 4b communities described earlier

(a) WPGMA on Euclidean Distance



(b) WPGMA on Sorensens

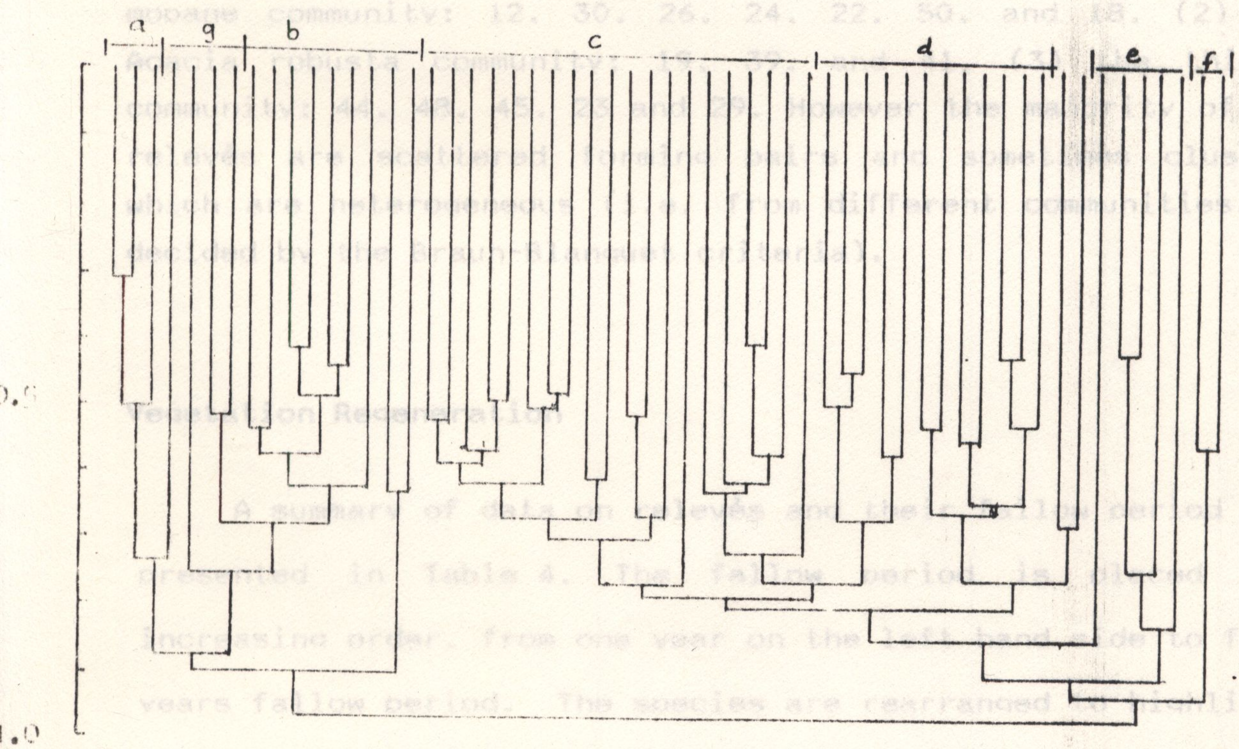


Fig. 4. Dendrograms for the numerical classification of the 57 releves. The communities are fepresented as: a=grassland; b=Abutilon; c=thicket aand ds; d=mopane; e=Pterocafpus thicket; f=Acacia robusta; g= ed.

in the phytosociological table reappear with some exceptions. The communities which can be spotted at a glance are: (1) the Eriochloa nubica community from the grassland, with relevés 1, 3, & 4 on the first clusters of the dendrogram of the WPGMA on Sørensens. (2) the Abutilon-Acacia community shown by relevés 20, 35, 32, 34, 33, 36, 40, 5 & 6. This group reappears without missing relevés. (3) jesse thicket shown as relevés 46, 10, 29, 21 and the last four do not have thicket species (53, 11, 56, 52) but are present in the cluster. (4) Colophospermum mopane community with the relevés 12, 14, 18, 26, 37, 50, 49, 30 and 22. (5) Acacia robusta community appearing with two relevés 19 and 39.

The Combretum eleagnoides wooded community appears frequently in clusters of different combinations of relevés. These are likely to be representing thickets of varying densities which are influenced by cultivation. The sites with emergent trees of Pterocarpus lucens ssp. antunesii are also clustered (relevés 23, 44, 45, and 31).

In the dendrogram for the WPGMA on Euclidean distance (fig 4a) three outstanding groups of relevés are: (1) the mopane community: 12, 30, 26, 24, 22, 50, and 18, (2) the Acacia robusta community: 19, 39, and 41, (3) the thicket community: 44, 48, 45, 23 and 29. However the majority of the relevés are scattered forming pairs and sometimes clusters which are heterogeneous (i.e. from different communities, as decided by the Braun-Blanquet criteria).

