CONDITION AND MANAGEMENT OF THE RANGELANDS IN THE WESTERN PROVINCE OF ZAMBIA

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Proefschrift

ter verkrijging van de graad van doctor
op gezag van de rector magnificus,
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Stellingen

1. Er is geen reden tot grote bezorgdheid over landdegradatie in de Western Province van Zambia.
(Dit proefschrift)

2. De lage populatiedruk van mens en vee in de Western Province remt de ontwikkeling van de veehouderij. Intensivering van de veehouderij, binnen de perken van de draagkracht van het rangeland, verhoogt de duurzaamheid van het landgebruik.
(Dit proefschrift)

3. In west Zambia is branden van de grasvegetatie geen optie maar noodzaak voor de voedervoorziening van rundvee.
(Dit proefschrift)

4. Terwijl zowel onderzoek als gezond verstand tot de conclusie kan leiden dat branden een plaats heeft in een bepaald ecosysteem, bepaalt het management, zowel voor als na het branden, het succes van de operatie.
(Pressland A.T. (1982) Fire in the management of grazing lands in Queensland. *Trop. Grassl.*, 16, 104-112)

5. Water en vuur vormen een welkome afwisseling voor het Barotse rund.

6. Op de westbank van de Zambezi rivier kan de veehouderij geïntensiveerd en gecommercialiseerd worden. Akkerbouw blijft op het zelfvoorzieningsniveau wegens beperkte bodemgeschiktheid.

7. Range management kent meer sociale dan technische problemen. Rangeland specialisten kunnen slechts dan hun kennis effectief uitdragen als sociaal-economen daarbij betrokken worden.

8. Door het wegvallen van onderwijs in tropisch grasland en range management aan de Landbouwuniversiteit Wageningen, kunnen vanaf nu alleen de daarin reeds afgestuurden nog het internationale imago van de LUW op dit terrein blijven bepalen.

9. Vele projecten in de ontwikkelingssamenwerking storten in na het vertrek van de experts omdat zij het budget meenemen.

10. Vredelievend zijn betekent volharden in de droom van de vrede en daarnaar te leven.
(Bouma H. (1990) *Vredelievend*. La Rivière + Voorhoeve, Kampen)

11. Wie tijdens reizen veel wil leren moet zijn oogkleppen afzetten.

12. Een mens is sterker naarmate hij de gebieden waaruit hij zijn zelfrespect haalt goed heeft verspreid.

13. Intensief sporten levert meer energie op dan het kost.

Stellingen van Robert Baars, behorende bij het proefschrift:
'Condition and management of the rangelands in the Western Province of Zambia'.

Wageningen, 13 september 1996.

Abstract

Baars R.M.T. (1996) *Condition and management of the rangelands in the Western Province of Zambia*. Doctoral Thesis, Wageningen Agricultural University, Wageningen, The Netherlands, x + 152 pp, English and Dutch summaries.

A land evaluation for extensive grazing was conducted to determine the potential carrying capacity (CC) of the Western Province of Zambia. A hierarchical land classification resulted in Land Regions (9), Land Systems (32), Land Units (124) and Land Facets (415). The vegetation was surveyed, resulting in a 1:500,000 map of landscapes and grasslands.

Mid dry season grazing capacities were assessed for the delineated Land Units. Grazing management systems were surveyed. Two transhumance and two sedentary grazing management systems were described. The calculated CC of one transhumance system was close to the actual number of cattle present. In the other systems, the calculated CC's greatly exceeded actual stocking rates. The total provincial CC was estimated at 1,075,000 Tropical Livestock Units. There is room to increase cattle numbers by about 500,000 head. Surface water development could further increase the CC by about 200,000 head.

An additional study showed that the condition of the rangelands in high cattle density areas ranged from poor to good. The extremes very poor and extremely good were not encountered. There were no signs of overgrazing.

Fire plays and important role in range management, despite the general poor regrowth after burning.

An economic analysis at herd level indicated the increase in cattle numbers, cattle sales, ploughing and milk production as the major sources of income. Manure, transport and local slaughter played minor roles. The economic output of 1.4 US $ per ha per year was considered low. There is a high potential to increase cattle numbers and improve livestock productivity.

Key words: carrying capacity, cattle, costs and returns, farmers' perception, fire, grassland, grazing capacity, land classification, land use, landscape, map, pastoralism, range condition, range management, vegetation, Zambia.

Acknowledgements

The research and surveys compiled in this thesis were executed through and financed by the DGIS-financed Animal Disease Control Project (ADCP), now the Livestock Development Programme, in collaboration with the Department of Veterinary and Tsetse Control Services (DVTCS) and the Animal Husbandry Section of the Department of Agriculture in the Western Province of Zambia. The Director of the DVTCS allowed publication of the results obtained.

In 1987, I was invited by Rob de Rooij, the Provincial Veterinary Officer and Team leader of the ADCP, to carry out a study on the economic importance of cattle. At the same time he invited Kevin Jeanes to carry out a rangeland resource appraisal. Mid 1988, when Kevin had returned to Australia, I took over his work and together we analyzed, wrote and edited the report and accompanying maps which were finalized early in 1991.

For almost three years (1990/92), Evaristo Chileshe, Dennis Kalokoni and I worked together in the Rangeland Management Team of the Livestock Development Programme. My work with Kevin, Evaristo and Dennis formed the essence of this Ph.D. thesis.

More than a year after I had left Zambia, whilst in Costa Rica, I became inspired to write this thesis. My colleague Ron Dwinger critically read the first draft papers. Leen 't Mannetje, professor in grassland science of the Department of Agronomy of the Agricultural University Wageningen supervised me during the past two years. His structural criticism and confidence resulted in the realization of this thesis.

The continuous interest and confidence of my wife Ria were very encouraging.

The institution and persons mentioned, all in their own way, have contributed constructively in the completion of this thesis and are greatly acknowledged.

Robert Baars

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Chapter 1

General introduction

Chapter 1

General introduction

Framework and area of study

The studies in this thesis were undertaken through the Department of Veterinary and Tsetse Control Services and the Animal Husbandry Section of the Department of Agriculture of the Western Province (WP) of Zambia. Both departments were supported financially and in manpower by the Dutch-funded Livestock Development Programme. From 1987 to 1992, this programme had four major areas of action: 1. Long term control of animal diseases; 2. Productivity studies of the Barotse cattle (Corten 1988; Brouwer *et al.* 1992; van Klink 1994); 3. Socio-economic aspects of cattle keeping; 4. Range management.

In the WP the slow but substantial growth of the provincial cattle population of about 2.5% per annum is subject of increasing concern. With various examples of rangeland deterioration in (semi-) arid zones such as the Sahel (e.g. LeLoup 1994), east Africa (e.g. Ahmed 1995) and Africa south of Zambia (e.g. Moyo *et al.* 1995), this concern finds support. No data was available to examine whether range deterioration is a matter of concern in the WP. For this reason, range management studies have been initiated in 1987 which are still being carried on. This thesis describes the inventory, the potential to graze cattle and aspects of management of the WP' rangelands.

The Western Province of Zambia

The WP is one of the nine provinces of Zambia. The main topographic feature is the Zambezi river with the Bulozi floodplain, running from north to south. The larger part of the WP is covered with savanna woodland to woodland, interspersed with treeless depressions, the so-called dambo's, pans, river valleys and plains.

The soils predominantly consist of permeable sandy soils (Trapnell and Clothier 1957). The landscape is gently sloping with the highest and lowest altitude of 1188 and 914 m respectively. The annual rainfall is 700 mm in the south to 1200 mm in the north (Verboom and Brunt 1970). There are basically three seasons: dry-cold (May to August), dry-hot (August to October) and wet-hot (November to April).

The entire west bank of the Zambezi river is a Game Management Area. Except for the two National Parks (Figure 8.1) and their direct surroundings, the game density on the west bank is extremely low.

In 1990 there were 607,000 inhabitants. Approximately 88% of the population lives in rural areas and relies on traditional farming (Census 1990). Settlement pattern has confined itself to the availability of water. From 1980 to 1990, the annual population growth in the WP of 2.2% was far below the national average of 3.2% (Census 1990) mainly due to out-migration of labour. Extrapolation of the growth rate foresees 692,000 inhabitants in 1996. The major and ruling tribe is the Lozi with a well established chieftainship.

The infrastructure is poorly developed, especially the road network and the marketing channels.