Vegetation Regeneration

A summary of data on relevés and their fallow period are presented in Table 4. The fallow period is placed in increasing order, from one year on the left hand side to five years fallow period. The species are rearranged to highlight those confined to fields of a given age. A total of 35

Table 4: Aged relevés in order of fallow period

Age of Stands	YEARS 1	2	3	4	5
Dactyloctenium aegyptium	+ 2	+ ++ 1 + +	+	++	
Brachiaria brizantha	2 +	1 1+	1		
Erlangea misera	1	+ +	+		
Cocculus hirsutus		1	+		+
Grewia flavescens olukonda		+	1	2++	+
Eragrostis viscosa		1 + 1+	1+	+	
Lonchocarpus capassa	+	+ +	+		
Boerhavia diffusa	+			++	
Holmskioldia tettensis		+	+	+	
Acanthospermum hispidum		+ +	+	+	
Cleome sp	+	+			
Eriochloa nubica		+ +			
Oldenlandia herbacea		++ +			
Colophospermum mopane		12 1.			
Zingiberaceae		+ + +			
Leptocarydion vulpiastrum		+ + 22	+++		
Commiphora edulis		+	+		
Eragrostis aspera		1	+ 1 +		
Markhamia acuminata		++ +	++		
Azanza garckeana	+	+	++		
Ceratotheca sesamoides		++ +	+	+	1
Xeroderris stuhlmannii		.	1+		
Ocimum canum		13	+ +	+	
Cassia singueana			11 + +	2++.	
Deinbollia xanthocarpa			+1	+	
Acacia albida			.	+	
Piliostigma thonningii			+	+	
Ziziphus mauritiana			+	+	
Sorghastrum bipennatum			.	1	
Pteleopsis myrtifolia			1	+	
Schrebera trichoclada			++	+	
Vernonia sp			+	++	+
Acacia nilotica		+	2		++
Capparis sepiaria			+ +	1	+3+
Abutilon angulatum		+	++	+ ++	++
Ximenia americana			+		++
Taccazea apiculata				21	
Amaranthus spinosus				++	
Bidens pilosa					++
Olax dissitiflora					+
Dalbergia melanoxylon					+
Dichrostachys cinerea	+	+2 ++++++ +	+ + 1+	+1+	2
Jacquemontia tamnifolia	1	++++++	++	+	+
Dregea macrantha	+	+ +++	+ ++	+	.
Panicum maximum	+	+	+ +	21	+
Friesodielsia obovata	1	+ ++	+ ++		+
Hippocratea indica		+ ++ +	+ 1 +	+	
Brachiaria/ZI2	+	1	1	4	.
Cleome hirta		++		+	
Balanites aegyptica			+		++.
Sesbania sesban			+		1

relevés were employed in this exercise. Although a clear and orderly successional segeunce does not emerge from the table it is felt that there is an initial phase of weed colonization followed by subsequent communities with less weedy material, especially in previously cultivated gardens. Generally absence of thick cover is a common feature in these fields, hence promoting growth of herbaceous vegetation. The mechanism of how this proceeds is left for speculation. Only a tentative explanation is therefore possible at this stage.

Weeds are generally more abundant in the first two years, and they include some of the following species: Dactyloctenium aegyptium, Brachiaria brizantha, Leptocarydion vulpiastrum, Eragrostis viscosa, Erlangea misera, Oldenlandia herbacea and Ocimum canum. In the following three to five years shrubs and small trees are increasing in abundance, these include Capparis sepiaria, Cassia singueana, Deinbollia xanthocarpa as well as woodland and thicket species.

Apart from a few species confined to the second, fourth and fifth age groups, the general pattern of distribution is that most of them do not occur in one particular year, but are overlapping. The following species are not overlapping: in the 2 year category they are: Eriochloa nubica, Oldenlandia herbacea, Colophospermum mopane and an unidentified species of the Zingiberaceae. 4 year category: Taccazea apiculata, Boerhavia diffusa and Amaranthus spinosus. 5 year category: Olax dissitiflora and Dalbergia melanoxylon.

The occurence of Colophospermum mopane in this group is perhaps worth mentioning. The plots from which samples of data were collected were felled mopane woodlands. Regrowth from stumps and sometimes seeds was observed to take place successfully in these fields, and the absence of shade appeared to encourage growth of herbs such as Oldenlandia herbacea, Leptocarydion vulpiastrum, Eragrostis viscosa and others.

The proposed mechanisms involved in succession have been very controversial, resulting in different explanations. The

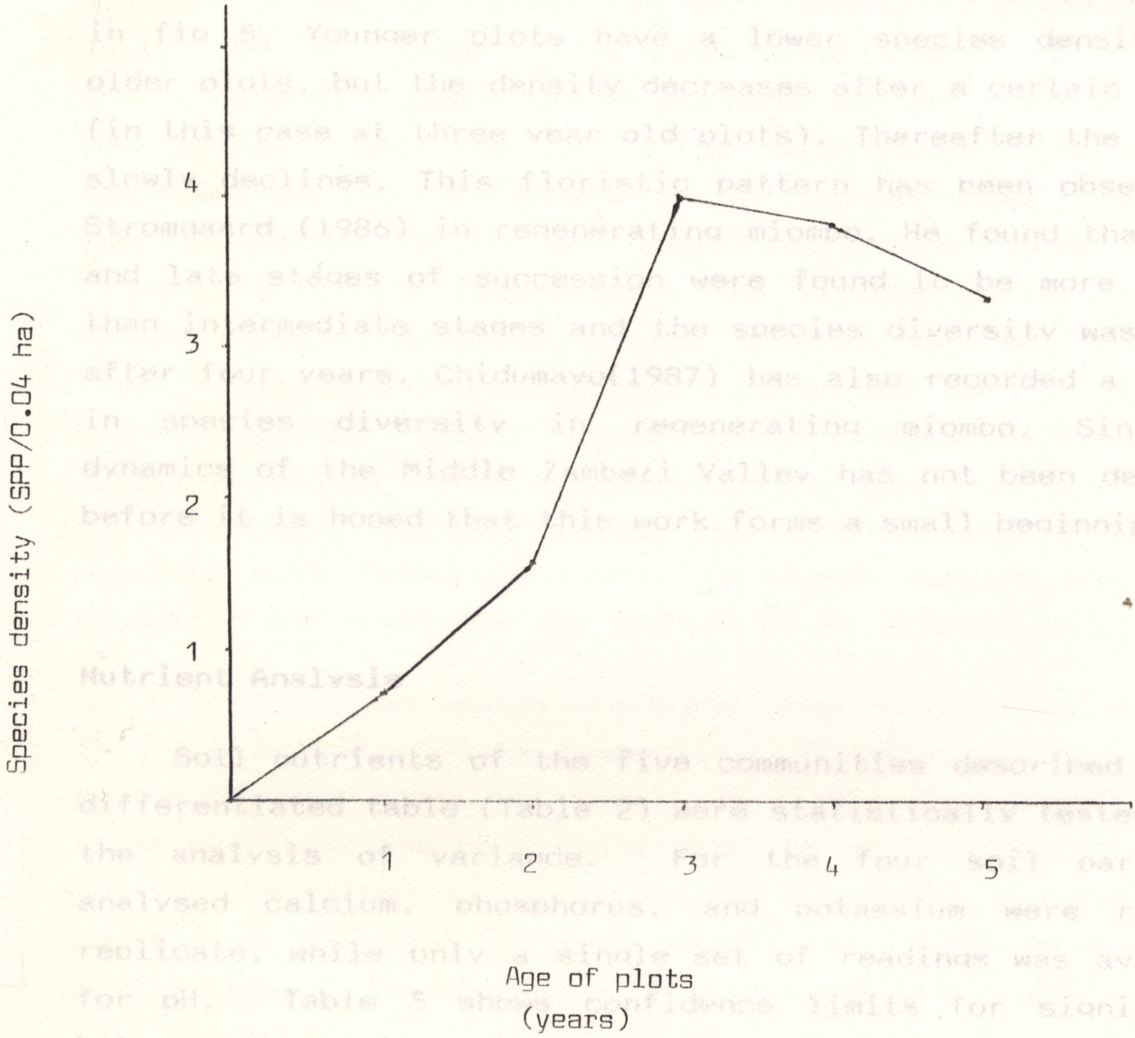


Fig. 5. Species density: Number of species per 0.04 ha (20 x 20 m) plot.

controversy has been focussed on two main points: (1) Does habitat modification by successional species render them incapable of proceeding through later seral stages leading to the climax? (2) Does diversity and stability of the community increase with the advance in succession? An analysis of species density in the regenerating plots in the MZV is shown in fig 5. Younger plots have a lower species density than older plots, but the density decreases after a certain maximum (in this case at three year old plots). Thereafter the density slowly declines. This floristic pattern has been observed by Stromgaard (1986) in regenerating miombo. He found that early and late stages of succession were found to be more similar than intermediate stages and the species diversity was lowest after four years. Chidumayo(1987) has also recorded a decline in species diversity in regenerating miombo. Since the dynamics of the Middle Zambezi Valley has not been described before it is hoped that this work forms a small beginning.

Nutrient Analysis

Soil nutrients of the five communities described in the differentiated table (Table 2) were statistically tested using the analysis of variance. For the four soil parameters analysed calcium, phosphorus, and potassium were read in replicate, while only a single set of readings was available for pH. Table 5 shows confidence limits for significance between mean values from any two communities at 95% level, derived from a single classification ANOVA (data in appendix).

Table 5: Confidence limits for Ca, P and K.

Soil Nutrient	Confidence Limits
Ca	$\sigma \pm$ 3.210 ppm
p	$\sigma \pm$ 0.087 ppm
k	$\sigma \pm$ 2.046 ppm

(i) pH

An analysis of variance (single classification) for the five communities shows that there is no significant difference between the mean pH values for each community, although the F value came very close to 5% significant level. The Abutilon-Acacia community found in the dry beds of the flood plain has the highest mean pH of 7.45, with relevé 36 (mainly characterised by the Capparis sepiaria 'sub-group') recording the maximum pH (8.10) and relevé 6 (charecterised by the Taccazea apiculata 'Sub-group') the minimum pH (7.01). The Acacia robusta community on the terrace, but on hard clays (the result of flooding) shows a reduction in pH indicating slightly acidic soils: (mean 6.89: minimum 6.28: maximum 7.65). Relevé 39, from a woodland with many shrubs of Acacia gataxacantha, has the lowest record while relevé 41, from woodland with Euphorbia ingens (a common species on termite mounds in the area) has the highest pH in this group.

The Eriochloa nubica grassland community, has a higher pH than the Acacia robusta community. Flooding occurs in many places of this grassland and it is likely that deposition of bases may raise the pH. The highest pH of this community is a relevé from raised ground within the grassland, and the lowest pH is from a relevé on level ground and likely to have been moist: (mean 7.20: Minimum 6.29: Maximum 8.64).

Colophospermum mopane community: In mopane woodlands with loose soils in many places, the mean pH value is 6.73, (Minimum:6.11, Maximum:7.36). The relevé with highest pH is no.12 sampled from a mopane woodland with a thick undergrowth of shrubs some of which are: Holmskioldia tettensis, Combretum mossambicense and Grewia bicolor. The lowest pH in this group is in relevé 24 in a regenerating field with mostly weeds and few woody species.

Thicket community: This is a very variable community ranging from thickets with closed canopies to open types but with generally more acidic soils. (mean 6.58: minimum 5.11: maximum 7.84). relevés 31 and 56 having the minimum and maximum pH respectively. Some of the highest values are recorded from fairly recently cultivated fields while the lowest values are from the thickets with most of the chracteristic species such as Pterocarpus lucens ssp. antunesii and Dalbergia martinii present.