The Western Province as a unit

The boundaries of the WP have been set for administrative purposes. However, they also delineate a cohesive physical unit with respect to cattle movements (Figure 2.1).

The WP is considered a quarantine area against the introduction of Contagious Bovine Pleuropneumonia (CBPP) from Angola. In the west, along the border with Angola, a buffer zone is maintained, separated by a cordon line with the rest of the Province, to prevent the introduction of CBPP into the WP. Cattle movements across this line are forbidden. There are guards who report cattle movements along the cordon line.

In the east, the larger part of the WP borders with the Kafue National Park where cattle are forbidden as well. In the north, two large tributaries of the Zambezi river separate the North-Western and the Western Provinces. In the south, the Caprivi Strip and the Zambezi river form the borders.

Agriculture in the Western Province

Agriculture is agro-pastoral in nature. The role of cattle in the subsistence farming system is to provide draught power, manure, milk, meat, cash income, security, investment, among several socio-cultural functions. Traditional grazing rights play an important role in the utilization of the extensive communal rangelands. The area under crops is much smaller and largely determined by soil suitability and the accessibility and proximity of drinking water. The right to cultivate a particular tract of land is obtained through traditional rules and rulers.

Although goats and pigs are kept by a number of farmers and most households have some chickens, cattle is the dominant livestock species. About half the cattle population is transhumant, the other half sedentary. Transhumance is over short distances only (range from about 5 to 40 km away from the main village).

Objectives and outline of the thesis

The overall objective of this thesis was to assess the carrying capacity of the rangelands, to see whether range deterioration is a threat at present and if management practices are sustainable.

Chapters 2 to 5 comprise a rangeland resource appraisal. Chapter 2 delineates the land classification of the WP. Based on this classification, the vegetation with emphasis on the grasses is described and mapped in Chapter 3. Chapter 4 provides grazing capacities for the land units outlined in Chapter 2 as well as overall carrying capacity figures. Chapter 5 deals with the condition of the rangelands in high cattle density areas.

Chapters 6 and 7 outline aspects related to range management. In Chapter 6, farmers' perspectives on fire management and the regrowth of grasses after burning is presented. Chapter 7 deals with the economics of cattle keeping.

Finally, in Chapter 8 a synthesis of the findings in the preceding chapters is presented and the consequences for future research and land use planning are discussed.

Chapter 2

Land classification

R.M.T. Baars and K.W. Jeanes
ITC Journal (submitted)

Chapter 2

Land Classification

Abstract

This paper presents a hierarchial land classification (LC) into Regions (9), Systems (32), Units (124) and Facets (415). The LC was based on vegetation types, drainage patterns and landforms. False colour MSS Landsat images, aerial photographs and available literature were used for the initial LC. During an extensive field survey, the vegetation was identified or literature data verified at Land Unit and Land Facet level. Areas were assessed within all classes.

Introduction

The soils of the Western Province (WP) of Zambia (Figure 2.1) are generally sandy, infertile, and of low moisture and nutrient holding capacity. Combined with climatic difficulties such as frosts, unreliable rainfall, flooding and waterlogging, most of the land area is unsuitable for crop production. On the other hand, the land has a good potential for livestock production.

With a continuing increase in cattle numbers, the need to estimate the grazing potential arose. A land evaluation for extensive grazing based on FAO guidelines (FAO 1991) was executed, comprising the following steps: 1) a land classification, 2) the floristic description of the land units, 3) the mapping of these units, and 4) the calculation of the provincial carrying capacity. The present chapter describes the land classification, which provide the basis for mapping and the calculation of the carrying capacity which will be reported in Chapters 3 and 4.

Materials and methods

The Land Systems approach was utilized for the classification of units (Dent and Young 1981). This approach recognises a hierarchical system of Land Region (LR),

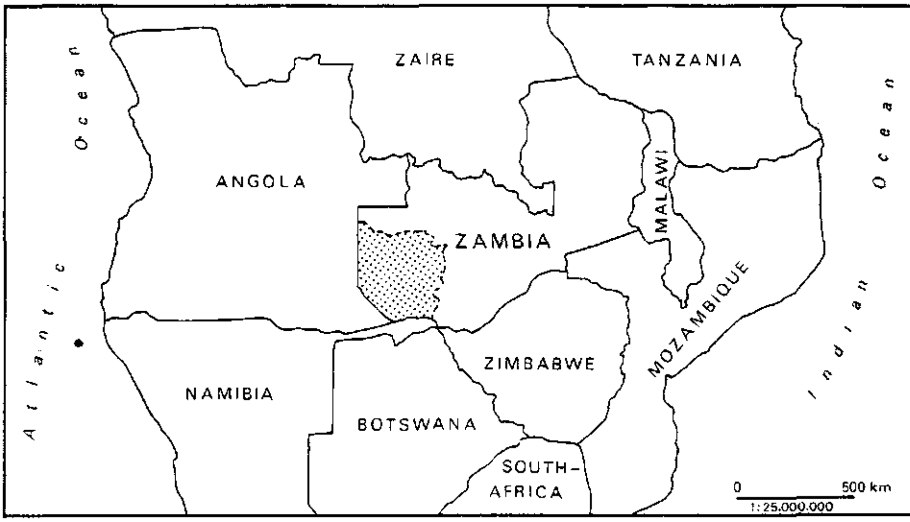

Figure 2.1 Location of the Western Province of Zambia.

Land System (LS), Land Unit (LU) and Land Facet (LF).

In this study, "landform" refers to a specific area with a particular topography or shape. "Landscape" refers to a large or indefinite area indicating a panorama. Landscape applied to LR and LS levels, whereas a landform to LU and LF levels.

LR's, the largest units, delineate broad areas of land displaying a similar overall pattern related to major woodland types, drainage patterns and/or a certain pattern of woodland versus lowland. The same criteria were used for LS's, which were delineated in terms of having a distinctive recurring pattern within a LR.

LU's are areas with a unique vegetation or landform. They were basically divided into 1) lowlands, 2) bush group savannas, and 3) woodlands. They may recur in the different LS's. A lowland was defined as a treeless depression or plain; a bush group (savanna) as a plain with scattered treed termitaria; and when the tree canopy covered 40% or more of the ground surface, it was defined as woodland.

The following lowland LU's were distinguished: floodplains, dry plains, pans, dambos/tributaries and river valleys/plains. They were separated into dry/high, low/wet and normal (if dry or wet could not be defined). Bush groups were subdivided into normal, palm and savanna. The classification of woodland LU's was based on the tree species dominating or typifying the vegetation.

LF's are areas with a distinct character within a LU. There were generally 2 to 5 LF's per LU. LF's recur in different LU's. In a woodland, the LF's encompass a catena of vegetation structure: from undisturbed woodland to fallow land. In a lowland or bush group, the LF's encompass a topographic catena: from the channels/bottom plain to the upper slope and intermound plain to mound respectively.

On several occasions, transitional LU's and LF's were encountered for a variety of reasons. When necessary, there was a deviation from the above criteria.

For the initial land classification, use was made of eight 1986 mid- to late-wet season scenes of 1:250,000 false colour MSS Landsat images (rows 070, 071, 072; paths 174, 175, 176; bands 5, 7), and occasionally Landsat images of earlier years. The latest aerial photographs (good quality black-and-white) of Sesheke District (1:50,000), Senanga West (1:80,000), and of the rest of the WP (1:80,000) dated from 1975, 1973 and 1980/82, respectively, of which photomosaics had been compiled. Study of the literature (mainly Trapnell and Clothier 1957; Verboom 1965; Verboom and Brunt 1970; Fanshawe 1971; Jeanes 1985) and existing maps facilitated interpretation of the initial classification.

A stratified field survey was conducted to identify vegetation types, to verify known vegetation types and to check the initial land classification (289 and 222 sites in the wet and dry season, respectively) (Table 2.1).

Areas of LR's and LS's were calculated using either a planimeter or overlay method (dots counted denoting a known area on the map). The LU's were estimated by the overlay technique in which the percentage contribution by area of each LU to the LS was estimated. Lastly, the percentage area of each LF within the LU was calculated either by the overlay technique, by consultation of the aerial photomosaics or by visual estimates gathered during the field survey.

Table 2.1 Data sheet indicating the type of observations per site during the field surveys. d = dominant, c = common, s = scattered, p = present.