It would appear that a pH gradient is thus present. starting with alkaline soil on the flood plain and terrace and proceeding to the thicket communities which are on neutral to slightly acidic soils. The data are summarised in Table 6.

(ii) **P. K & Ca**

Data for the soil nutrient: calcium. potassium and phosphorus are given in Table 6. Since the data was replicated a nested anlysis of variance was carried out on 46 sample pairs. using the same phytosociological groups as in

Table 6. Summary data for soil nutrients P. Ca. K. Mean. minimum and maximum value for each community are given. 1=Abutilon-Acacia. 2=Acacia robusta. 3=Eriochloa nubica. 4=Colophospermum mopane. 5=Jesse thicket. Tr=Trace. All units are in micro gram per gram of soil (μg/g soil).

Community Type		1	2	3	4	5
pH	MEAN	7.45	6.89	7.20	6.73	6.58
	MIN	7.01	6.28	6.29	6.11	5.11
	MAX	8.10	7.65	8.64	7.36	7.84
P	MEAN	1.9	2.4	1.4	1.8	2.1
	MIN	Tr	0.8	0.5	Tr	0.024
	MAX	3.6	3.1	2.1	2.5	3.3
K	MEAN	257	300	315	182	160
	MIN	139	225	151	124	76
	MAX	331	460	460	288	379
Ca	MEAN	1075	988	1423	677	627
	MIN	907	530	698	216	7
	MAX	1533	1776	2503	1200	1300

the description of pH above. For all the three nutrients there are significant differences between the means of the five communities.

The Acacia robusta community had relevės with some of the highest K, Ca and P records mainly in those samples associated with Euphorbia ingens, but there is an overall trend of decrease in Ca and K from communities on the floodplain to those on the terrace.

The mean values for phosphorus do not show a clear-cut trend of either increasing or decreasing amounts in the five communities. The minimum and maximum values range from trace to as high as 2.5*f*g/g soil in the mopane community and 3.6*f*g/g in the Abutilon-Acacia community. These communities show some of the lowest mean values (mopane 1.8, Abutilon-Acacia 1.9). High phosphorus means are occurring in the Acacia robusta community with 2.4*f*g/g (minimum 0.8, maximum 3.1) and in the thicket community 2.1*f*g/g (minimum 0.024, maximum 3.3). A common feature in these two communities is that they have high percentage tree cover. It is likely that a lot of litter is deposited on the ground where it is decomposed.

Potassium is highest in areas associated with moist conditions: grassland community on the flood plain has a mean value of 315*f*g/g (minimum 151, maximum 460), the Acacia robusta community has a mean of 300*f*g/g (minimum 225, maximum 460). The latter community is characterised by low lying areas of the terrace which floods in the wet season. The Abutilon-Acacia community occcurring mainly on the drier edges of the flood plain has a mean value of 257*f*g/g (minimum 139, maximum 331). Marked decrease in potassium occur in the drier upper terrace communities of the mopane (mean 182, minimum 124, maximum 288) and in the thicket (mean 160, minimum 76, maximum 379). Relevės in which Pterocarpus lucens ssp antunesii occur have some of the lowest potassium levels (relevės 23, 27 and 31).

A somewhat similar pattern emerges for the calcium mean values in the five communities. The thicket community has the lowest mean value of 627 fg/g (minimum 7, maximum 1300) and an upper terrace mopane community has a mean of 677 fg/g (minimum 216, maximum 1200). Most of the bases of these two communities were probably washed away to low lying areas of the flood plain and grassland, hence the high base content in the soil. These communities on lower ground consequently have a higher pH.

The mean calcium value in the grassland community is 1423 fg/g (minimum 698, maximum 2503) and in the Abutilon-Acacia community 1075 fg/g (minimum 907, maximum 1533). The Acacia robusta community, though on the terrace, is closely associated with moist pans and the calcium value is intermediate between the terrace and flood plain communities (mean 988, minimum 530, maximum 1776) fg/g of soil.

Chapter 5

DISCUSSION

Vegetation Pattern

Four main structural types have been characterised for the vegetation in Zambia (Fanshawe 1969). These are closed forests, open forests (or woodland), termitaria and the grasslands (which include most of the wetland communities). Most of the types occur in small isolated patches scattered in different places in Zambia and they have been called relicts and are characteristically semi-evergreen or evergreen in nature.

The miombo woodland however, is the most extensive and important vegetation type in Zambia and covers about 80% of the territory. It is an open and semi-evergreen woodland which does not show significant regional differences in the distribution of dominance and species evenness (Chidumayo 1987), but can be differentiated by species richness.

The vegetation pattern in the Middle Zambezi Valley and Gwabi in particular, show a marked contrast to the plateau types. The most marked contrast is that the vegetation is deciduous and completely bare for almost five months or more, while in the miombo woodlands there are always some tree species in leaf. Howard et al(1987) have noted that phenological activities lag behind by about a month in the valley. Species of Balanites aegyptica often break into leaf earlier, followed by the Combretum species. The other feature of the vegetation of the Middle Zambezi Valley is the patchiness of the vegetation types. This mosaic pattern is very distinct even at extremely short distances of less than a kilometer and is well illustrated from airphotos and spot satellite images.

Within Zambia, the relatively uniform miombo woodland has been reported to cover hundreds of square kilometers with minimal localized variation either in species composition, structure and/or physiognomy, despite differences in geological strata (White 1983). Published literature on the causes of structural differences in miombo species have laid emphasis on climatic factors rather than edaphic ones. The only edaphic factor having a marked effect on the strutural differentiation is in dambos and flood plains or grasslands.