		Wet season 289 sites	*Dry season 222 sites*
Site marking on aerial photograph (1:250,000)		x	x
Description of landform:	- LU	x	x
	- all LF's	x	x
% area of each LF within the LU		x	x
Description of position of the LU in the LS		x	x
Soil indication (sandy, loamy, clayey)		x	x
Tree species:	- identification	x	x
	- frequency (d, c)	x	x
	- structure	x	x
Grass species:	- identification	x	when possible
	- frequency (d, c, s, p)	x	
Signs of grazing:	- extent		x
	- species		x
Incidence of burning			x
Dry matter estimates			x
Forage collection for chemical analyses			x

Land Units and Land Facets

At the first level, nine broad LR's were described. Each LR was further divided into a total of 32 LS's at the second level (Table 2.2 and Figure 2.2). At the third level, 124 LU's were determined (Table 2.3). However, there were only 42 different LU's distinguished: 20 occur in one LS, the other 22 in 2 up to 11 LS's. At the fourth level, 415 LF's were determined. As the delineation of LR's and LS's depended largely on the pattern of LU's and to a lesser extent of LF's, the LU's and LF's are described first.

Lowland and Bush group savanna Land Units

The floodplain LU's are predominantly found in LR's 4, 5, 8 and 9. They were divided into upper (2)[1], central (1), and lower floodplain (2), channels/pools (3) and river edge (2). The Machili floodplain (1) was differentiated separately.

The dry plains dominate the western part of the WP. They were separated into dry (5), wet (1), upper (4), lower (2) and sand plain (3), dry river plain (6) and wet river plain (9). Five delta plains were treated as different LU's (5*1). In one area mounds (1) were delineated.

In the eastern part, dambo tributaries leading to river valleys are the dominating lowlands. The dambos were divided into dry (2), wet (2) and dambo/tributary (6). The river valleys were divided into normal to wet (2) and swampy (1).

Below the level of woody vegetation types, but above the dissecting drainage lines such as dambos and river plains, the pans and allied dry plains are situated. They occur scattered throughout the wooded uplands and in the lower and more waterlogged western parts of the WP were they form the same typical more or less rounded depressions, usually from a hundred metres to a few kilometres in diameter. Pans were divided into dry (11) and wet (4), although in one area they were considered transitional to dry plains: dry pan/plain (2) and wet pan/plain (1).

Bush groups are found scattered throughout the WP. They had a normal appearance (8), had a distinct palm vegetation on the mounds (1) or were termed savanna due to few mounds (1).

Woodland Land Units

The following woodland LU's were distinguished: Mopane (*Colophospermum mopane*) (1), Teak (*Baikiaea plurijuga*) (1), Munga (*Acacia* and *Combretum* spp.) (1), *Cryptosepalum* (*Cryptosepalum exfoliatum* ssp. *pseudotaxus*) (6), Kalahari (*Guibourtia coleosperma, Erythrophleum africanum, Burkea africana*) (11), Open Kalahari (2), Miombo (*Brachystegia, Julbernardia* and *Isoberlinia* spp.) (1), Open Miombo (1), and Mixed Miombo-Kalahari (10). Fallow Teak/Munga (1) and the

[1] The figure in parentheses indicate the number of LS's where this LU's is encountered.

Table 2.2 Land Regions and Land Systems of the Western Province of Zambia. For location see Figure 2.2.

Land Region	*Land System*	*Ha (*1000)*
1 Kaoma Terrace	1.1 Plateau Terrace	693
	1.2 Transitional Terrace	674
2 N.E. Forest Terrace	2.1 Forest Terrace	706
	2.2 Kabompo Watershed	78
3 Luampa-Lui Watershed	3.1 Luena Catchment	271
	3.2 Luampa Watershed	385
	3.3 Plateau Watershed	87
4 Lower Luena Basin	4.1 Luena Flats	156
	4.2 Savanna Terrace	213
	4.3 Woodland Terrace	103
	4.4 Kabompo Valley	14
5 N.W. Watershed Plains	5.1 Watershed Plains	883
	5.2 River/Woodland	272
	5.3 Wet River Plains	97
	5.4 Nyengo Delta	45
	5.5 River Delta Plains	103
6 Mongu-Kalabo Terrace	6.1 Ridge Terrace	1090
	6.2 Inner Basins	352
	6.3 Lui Valley	29
	6.4 Western Border Plains	252
	6.5 Bush group Basins	380
7 Eastern Tributaries	7.1 Southern Watersheds	764
	7.2 Central Terrace	1459
8 Siloana-Teak Terrace	8.1 Woodland Terrace	1435
	8.2 Mopane Lowlands	217
	8.3 Caprivi Floodplain	21
	8.4 Cholola Woodlands	116
	8.5 North Siloana Plains	329
	8.6 Central Siloana bush group	316
	8.7 Mulonga Plains	200
9 Bulozi Floodplain	9.1 Upper Terrace	43
	9.2 Lower Terrace	384
Total		12166

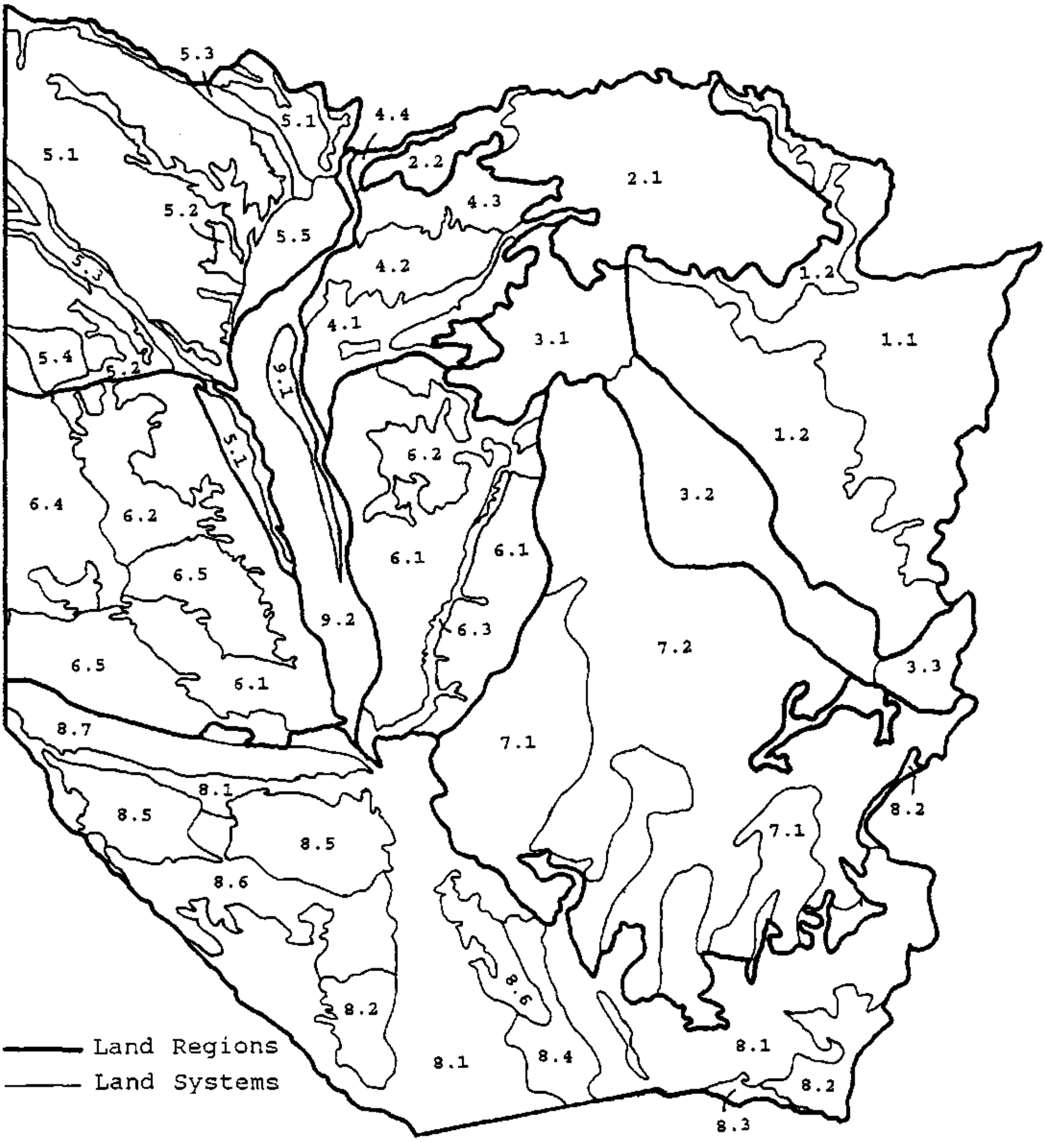

Figure 2.2 Land Regions and Land Systems of the Western Province of Zambia. For names and areas see Table 2.2.

Table 2.3 Land Units of the Western Province of Zambia. MMK = Mixed Miombo-Kalahari, wdl = woodland, pl = plain, trib = tributary.

LS	*Land Unit*	*%LS*	*LS*	*Land Unit*	*%LS*	*LS*	*Land Unit*	*%LS*
1.1	Miombo wdl	45		Upper pl	9	7.1	MMK wdl	70
	Open Miombo wdl	19		Dry dambo	20		Bush group	7
	Bush group	15		Wet dambo	2		Wet pan	5
	Dambo/trib	16	4.3	Kalahari wdl	67		Dry pan	6
	River valley	5		Dry pan	10		Dambo/trib	3
1.2	MMK wdl	72		Dambo/trib	23		Wet river pl	7
	Cryptosepalum	11	4.4	Bush group	47		Dry river pl	2
	Dambo/trib	5		River pl	53	7.2	MMK wdl	81
	Dry pan	7	5.1	Savanna	16		Dry pan	2
	Dry river pl	3		Upper pl	60		Dambo/trib	8
	Wet river pl	2		Lower pl	24		Wet river pl	6
2.1	MMK wdl	18	5.2	Kalahari wdl	84		Dry river pl	3
	Cryptosepalum	65		Wet river pl	6	8.1	Fallow	5
	Dry pan	11		Dry river pl	10		Teak wdl	26
	River valley	6	5.3	River pl	35		Munga wdl	21
2.2	MMK wdl	47		Swamp	65		MMK wdl	42
	Cryptosepalum	32	5.4	Kalahari wdl	8		Dry river pl	6
	Dry pan	9		Outer delta	48	8.2	Machili floodpl	9
	Dry dambo	12		Inner delta	44		Loazamba delta	21
3.1	MMK wdl	58	5.5	Kalahari wdl	44		Loanja delta pl	9
	Cryptosepalum	20		Upper pl	27		Loanja delta wdl	9
	Dry pan	8		Lower pl	29		Mopane wdl	41
	Wet pan	2	6.1	MMK wdl	83		River edge	11
	Dry pl	6		Dry pan	6	8.3	Upper pl	75
	Wet river pl	6		Wet pan	4		Central pl	25
3.2	MMK wdl	49		Dry river pl	3	8.4	Open kalah. wdl	100
	Cryptosepalum	25		Wet river pl	4	8.5	Sand pl	39
	Bush group	4	6.2	Kalahari wdl	25		Bush group	41
	Dry pan	6		Open Kalah. wdl	27		Kalahari wdl	20
	Dry pl	9		Dry pan/pl	29	8.6	Sand pl	11
	Dambo/trib	7		Wet pan/pl	13		Bush group	51
3.3	MMK wdl	31		Wet dambo/trib	5		Kalahari wdl	38
	Cryptosepalum	9	6.3	Delta pl	31	8.7	Dry pl	50
	Bush group	19		Wet river pl	69		Wet pl	42
	Dry pl	41	6.4	Kalahari wdl	50		Mounds	8
4.1	Kalahari wdl	10		Dry pl	38	9.1	Upper floodpl	
	Palm bush group	12		Wet pan/pl	12		Channels/pools	
	Upper floodpl	29	6.5	Kalahari wdl	33	9.2	Lower floodpl	
	Lower floodpl	35		Bush group	51		Channels/pools	
	Channels/pools	14		Sand pl	7		River edge	
4.2	Kalahari wdl	66		Wet pan	5			
	Dry pan	3		Dry pan	4			

Loanja Delta woodland were also delineated (1). The Mixed Miombo-Kalahari woodland is most prominent in terms of area coverage with 35 percent of the WP and 51 percent of the woodlands.

Land Facets

For the sake of demonstration, the LF's of only LS 1.1 are shown (Table 2.4). An overview of identified Land Facets is presented in Table 2.5.

Land Regions and Land Systems

Land Region 1: Kaoma Terrace

Land System 1.1. The vegetation is Miombo woodland, supporting *Brachystegia* and *Julbernardia* species. The relatively fertile soil consists of a thin sand cap with the outcropping Karroo sandstones, basalts and granites in the Luena, Lalafuta and Dongwe valleys (Verboom and Brunt 1970). The landscape is dissected by deep river valleys and dambos. Long side slopes falling to generally narrow valley bottoms, the occurrence of seepage zones with large termite mounds in the dambos and some pans, and the occurrence of bush group, are all distinct. The frequency of termite mounds shows a relatively high degree of silt and/or clay in the subsoil of areas that have not been subjected to alluvial deposits (Trapnell and Clothier 1957).

Land System 1.2. LS 1.2 occurs as an intermediate rim between the coarse sands to the west (LR's 2, 3, 6 and 7) and the more loamy soils of LS 1.1 to the east. With a drainage pattern similar to that of LS 1.1, not too dissimilar woodland floristics and reports (Verboom and Brunt 1970) that rock outcrops of Karroo sandstone occur in the Luampa river valley, this system has been grouped with LS 1.1 to form LR 1. *Cryptosepalum* forests, associated with dambos and scattered small circular pans, are found on the watershed. Dambos begin to take a steeper

Table 2.4 Land Units and Land Facets of Land System 1.1 of the Western Province of Zambia.

Land Unit	*Land Facet*	*% of LU*	*Ha (*1000)*
Miombo woodland	Normal	60	187
	Fallow	40	125
Open Miombo woodland	Open woodland	100	132
Bush group	Wooded mounds	20	21
	Termitaria mound	10	10
	Intermound	65	68
	Channels	5	5
Dambo/tributary	Mounds	2	2
	Upper slopes	30	33
	Mid slopes	29	32
	Lower slopes	29	32
	Channels/pools	10	11
River valley	Upper slopes	30	10
	Mid slopes	45	16
	Lower slopes	13	5
	Channels/pools	13	5

Table 2.5 Overview of Land Unit and Land Facet classes. Exceptional LU's and LF's not included.

Land Unit	*Land Facet*
Lowlands:	
Floodplain (high, low, channel)	Mound, upper-, lower plain, levee, channel, pool, ox-bow
Dry plain (dry, delta, sand)	Savanna, mound, intermound, upper-, lower-, bottom plain, pool
Pan (dry, wet)	Savanna, fallow, upper-, mid-, lower slope, plain, pool
Tributary/dambo (dry, wet)	Savanna, mound, upper-, mid-, lower slope, upper-, lower plain, channel
River valley/plain (dry, wet)	Savanna, upper-, mid-, lower slope, upper-, lower-, bottom plain, channel
Bush group savannas:	
Bush group	Wooded-, termitaria mound, intermound, channel
Palm bush group	Mound, intermound, plain, channel
Savanna	Mound, intermound, open woodland
Woodlands:	
Mopane	Normal, open, low, savanna
Munga	Normal, bush group, savanna
Teak	Forest, degraded, fallow
Kalahari (normal, open)	Normal, open, bush group, savanna, fallow
Miombo-Kalahari (normal, open)	Normal, thicket, open, bush group, fallow
Miombo (normal, open)	Normal, fallow
Cryptosepalum	Forest, thicket, bush group, fallow

sided, flatter bottomed, cross section and no longer have large termite mounds. Bush group vegetation no longer occurs.

Land Region 2: North-East Forest Terrace

Land System 2.1. The vegetation is dominated by *Cryptosepalum* forest. Other unique features are the broad relatively featureless watershed, lack of major dissecting river valleys and paucity of dambos. The presence of scattered circular pans and dry plains, associated with drainage lines, and *Cryptosepalum* forest, ally LR 2 with LR 3 to the south.

Land System 2.2. LS 2.2 is thrusted out to the west as an elevated strip of land between LS's 4.3 and 4.4. Because the woodland supports *Cryptosepalum, Brachystegia* and *Julbernardia* species, it is allied with LS 1.2 and LS 2.1 woodlands beyond. The frequency of dambos, whose headward ends dissect the southern edge of the system before draining into the Luena Basin, however, give the landscape a dissected appearance which ally it to the LR 4.