Within the Middle Zambezi Valley as well as other hot valleys in Zambia Colophospermum mopane woodland forms a major group under which they have been described, and most of the other vegetation types have been left out (see for example the maps by Rattray & Wild 1961, Wild & Barbosa 1967, and White 1983). This perhaps is an over simplification, because even within the mopane woodland there are considerable variations in physiognomy over relatively short distances. It tends to have differently assorted species. Guy(1977) attributes the heterogeneous structure exhibited by mopane to differences in soil.

The present study as well as other recent publications (e.g. Muller & Pope 1982) have confirmed that the MZV has several vegetation types besides the mopane woodland. These also display structural differentiation in different parts of the valley.

The vegetation around Gwabi show a mosaic pattern with many and different types of vegetation patchily distributed over a large area. The thicket vegetation provides a good example. It has several outliers around the Gwabi area. On the alluvial plain it approaches a closed forest physiognomy, but there is usually a broken canopy of trees over a discontinous layer of smaller trees and shrubs. The most conspicuous shrubs are Combretum eleagnoides and Grewia flavescens with Pterocarpus emergents towering over them. The layer of shrubs and small trees is usually more open when a canopy layer of trees is present. In certain places the thicket is dense and closed to a height of five meters above the ground. A sparse substratum of herbs and small shrubs are often present. Where the ground recieves little light due to a closed layer of shrubs. herbaceous vegetation is usually absent.

This mosaic pattern extend eastwards towards the Chongwe confluence were a pure stand of Acacia albida is found. The major influences likely to account for this mosaic are human and edaphic factors. Human influences can be characterised by three main aspects:(1) felling of trees in preparation for cultivation. concentrated in thicket vegetation and Acacia woodlands. (2) selective thinning of mopane woodland which provide a source for construction poles and for firewood. (3) bush fires. As a result of these influences such areas have open canopies with increased herbaceous cover and grasses such as Brachiaria serrata. Digitaria setivalva. Panicum maximum present. Herbs such as Corchorus olitorius and Ceratotheca sesamoides frequently inhabit these vegetation types with a reduced canopy. especially where cultivation is carried out.

The patchy distribution of vegetation may also be attributed to edaphic conditions. Most of the MZV was reported to be covered by Karoo sedimentary rocks (Gair 1959). Within the Gwabi region the nature of Karoo strata rocks vary from sandstone to fine shales rich in calcium. while basalt intrusions on the other hand are common and distinct in some places west of the Kafue River. This may well be an indication that there has been a variable history of sedimentation which might have indirectly dictated the nature of the present vegetation formations. A soil analysis of the communities studied (see Table 2) around Gwabi showed significant differences. This may be an indication that the soil parent material differed considerably. Presumably the different patches of vegetation had different tolerances within their micro-environments. especially since the climate was more or less uniform over most of these patches. However a general observation made from this mosaic pattern is that older soils are more likely to be carrying trees with a more or less continuous canopy typified in thickets while the more open vegetation types such as the Acacia woodlands are occurring on recent soils.

In the present study a survey of the soils of the termite mounds was not done. However it is generally accepted that termites concentrate nutrients and organic matter in the soil of the termite mound owing to their carrying of plant material into the domatia. Termites were generally abundant in the study area, they were actively harvesting dry grass during the hot season of November 1988. The only relevé sampled on a flat mound in the grassland showed a pH (8.64, rel. 4) higher than all the other samples of the study area. This relevé had some of the highest values for calcium (2503 *fg/g* soil) and phosphorus (2.2 *fg/g* soil).

An outline of plant species growing on the termite mounds of different vegetation types in Zambia has been given by Fanshawe(1969). He found that most termite mound species had a wide distribution in other woodland types, with certain species occuring on all types, e.g. Asparagus racemosa, Boscia angustifolia, Capparis tomentosa, Maerua juncea, Friesodielsia obovata and Strychnos potatorum. These, apparently were recorded in our study area. In the Acacia robusta woodland around Gwabi termite mounds frequently occurred and usually had a prominent specimen of Euphorbia ingens growing on them. It was likely that the termitaria in different types of vegetation have varying combinations of species although there are some species such as Capparis tomentosa which seem to be always associated with this type of habitat and are present in most vegetation types.

Aspects of Regeneration

Regeneration of vegetation from cleared fields in the Gwabi area is common in many places. Species which dominate these fields include Albizia anthelmintica, Dichrostachys cinerea, Combretum eleagnoides and Combretum mossambicense. Acacia tortilis is occasionally present in these fields. When the tree and shrub cover is not dense, herbs are common. An attempt to biuld a successional sequence from younger to older plots (Table 4) did not yield a clear-cut pattern, since weeds and woody species were seemingly mixed in the different age groups. However the general appearance of herbs to concentrate in younger plots to the left of the table and woody species in older plots to the right provide some indication of early successional stages with a broken canopy allowing more light, proceeding to more closed canopy woodland types, with a reduced herbaceous cover.

The approach taken towards successional studies are reported to affect accuracy of results (Mueller-Dombois & Ellenberg 1974). These two workers suggested that studies carried out on the same area offered a more reliable approach to vegetation dynamics than the method based on comparison with the adjacent stands of vegetation. However the latter approach was usually adopted by many investigators. Few investigators were able to follow changes occuring on the same habitat for a long period, and besides, evidence of change in the same habitat, from written records or organismic remains are not readily available for study.