Land Region 3: Luampa-Lui Watershed

The woodlands of LR 3 are dominated by Kalahari woodland species and *Cryptosepalum* thickets associated with upper level dry plains and/or pans. These plains have elevated water tables, due to the general lack of major tributaries dissecting the landscape. Scattered small circular to sub-circular watershed pans are common.

Land System 3.1. This LS is adequately described above. The Lukute, Luamba and Likolomeni rivers, however, have cut deep valleys into the watershed (a pattern also seen in LR 7).

Land System 3.2. There are large wooded termitaria mounds (4 to 5 m tall) on this watershed ridge, occurring as a bush group woodland adjacent to some of the dry watershed plains. This type of large mound also occurs within LS 1.1 to the east, yet is not seen elsewhere. This linked the soils of LS 1.1 and 3.2 (i.e. more silt or clay in the subsoil).

Land System 3.3. Being close to the highest point of the WP (Kataba, 1188 m altitude (Verboom and Brunt 1970)) the Siziba Sa Balui Plains sit on top of the watershed between the Kafue river tributaries to the east, the Machili river basin to the south, and the Luampa river valley to the north. The landscape is dominated by dry watershed plains and a bush group savanna with low termite mounds (1 to 2 m tall). LS 3.3 has been included in LR 3 because of *Cryptosepalum* thickets and Kalahari woodland patches fringing the plains, the watershed landscape showing no distinct drainage lines, and the presence of bush group woodland.

Land Region 4: Lower Luena Basin

The Luena Flats and the surrounding catchment form LR 4. The region has an unusual high percentage of linear to sub-linear dambos. The whole tone of the region is one of a "drowned" landscape caused through subsidence.

Land System 4.1. The Luena Flats, an annually flooded plain, appears to have been formed by faults because of the unusual degree of linearity of the boundaries. Patches of higher plain within the flats, towards the edges at the western end, support an unusual *Borassus* palm and *Acacia* bush group. Grass and tree species show affinities with salty soil areas of LS's 8.2 and 8.7 (Jeanes and Baars 1996).

Land System 4.2. Rising up from the central trough, LS 4.2 forms a low-lying fringe to the flats with a waterlogged open savanna and occasional patches of higher open woodlands. Dissection occurs by a drainage system of frequent dambos.

Land System 4.3. It has the same degree of dambo dissection as LS 4.2. The higher land between dambos now supports woodland to open woodland, instead of savanna, as the water table becomes deeper. Dambos also take an increasingly steeper sided form with fairly narrow lower plains. To the north LS 2.2 rises as a rim to the basin.

Land System 4.4. LS 4.4 was included within LR 4 because it is a lower lying country leading into the north-east corner of the Bulozi floodplain (LR 9). The occurrence of the salty *Acacia* bush group savannas at the lower end of the valley, ally it to LS 4.1 and LS 5.5 to the west.

Land Region 5: North-West Watershed Plains

"West of the upper Zambezi the sands are extraordinarily flat, forming vast table-like plains, which are waterlogged in the rains but in the dry season present the paradox of water-less prairies..." (Trapnell and Clothier 1957). Underlying fault systems appear to have formed the boundaries. To the east, the lower lying trough of the Bulozi floodplain (LR 9) isolates this region from the uplands further east. To the south, a series of faults, in rough alignment with those forming the lower Luena "trough", have extended under the Bulozi floodplain (possibly a later structural event), to separate LR 5 from the upthrust western block of LR 6.

The landscape is dominated by north-west to south-east faulting river systems. They drain a much larger catchment than those to the east of the Zambezi and thus carry larger volumes of water, and have carried even larger water volumes in the wetter periods of past millennia. Consequently, the landscape is influenced in varying degrees by past or present floods.

Land System 5.1. LS 5.1 comprises flat plains with no or few scattered trees, occupying the broad watersheds between the river systems. Underlying layers of impermeable subsoil (clay or silcrete) have probably led to the formation of the seasonally flooded plains (Trapnell and Clothier 1957). Alternative, maybe, a lack of drainage lines and slow rates of ground water flow or maybe the larger volumes of water draining off the more extensive north-western basin catchment are causing the flooding of the plains. The broad lower lying floodways often carry small termitaria.

Land System 5.2. LS 5.2 has woodlands and savannas associated with the smaller tributaries, occurring adjacent to the larger river valleys or plain escarpments (closer association to valleys depresses water tables which allow tree growth).

Land System 5.3. LS 5.3 accommodates the larger valleys of the Lungwebungu and Luanginga rivers. The former shows the more complex landform of a larger river (larger catchment) and the latter is a swampy linear depression of braided channels.

Land System 5.4. LS 5.4 is overlain on the watershed landscape due to the formation of an inland delta at the end of a lesser tributary, seemingly blocked from its former drainage into the Zambezi by the upthrust of LR 6. The LS is unique in having a central swampy area expanding out in a series of minor distributaries and channels, eventually draining into the Northern Lueti. Its formation and position in the landscape resemble the Okavango Delta in Botswana.

Land System 5.5. LS 5.5 is a complex of past channels, ox-bows, alluvial depositional plains and wooded uplands on a slightly higher terrace than the Bulozi floodplain (LR 9). It is allied to LR 5 because it is formed as the alluvial fan of the Lungwebungu river (and to a lesser extent the Luambimba river). It is separated from LR 9 because it is apparently very infrequently, if ever, completely flooded. LS 5.5 lies at a lower level than LS 5.2 to the west. Occurrence of patches of salty ground and *Borassus* palm mounds give it a close affinity to LR 4.

Land Region 6: Mongu-Kalabo Terrace

This is the region of the "deep, loose, wind-abraded sands of whitish to golden colour" (Trapnell and Clothier 1957; Verboom and Brunt 1970). The overall character is a relatively elevated wooded terrace, supporting an unusually high population of pan-like depressions, with generally no well developed pattern of drainage. The terrace is dissected into two portions by the Bulozi floodplain trough.

To the north-east, the region has been separated from the furthest western major occurrence of the *Cryptosepalum* forest/Chipya complex of LS 3.1. To the east, the delineation with LR 7 is not so obvious and tentatively coincides with the most easterly occurrence of the Humic Podzol soil type (Soil Survey Unit 1983). Two factors were utilized to position the boundary between LR 6 and LR 8 to the south. Firstly, the first occurrence of Teak forest and Munga woodland, and secondly the transition from more elevated, more undulating pan and ridge landscape to flatter, lower lying, landscapes.

Land System 6.1. LS 6.1 comprises the most elevated ridge of wooded land. It shows little development of drainage lines and is characterized by circular to sub-circular pans, generally not connected to drainage systems.

Land System 6.2. A relatively high water table gives rise to belts of more open woodland. The pattern of isolated upland pans is replaced by series of sub-circular to circular depressions, with drier connecting plains forming the basis of a weakly developed drainage system.

Land System 6.3. LR 6 is cut by one major tributary, the Lui river. This unusually linear river valley again suggests underlying faulting as the cause of its formation.

Land System 6.4. This LS extends into Angola up to the Kwando river and as such it forms a belt of lower wetter country interconnecting LR 5 to the north and the plains of LR 8 to the south. The dominance of open woodland (LS 6.2) is replaced by an increased proportion of more open bush group woodland and savanna. The pattern of sub-circular dambos disappears and is replaced by a system of broader wet plains interconnected by dry plains and belts of savanna.

Land System 6.5. LS 6.5 is a variant of the lower lying landscapes of LS's 6.2 and 6.4. It has a complex landscape of woodland, bush group, savanna, sand plain and unusual east-west linear pan-like depressions, unique in the WP. The east-west linear pattern of pans, sand plains and woodland patches, shows similar alignment to the sand plain, bush group and woodland belts of LS 8.5 to the south. This suggests that aeolian influences, and ancient sand dune formations, have had an influence in shaping the landscape, and hence suggest an alliance with those systems further south.

Land Region 7: Eastern Tributaries

The general nature is a sparsely populated area of wooded watersheds, with few occurrences of circular pans, and a well developed drainage pattern of river valleys of the typical Kalahari sands cross-section (steep side slopes leading down to a broad flat to slightly concave river plain). LR 7 is delineated from LR 8 to the south and west at the point where the Kalahari-Miombo woodlands are being replaced by Teak forest and allied Kalahari woodland. This boundary also coincides with the present limit of perennially available surface water in southward flowing rivers.

Land System 7.1. In the lower catchment, a high water table is causing the occurrence of bush group savanna vegetation, more frequent sub-circular to circular pans, denser patterns of channel-like tributary/dambos, and a less dense woodland. The most northern area shows a well developed pattern of circular-pans and connecting dry plains, as found in LS 6.2.

Land System 7.2. In the upper catchment, the landscape is dominated by largely unbroken woodland with river valley systems overlain. The highest upper catchment contains numerous narrow dambos/tributaries draining the *Cryptosepalum* and dry plain complexes of LR 3. These dambo-like tributaries merge to form the broad river valleys.

Land Region 8: Siloana-Teak Terrace

A series of generally interlinked features lies behind the delineation of the region:
1. Dry upland watersheds with few pans, and little or no development of a drainage system.
2. Upland soils characterized by the major occurrence of Transitional/Teak Sands (Trapnell and Clothier 1937), and related Munga woodland soils. These soils support Teak (*Baikiaea*) and Munga (*Acacia-Combretum*) woodlands and thickets.
3. Lower-lying dry plains and bush group mosaics west of the Zambezi, seldom flooded, showing influences of past flooding and ancient dune formations; major occurrences of broad sand plains and *Acacia-Combretum* bush group types; no drainage systems obvious; and distinct soil types (Soil Survey Unit 1983).
4. Lowest lying basins, "inland deltas" and plains show major occurrences of Mopane (*Colophospermum mopane*) woodlands and bush group landforms, of which the lowest areas are subjected to seasonal flooding.

Land System 8.1. LS 8.1 made up the most elevated position of the landscape and is described adequately above within points 1 and 2.

Land System 8.2. LS 8.2 includes river valleys, basins and lower Machili as outlined in point 4.

Land System 8.3. LS 8.3 comprises channels, ox-bows and overflow plains of the Zambezi river between Sesheke and Mwandi. It resembles the lower areas of the Bulozi floodplain (LR 9). Its occurrence within Zambia is only the northern tip of a more extensive floodplain to the south and south-east within the Caprivi Strip.

Land System 8.4. LS 8.4, much the same as LS 7.1, is characterized by open woodlands to bush group woodlands, caused by high water tables, and forms a rim to the lower lying southern arm of LS 8.6.

Land System 8.5. LS 8.5 exhibits the unusual phenomenon of a regular pattern of long linear sand plains separated by belts of *Acacia-Combretum* type bush group savanna or *Terminalia sericea* woodland. This patterning seems to hint at the aeolian influence of deposition of sand dunes in ancient times. The patterning is also seen to a lesser extent in LS 6.5 and is very extensive in the far south-east corner of Angola and Caprivi Strip beyond the Kwando-Mashi river. A possible genesis could be as proposed for an old dune landform in north-west Nigeria (Zonneveld *et al.* 1971). The sand plains represent the eroded remnants of the old dune. Their level above the water table is not high enough to allow tree growth (water tables 2.0 m deep during the dry season 1984 (Jeanes 1985)). The bush group belts were the hollows between the dunes. With the subsequent flooding of the area, silt and fine soil deposition built up the soil surface, and provided fine particles of soil to be utilized by termites to form termitaria high enough to allow tree growth.

Land System 8.6. The general nature is a complex mosaic of bush group, savanna, pans and patches of sand plain. Linear dunes are not seen, possibly as a result of more frequent flooding, eroding the pattern away. The interlinking pans of the system suggest that this system may be the lowest lying "drainage line" of the Siloana plains.

Land System 8.7. LS 8.7 encompasses an ancient floodplain of a river system (Verboom 1965; Verboom and Brunt 1970). Rare flooding occurs with waters flowing from the Kwando-Mashi river to the Zambezi in years of exceptionally high rainfall. The linear west-east plain may also have been a fault formed trough, and once been a floodplain like the Bulozi. Further faulting could easily have re-routed the original river course, leaving the plain high and dry.

Land Region 9: Bulozi Floodplain

LR 9 is an annually flooded plain with a complexity of recent and older alluvial features. It has a broad upper level which only exists east of the Zambezi river (LS 9.1). Further south this upper level appears quite narrow. The remaining landscape (LS 9.2) is a complex mixture of pools, swamps, ox-bows, old and recent channels, old and recent level banks and an occasional broader expanse of lower level plain.

Discussion

Vegetation is the major feature on which to base land classification in the WP for the following reasons: 1. Vegetation is the main factor of concern in this present land evaluation for extensive grazing; 2. Vegetation can be an indicator of soil type, relief, hydrology, climate and the influences of man and time; 3. Vegetation can be interpreted through aerial photomosaics and Landsat images.

Units of land classification should each be of comparable size (FAO 1991) and is true for the LR's and LS's. However, in our approach the LU's and LF's differed considerably in size (see Tables 2.3 and 2.4).

Van Gils (1988) described, based on the vegetation, landform and land use, ten preliminary land systems of the WP. The boundaries of his land systems coincide generally with the boundaries of the LR's and occasionally of the LS's of the present study. This coincidence in boundaries is expected because the present study and the study of van Gils were based on the same approach. The major difference was that he did not delineate the Bulozi floodplain separately.

The identified LU's and LF's in the present land classification (Table 2.5) were further divided or lumped on the basis of having different respectively similar typifying of dominant tree or grass species, and is presented in part 2 of this study (Jeanes and Baars 1996).

A land evaluation may answer questions dealing with the actual use of the land such as: How is land currently used? Are existing practices sustainable? etc. The present study dealt with the first two steps of land evaluation, namely land classification, as presented in this paper, and land capability assessment. Data generated in the first step are useful for planning for any land use. Data gathered for the land capability assessment have been restricted to factors influencing land use for extensive grazing (for cattle only) (Baars and Jeanes 1996b). The final step of land evaluation, and hence the answers to the type of questions outlined above, was not part of the present study.

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Chapter 3

Landscapes and grasslands map

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Chapter 3

Landscapes and grasslands map

Abstract

A hierarchical land classification into Land Regions, Land Systems, Land Units and Land Facets was carried out as part of a land evaluation for extensive grazing (based on FAO guidelines). Existing maps and literature were studied to make initial botanical descriptions at Land Unit level. During a field survey, the botanical descriptions were verified or identified if not known. A 1:500,000 map of landscapes and grasslands in colour, describing 71 Map Units (MU's), resulted. The delineation of the MU's was based on landforms; dominant and common tree and grass species; and vegetation structure. The classification of vegetation structure was based on the cover by trees >5m, shrubs <5m and grasses/sub-shrubs <0.5m. The Land Units and/or Land Facets of the land classification were lumped or separated to form MU's, determined by the results of the field survey and the scale of the final map. The MU's also describe scattered and present grass species.

Introduction

In these times of environmental awareness, sustainable land use is promoted worldwide. Similarly, in the Western Province (WP) of Zambia, concern has been raised about possible overgrazing of the rangelands, due to the annual increase in cattle numbers of 2.5% over the last two decades (Cattle census 1990). This gradual increase occurred without knowing the potential carrying capacity of the rangelands in the WP. The existing maps and accompanying reports, as found in many parts of Africa (Fanta 1992), were found either to be incomplete or inaccurate to estimate this potential.

The general approach of the study was, based on FAO guidelines (FAO 1991), to first classify (Chapter 2) and describe the landscape and vegetation and thereafter calculate the potential carrying capacity of the WP (Chapter 4). This chapter describes the vegetation with emphasis on grass vegetation and how this resulted in a 1:500,000 scale landscapes and grasslands map.

Review of earlier landscapes and vegetation maps

The initial study of the region by Trapnell and Clothier (1937; 1957), including the Vegetation-Soil Map produced for this report (Trapnell *et al.* 1962) still provides a useful record of the landform patterns, vegetation and soil units of the region. A second map (Rattray 1960), provides a broad overview and distribution details (1:10,000,000) of the grass types of the Kalahari sands region on a continental scale. In contrast, Peters (1960) added to Trapnell's account a more detailed appraisal of landform and vegetation types of the Bulozi floodplain only. Fanshawe (1961; 1962; 1963a; 1963b; 1964) produced detailed lists of the woody vegetation at district level but detail on grass species are scant and no detailed maps were produced.

The results of the Barotse Ecological Survey (Verboom 1965) were summarized by producing a map of the grasslands and range types of the WP (Verboom 1970), including a list of common grass, sedge and legume species and their frequency of occurrence. Further study resulted in the Land Units Map of the Mulonga and Matabele plains (Verboom 1966b), with supporting data on soils and vegetation which was also included in Verboom and Brunt (1970). Lastly, Verboom (1982) outlined a summary of all his previous works, and added the previously unreported Soil Vegetation Map of the Bulozi floodplain (cross section from Mongu to Kalamba forest, 1:60,000). The latter map with associated legend of soil, vegetation and land units represented the only existing detailed land evaluation of the Bulozi floodplain.