Successional information is in most cases inferred from studies of different communities. The present study also followed this approach. The major difficulty in this method is that of keeping all other ecological factors constant except time of disturbance. Climate and soil are assumed uniform when comparisons of a vegetation stand with the adjacent regenerating plot are made. Fallow periods obtained from interviewing the local people are in some cases estimates without independent confirmation, hence prone to error.

A great deal has been written concerning the changes of diversity, stability and other community characteristics which take place during succession (see for example Diamond and Cody 1975). It is, however, obvious that diversity must increase during early succession. Horn(1975) viewed succession as a random replacement of plants. This occurred with a probability defined by the present status of the ecosystem. This theory was in sharp contrast with the mechanisms put foward by Connel and Slatyer(1977). These workers proposed three successional mechanisms: facilitation, tolerance and inhibition. The facilitation mechanism involved the currently discredited concept of early invaders in the community which prepared a habitat for the next generation of species. Tolerance involved sequential filling of niches by species whilst gaining competitive advantage, and the last mechanism, inhibition, occurred when species resisted invasions by competitors, but that later species accumulate gradually by replacing early invaders when they died. The most recent explanation for the mechanisms involved in succession have been given by Pickett & McDonnell(1989). These workers have proposed a theory of successional forces through which they expose major causes of community dynamics. They stress the concept of community dynamics which focusses on process rather than the climax state most emphasised in succession studies. Three major categories of cause which influence vegetation dynamics (and are applicable to successional studies) are singled out: if a site became available, and if species availability, or perfomance at a particular site was differential then vegetation structure or composition would change through time.

Site differentiation is perhaps a major contributing factor in the regeneration of vegetation of the MZV. Most vegetation types are restricted to a particular soil type with the exception of the thicket which happens to occur on most terrace soils but showing structural differences. whilst not completely rejecting the successional mechanisms outlined earlier, an alternative view to the present vegetation dynamics in the Middle Zambezi Valley is that cover of canopy species contribute significantly to the performance of successional species as explained below.

Regeneration in the Gwabi area appears to be determined most by the presence of shade from canopy trees. Where dense cover were present, there was little herbaceous vegetation. Fields which were visited a short while after felling of some woodlands in preparation for cultivation showed an increase in the herb layer almost instantaneously. These species presumably were opportunists taking advantage of the absence of shade. It is however not very clear whether a seed bank is present. Most seeds are likely to have remained dormant until such a time that growing conditions were suitable. Three different modes of regeneration were distinguished in the Gwabi area: from seeds, stumps and roots. Regeneration from seeds was common in mopane derived plots (see Tietema 1989), but the seedlings did not survive through the next rainy season. Seedlings of Colophospermum mopane started off very well at the beginniq of the rainy season but eventually died after the rains. Some of the mopane seedlings uprooted showed termite destruction, leading to plant death. Shoot death could be distinguished since the stems started budding early in the rain season. One likely contributing factor could have been that the herbaceous cover comprising mainly perennial and annual grasses provided stiff competition such that resources were limiting, but later on in the dry season bush fires contributed significantly to the high mortality of mopane seedlings. Regeneration of mopane on the other hand proceeded relatively well in coppice plots. This gave rise to multistemmed plants, which were shrub-like and were growing in dense grass cover. But it was likely that later on in growth only a few stems remained as there were dead stems on some of the older trees. The competitive ability of mopane in this case perhaps lay in the fact that the stems were already rooted and functional. Weeds eventually get suppressed most likely due to the increase in mopane tree cover which forms a barrier to the light in the growing season. In the mopane woodlands with minimum disturbance such as those towards Chiawas Palace the herbaceous cover is minimal, probably providing an example for the anticipated mature stage (or "climax") in the regenerating fields in the mopane woodland around Gwabi.

Regeneration in Acacia woodlands probably took place mainly from seeds other than stems. Although development from stems was noted in isolated cases of cleared gardens, these eventually died leaving stumps. Competition from invading shrubs and subsequent suppression through resource competition may eventually have lead to mortality. After felling, Acacia tortilis vegetation seemed to go through a series of stages in which some of the dominant competing woody species included Combretum obovatum, C. mossambicense , Dichrostachys cinerea and the grasses. However, it was hard to tell whether an Acacia tortilis or A. robusta scrub would return to the original structural and physiognomic condition. The tendency of this vegetation type in some of the presently regenerating fields was to assume appearance of thickets.

Regeneration in felled thicket vegetation was noted to take place mainly from roots. Some of the gardens located on cleared thicket showed this aspect of regeneration. The gardens were orginally cleared to ground level and regeneration was seen to take place from the ground, free from the protruding cut stems, presumably from underground suckers. Stems occasionally gave rise to multistemmed young trees but most of these later died, as was seen in most old gardens. This vegetation type perhaps has the highest potential of reverting to the original form since it constitutes some of the species which may be termed as "opportunist" woody plants. But it is likely that some of the present vegetation in the Gwabi area is derived from previously more mature thickets or woodlands with a single dominant species.

An alternative influence on the present vegetation could be grazing by mammals. Generally large mammals are absent in the Gwabi area, but there was a lot of small mammal activity (mainly rodents). These were present in most of the vegetation types apart from mopane woodlands. They probably had an effect on the vegetation through their underground burrows.

Classification of Communities

In the present study an attempt was made to classify the vegetation of which 57 samples were recorded, through numerical means and Braun-Blanquet table method. Four associations and two of them within the one alliance were tentatively arrived at. In addition a grassland community was recognised but not assigned an official name since it was felt the relevés were inadequate to establish an association.

So far there has not been a formal phytosociological classification of the vegetation of Zambia. Existing phytosociological studies in the Central African region were done in Shaba (Southern Zaire) by Schmitz(1963 1971) and in Angola by Monteiro(1970). In their review Werger & Coetzee(1978) extrapolated these results to parts of northern and western Zambia. These studies constitute some of the most detailed phytosociological surveys of the miombo vegetation. They resulted in a classification of the miombo communities into one Order: the Julbernadio-Brachystegietalia spiciformis and four Alliances: (1) Berlinio-Marquesion, characterised by semi-evergreen forests of Angola and parts of north west Zambia in places of rainfall more than 1200 mm/annum. (2) Meso-Brachystegion, characterised by high rainfall miombos (>1100mm) on mesic, fertile loamy soils as well as on large termitaria. (3) Xero-Brachystegion, characterised by low rainfall miombos (>1000mm) on drier, poor and shallow soils. (4) Guibourtia-Copaiferion baumianae, on Kalahari sands of Central Angola and western Zambia. These were places of rainfall between 700-1300mm. These results may not necessarily be applicable to southern and eastern Zambia since they were done in the wet parts of the north with high rainfall. However in the southernmost end of Zambia with very low rainfall and temperatures considerably higher than the plateau, a completely new classification system is needed.

The present study is so far the first effort made in Zambia at applying the Braun-Blanquet phytosociological method. Perhaps one of the merits of this method is that a framework is created for all ecological studies whether theoretical or applied e.g for various aspects of landuse and vegetation dynamics. Studies of interrelations between plant communities and the environment are poorly developed, and there is a need for more detailed studies.

It is hoped that the present study may form a small beginning for the setting up of a comprehensive system which would characterise and classify critically the vegetation of the whole of Zambia.

APPENDIX I

Standard solutions and reagents for calibration curves

1. Phosphorus

Primary standard: 0.4393g potassium hydrogen phosphate (KH_2PO_4) dissolved in 250ml water (100mg/l P. or 100ppm).

Secondary standard (1mg/l): 1ml primary standard solution diluted to 10ml with water.

Reagents: Ammonium molybdate-sulphuric acid reagent. 25g $(NH_4)_6Mo_7O_{24}.4H_2O$ dissolved in water. 280ml conc H_2SO_4.

Stannous chloride reagent. 0.5g $SnCl_2.2H_2O$ dissolved in 250ml of 2% v/v HCl.

2. Potassium

Primary standard (1000ppm): 0.4676g potassium chloride (KCl) dissolved in 250ml water.

Secondary standard (20ppm): 1ml primary standard solution diluted to 50ml with water.

3. Calcium

Primary standard (1000ppm): 0.6243g calcium carbonate ($CaCO_3$) dissolved in 250ml water.

Secondary standard (100ppm): 1ml primary standard solution diluted to 10ml.

APPENDIX II
Soil nutrient data(μg/g soil), pH and age of relevés

No.	Age	pH	Potassium		Calcium		Phosphorus	
35	3	7.14	290.4	276.0	859	840	2.592	2.280
5	4	7.67	139.2	141.6	953	907	2.976	3.288
6	4	7.01	199.2	206.4	1224	1176	.001	.001
20	3	7.34	331.2	331.2	1118	1109	3.576	3.048
40	4	7.19	261.6	266.4	478	475	.288	.408
32	4	7.71	273.6	276.0	1450	1404	1.920	1.920
36	3	8.10	302.4	304.8	1534	1529	2.160	3.048
39	5	6.28	225.6	230.4	574	576	.864	.864
41	0	7.65	460.8	458.4	1102	1068	2.280	2.400
19	0	6.79	273.6	297.6	1776	1771	3.072	3.792
38	1	6.85	228.0	230.4	530	509	3.024	2.808
4	0	8.64	151.2	168.0	2503	2498	2.160	1.848
3	0	6.29	324.0	319.2	725	698	1.656	1.536
1	0	6.67	460.8	465.6	1061	1056	.528	.720
25	1	6.88	280.8	288.0	1483	1481	2.328	2.184
2	1	7.91	427.2	463.2	2604	2597	1.176	1.680
7	2	7.15	148.8	153.6	677	672	2.784	3.048
42	2	6.48	115.2	122.4	386	382	1.680	1.704
37	5	6.20	184.8	189.6	802	782	2.256	2.424
55	3	7.02	139.2	144.0	605	598	1.704	2.256
57	2	6.89	153.6	160.8	866	838	2.256	2.136
26	0	7.10	184.8	187.2	581	576	1.872	2.016
18	0	6.20	124.8	129.6	509	506	2.376	.360
50	0	5.72	220.8	223.2	334	331	2.496	2.208
24	2	6.11	244.8	240.0	218	216	2.496	2.472
22	0	6.24	148.8	151.2	410	406	2.328	2.280
13	2	6.85	187.2	187.2	842	838	.001	.001
14	0	7.26	136.8	134.4	756	732	2.496	2.256
49	0	7.15	172.8	180.0	821	816	2.976	3.312
12	0	7.36	211.2	220.8	840	814	2.232	2.112
16	2	7.17	283.2	288.0	1200	1188	.001	.001
15	2	.00	.0	.0	0	0	.000	.000
9	1	6.90	132.0	134.4	766	761	.576	1.104
23	0	6.11	115.2	127.2	14	7	2.160	2.616
47	0	6.36	345.6	379.2	770	770	3.240	3.360
8	2	6.46	254.4	259.2	478	480	1.920	1.800
43	5	.00	.0	.0	0	0	.000	.000
27	4	5.89	163.2	165.6	480	468	2.256	2.760
31	0	5.11	117.6	129.6	365	362	.024	.216
51	4	6.86	249.6	249.6	823	814	2.160	2.280
48	0	6.50	158.4	182.4	1301	1274	3.048	3.024
17	3	6.64	76.8	88.8	331	324	1.704	2.256
28	2	6.97	139.2	148.8	619	617	.720	1.080
54	0	6.81	112.8	115.2	766	763	3.216	3.600
10	3	7.75	86.4	86.4	890	888	2.496	2.664
46	2	5.72	180.0	184.8	307	302	2.088	2.880
21	3	7.13	139.2	141.6	826	821	2.280	2.568
29	2	5.79	115.2	110.4	458	456	2.520	3.024
53	2	5.98	165.6	172.8	427	422	1.128	1.464
11	2	7.53	144.0	151.2	1042	1037	1.776	1.392
56	2	7.84	110.4	112.8	1003	1001	1.056	1.128
52	1	6.95	148.8	153.6	437	432	2.184	2.640