Fanshawe (1971) produced "The Vegetation of Zambia" which concentrated on the woody species and briefly dealt with grassland types. This work largely formed the caption for the 1:500,000 Vegetation Map of Zambia (Edmonds 1976). No further work was done until Jeanes (1985) extended Verboom's land unit mapping approach to the whole area of Senanga District west of the Zambezi (1:250,000). Grass, tree and shrub species lists, among other details, were presented. Mulungushi (1986) continued the land evaluation approach with a study of southern Mongu District.

Although the maps and land capability appraisals of Verboom (1966b; 1982), Jeanes (1985) and Mulungushi (1986), provide examples of comprehensive land evaluations, they covered small parts of the WP. On the other hand, other studies covering the entire province, lacked sufficient detail on grass species to allow a land evaluation for extensive grazing.

Materials and methods

The scale to be used for publication of the final map was determined by 1) the scale of the best available base map, the 1:500,000 vegetation map of Zambia (Edmonds 1976), 2) the scale of available Landsat images and aerial photomosaics, and 3) the need for a practical size for provincial land use planning.

The starting point formed the 1:500,000 preliminary map, based on the results of the land classification (Chapter 2), which was utilized together with existing maps (Edmonds 1976; Jeanes 1985; Verboom 1966b) to plan and position survey sampling sites. During the field trips the preliminary map was continuously updated. Sampling sites were selected to span the maximum number of landforms, vegetation types and vegetation structures (stratified samples), to determine the characteristic vegetation (both trees and grasses), and the within vegetation type variation of grass associations. During the late wet season of 1987 (January-February), 289 sites (Land Units) were described in detail. The grass species composition was assessed for all Land Facets (up to a maximum of 11 grass species per assessment) resulting in 614 assessments. A total of 424 grass specimens were collected and forwarded to the National Herbarium of Zimbabwe for identification. Data collection per site consisted of: marking on aerial photomosaic; general description of woody vegetation type if present; description of position in the landform, usually by a small catena diagram in sites showing variable grass associations due to slope, drainage etc.; description of the grass flora; rating grass species frequency per site using 4 levels of occurrency: dominant (d), common (c), scattered (s), present (p). During the dry season (June to August) another 222 sites were visited. Although these visits were aimed at collecting dry matter of biomass for grazing capacity estimates, they permitted minor adjustments on the map (Table 2.1).

The arrangement of Map Units (MU's) comprised four steps. The first step was to define the Land Unit as lowland, bush group or woodland. The second step was to define the type of Land Unit (LU) (Table 3.1). The third step separated lowland LU's into dry and wet, the bush group were arranged according to the tree species (d or c) found on the mounds, and the woodlands were differentiated according to the vegetation structure. The fourth step divided LU's into MU's according to the grass species (d or c) encountered. Additional data on grass species (s and p) were collected but not used to delineate MU's. The number of observations per LU (614 botanical descriptions in 17 LU's) and the possible delineation at 1:500,000 scale resulted in up to 5 MU's per LU.

Table 3.1 Procedure employed to arrange Map Units.

Step 1	Lowland	Bush group	Woodland
Step 2	Floodplain Dry plain Pan Dambo/tributary River plain	Savanna Bush group	Mopane Munga Teak Kalahari Miombo-Kalahari Transit. Miombo Miombo Cryptosepalum
Step 3	Dry or wet	Dominant/common tree species on mound	Vegetation structure
Step 4	Dominant/common Grass species	Dominant/common grass species intermound plain	Dominant/common grass species

Data on vegetation structure were derived from aerial photographs and assessments made during the field survey. The aerial photo interpretation and assessments in the field were realised unitedly. The description of the vegetation structure followed the ITC approach (van Gils and van Wijngaarden 1984). The woody vegetation units were divided into trees (>5m) and shrubs (<5m). Grasslands and sub-shrubs (<0.5m) formed the third category.

Topographic maps (1:250,000) used were: Libonda 1966; Kaoma 1986; Lealui 1966; Luampa 1985; Senanga 1975; Mulobezi 1973; Luiana 1971; Sesheke 1971. The final map was digitalized and printed (attached as appendix).

Results

The legend was divided into on three categories of LU's: 1) lowlands, 2) bush group savannas and 3) woodlands (Baars and Jeanes 1996a). Each LU generally had 3 to 5 MU's. There were 5 lowland LU's (floodplains; dry plains; pans; dambos/tributaries and river valleys/plains), comprising 22 different MU's. There were 4 bush group savanna LU's (Kalahari savanna, Kalahari bush group savanna, Munga bush group savanna and Miombo bush group savanna) comprising 8 MU's and finally there were 9 woodland LU's (Mopane, Munga, Teak, Kalahari, Mixed Miombo-Kalahari (2), Transitional Miombo, Miombo, *Cryptosepalum*) comprising 36 MU's. There were also 4 composite MU's and 1 MU was not surveyed.

To each MU, a colour, code and hatchure (shading) was assigned, all appearing in the legend and on the map. The dominant tree and/or grass species of each MU are described in the legend (Figure 3.1). A more detailed description is shown in Table 3.2.

The vegetation structure was divided into 12 categories. To express the vegetation structure, for each category a different type of hatchure was used. Grassland and fallow land were not given a hatchure, denoting no or least density of woody vegetation. At the other side of the spectrum, dense forests were given most hatchure, denoting maximum density of woody vegetation. All other categories, savannas and (open) woodlands, were illustrated by intermediate density hatchures (Figure 3.2).

Finally, topographic data were included originating from Edmonds' vegetation map (Edmonds 1976). The resulting map is shown in the Appendix of this thesis.

GRASSLAND

RIVERINE FLOODPLAINS AND INLAND DELTAS

FLOODPLAIN GRASSLANDS

F1 *Echinochloa spp.-Oryza barthii Channel Complex*

F2 *Echinochloa spp.-Mixed Wetland spp.² Low Plains and Floodways*

F3 *Trachypogon spicatus Low Plains ²*

F4 *Loudetia simplex-Themeda triandra Low Plains ²*

F5 *Loudetia simplex Upper Plains to Loudetia simplex-Parinari capensis Dwarf Shrub Savanna*

WATERSHED DRAINAGE PLAINS

WATERSHED AND DRY PLAIN GRASSLANDS

D1 *Loudetia simplex-Tristachya nodiglumis Dry Plains*

D2 *Trachypogon spicatus-Hyparrhenia spp. Dry Plains*

RELICT (DRY) ALLUVIAL AND DUNE LANDSCAPES

D3 *Tristachya nodiglumis Sandplains*

D4 *Eragrostis pallens-E. rigidior Delta Plains and Channels*

PANS: (SUB) CIRCULAR WATERSHED DEPRESSIONS

PAN GRASSLANDS

Mixed Wetland spp.²-Sedge Wet Pans

P2 *Loudetia simplex Dry Pans*

P3 *Trachypogon spicatus-Loudetia simplex Dry Pans*

P4 *Eragrostis spp.-Hyperthelia dissoluta Dry Pans*

UPPER DRAINAGE VALLEYS AND DAMBOS

RIVER VALLEY AND DAMBO GRASSLANDS

Hyparrhenia bracteata-Trichopteryx dregeana Moist Tributary Valleys

V2 *Loudetia simplex-Trachypogon spicatus-Hyparrhenia spp. Plateau Transitional Dambos*

V3 *Loudetia simplex-Monocymbium ceresiiforme-Hyparrhenia spp. Moist Plateau Dambos*

V4 *Hyperthelia dissoluta-Imperata cylindrica Drier Tributary Valleys*

LOWER DRAINAGE VALLEYS

Papyrus spp.-Sedge Riverine Swamps

Mixed Sedge-Andropogon eucomus. Wetland spp.² & Trichopteryx dregeana-Hyparrhenia bracteata Wet Riverplains

Loudetia simplex-Tristachya nodiglumis Dry Riverplains

Loudetia simplex-Themeda triandra Plateau River Valleys

R5 *Eragrostis spp.-Aristida meridionalis Dry Riverplains*

TERMITARIA VEGETATION AND BUSHGROUP SAVANNA

LOWEST WOODED TERRACES (SANDY), ASSOCIATED WITH SANDY PLAINS

KALAHARI (DIPLORHYNCHUS) SAVANNAS

KS1 *Tristachya nodiglumis-Loudetia lanata Diplorhynchus condylocarpon Dry Shrub to Tree Savanna*