APPENDIX III

Example of NESTED ANOVA using replicate data for calcium

Communities:	1	2	3	4	5
n:	14	8	6	28	36
Zeros:	22	28	30	8	0

GT=73029.6
ddd X^2 = 75.473.596.8
d T^2/n = 75.466.941.12
d $(TC)^2/n$ = 63.146.362.17
CT = (GT)/ddn Total Sample Size = 57.970.896

Source	df	SS	MS	F
5 communities	4	5.175.465.5	1.293.866.4	4.31 **
Rel. within comm.	41	12.320.579	300.501.9	2076.7
Error readings	46	6.655	144.67	
Total	91	17.502.700		

APPENDIX IV

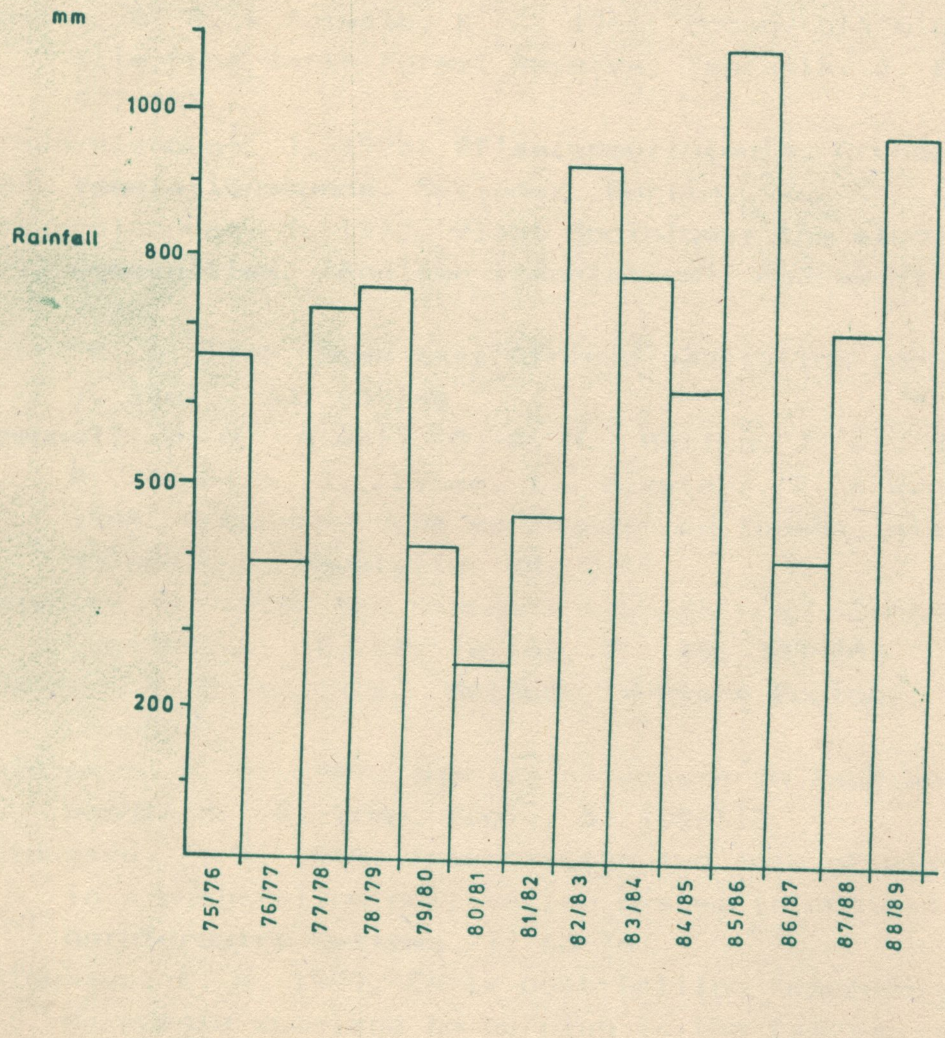
SOIL COLOR

Relevé No	color
7	7.5YR 4/2
8	5YR 4/8
12	5YR 4/4
14	2.5YR 5/2
19	7.5YR 5/2
20	5YR 3/4
22	5YR 4/3
23	7.5YR 4/6
24	5YR 5/2
26	5YR 5/3
50	5YR 5/4

Relevé No	color
35	5YR 4/6
36	5YR 5/2
37	5YR 4/6
38	5YR 4/4
39	5YR 5/3
40	5YR 5/4
41	5YR 5/2
47	7.5YR 6/2
48	5YR 5/4
49	5YR 5/2

APPENDIX V

RAINFALL TOTALS FOR THE MIDDLE ZAMBEZI VALLEY
(Compiled at Lusitu District Agriculture Office)



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