KS2 *Loudetia simplex-Monocymbium ceresiiforme Diplorhynchus condylocarpon Moist Shrub to Tree Savannas*

LOWEST WOODED EDGE TERRACES LEVEES (SILTY ALLUVIUM), ASSOCIATED WITH ALLUVIAL PLAINS

MUNGA (ACACIA) BUSHGROUP SAVANNAS

AB1 *Eragrostis lappula-E. stapfii Acacia spp.-Borassus aethiopium Palm Bushgroup Savanna*

AB2 *Eragrostis trichophora-E. heteromera Acacia erioloba-Colophospermum mopane Munga-Mopane Bushgroup Savanna*

LOWEST EDGE TERRACES (SILTY OR TRANSITIONAL), WITH REMNANT (DRIER) SAND PLAINS AND DRAINAGE

AB3 *Eragrostis trichophora-E. heteromera Acacia erioloba-Terminalia sericea Munga Bushgroup Savanna*

AB4 *Hyperthelia dissoluta-Hyparrhenia spp. Acacia spp.² Drainage Line Bushgroup Savanna*

FRINGING EDGES AND ELEVATED TERRACES, ASS. WITH WETTER SANDY DRAINAGE VALLEYS

KALAHARI (BURKEA) BUSHGROUP SAVANNAS

KB *Tristachya nodiglumis Burkea africana-Guibourtia coleosperma and Tristachya nodiglumis Burkea africana-Combretum spp. Bushgroup Savannas*

MIOMBO (JULBERNARDIA) BUSHGROUP SAVANNAS

MB *Trachypogon spicatus-Hyparrhenia spp. Julbernardia paniculata Bushgroup Savanna to Bushgroup Woodland*

WOODLANDS

LOWEST ALLUVIAL TERRACES (CLAYS) AND VALLEY SKELETAL SOILS (LOAMS AND BEDROCK OUTCROPPI

MOPANE (COLOPHOSPERMUM) WOODLANDS

MP1 *Aristida adscensionis-Chloris virgata Colophospermum mopane Woodland ²*

MP2 *Aristida adscensionis-Heteropogon contortus Colophospermum mopane Open Woodland to Tree Savanna*

MP3 *Panicum phragmitoides-Diplachne fusca² Colophospermum mopane Low Woodland to Tree Savanna*

FRINGING LOW TERRACES (TRANSITIONAL), LOAMIER ASSOCIATED WITH SOUTHERN LOW WATERSHEDS

MUNGA (ACACIA) WOODLANDS

A1 *Eragrostis trichophora-Dactyloctenium giganteum Acacia erioloba-Terminalia sericea Scrub Woodland to Bushgroup Woodland*

A2 *Aristida stipitata Acacia erioloba-Terminalia sericea Scrub Woodland to Open Woodland*

A3 *Tristachya nodiglumis Terminalia sericea Open Woodland to Tree Savanna*

SOUTHERN LOW WATERSHED (TRANSITIONAL, LOAM

TEAK (BAIKIAEA) WOODLANDS

Panicum kalaharense-Leptochloa uniflora Baikiaea plurijuga Scrub Woodland to Forest

Panicum kalaharense-Eragrostis trichophora Acacia erioloba-Baphia massaiensis Degraded Scrub Woodland to Bushland Thicket

Aristida stipitata-Eragrostis spp.² Baphia massaiensis-Bauhinia spp. Fallow Shrubland to Bushland

L WEST WOODED TERRACES OF WESTERN PLAIN AND DRAINAGE BASIN LANDSCAPES (ON KALAHARI SAN

KALAHARI (BURKEA-GUIBOURTIA-ERYTHROPHLEUM) WOODLANDS

K1 *Digitaria gazensis-Tristachya superba Burkea africana-Guibourtia coleosperma Woodland*

K2 *Tristachya nodiglumis Burkea africana-Erythrophleum africanum Open Woodland*

K3 *Tristachya nodiglumis Burkea africana-Guibourtia coleosperma Bushgroup Woodland*

K4 *Tristachya nodiglumis Burkea africana-Terminalia sericea Bushgroup Woodlands*

K5 *Digitaria spp.-Aristida stipitata Mixed spp. Fallow Shrubland to Bushland*

CENTRAL AND NORTHERN LOW WATERSHEDS (CENTRAL LOOSE KALAHARI SANDS)

BRACHYSTEGIA SPICIFORMIS-KALAHARI WOODLANDS

Digitaria gazensis-Brachiaria dura Brachystegia spiciformis-Burkea-Guibourtia Woodland

Digitaria milanjiana-Andropogon schirensis Brachystegia spiciformis-Cryptosepalum exfoliatum Bushgroup Woodland

Pogonarthria squarrosa Brachystegia bakerana-Brachystegia spiciformis Bushland to Bushland Thicket

Digitaria spp.-Aristida stipitata Baphia massaiensis-Bauhinia spp. Fallow Shrubland to Bushland

SOUTHERN MEDIUM LEVEL WATERSHEDS (TRANSITIONAL TO UPLAND SANDS)

MIXED MIOMBO (BRACHYSTEGIA-JULBERNARDIA) KALAHARI WOODLANDS

BK5 *Digitaria spp.-Schizachyrium jeffreysii Brachystegia spiciformis-Dialium engleranum-Julbernardia paniculata Woodland*

BK6 *Schizachyrium jeffreysii Dialium engleranum-Brachystegia spiciformis Low to Open Woodland*

BK7 *Digitaria spp.-Schizachyrium jeffreysii Brachystegia spiciformis-Erythrophleum africanum-Julbernardia paniculata Woodland*

BK8 *Schizachyrium jeffreysii Brachystegia spiciformis-Erythrophleum africanum Low to Open Woodland*

BK9 *Mixed Hyparrhenia spp.-Hyperthelia dissoluta and Aristida stipitata/Mixed spp.⁴ Fallow Shrubland to Bushland*

NORTHERN AND CENTRAL MEDIUM TO HIGH LEVEL WATERSHEDS (UPLAND KALAHARI SANDS)

Digitaria milanjiana-Andropogon schirensis Brachystegia spiciformis-B. longifolia-Cryptosepalum exfoliatum Woodlands

Mixed Digitaria spp.-Aristida stipitata to Hyparrhenia spp.-Hyperthelia dissoluta/Mixed spp.⁴ Fallow Shrubland

EASTERN HIGH LEVEL WATERSHEDS OF UPPER PARTS OF ZAMBEZI BASIN (KALAHARI CONTACT SANDS)

TRANSITIONAL MIOMBO (BRACHYSTEGIA-JULBERNARDIA) WOODLANDS

Hyparrhenia filipendula-Andropogon schirensis Brachystegia spiciformis-Julbernardia paniculata-Burkea africana Woodland

Hyparrhenia filipendula-Andropogon schirensis Julbernardia paniculata Open Woodland

Digitaria spp.-Hyparrhenia spp.-Hyperthelia dissoluta/Mixed spp.⁴ Fallow Shrubland to Bushland

EDGE OF THE CENTRAL ZAMBIAN PLATEAU (PLATEAU SOILS, CONTACT SANDS)

MIOMBO (BRACHYSTEGIA-JULBERNARDIA) WOODLAND

Hyparrhenia filipendula Brachystegia spiciformis-B. longifolia Woodland

Hyparrhenia filipendula-Hyperthelia dissoluta Julbernardia paniculata-Uapaca spp. Open Woodland

Hyparrhenia rufa-Pennisetum polystachion Mixed spp.⁴ Fallow Shrubland to Bushland

CRYPTOSEPALUM AND CHIPYA WOODLANDS

Mixed Hyparrhenia spp. Cryptosepalum exfoliatum-Guibourtia coleosperma and Digitaria milanjiana Brachystegia spp.-Cryptosepalum exfoliatum Woodlands

Mixed Hyparrhenia spp.-Digitaria milanjiana Cryptosepalum exfoliatum-Brachystegia spp. Woodland to Pogonarthria squarrosa/Cryptosepalum exfoliatum-Julbernardia paniculata Woodland Thicket

Digitaria milanjiana/Cryptosepalum exfoliatum-Burkea africana-Erythrophleum africanum Bushgroup Woodland

Mixed Digitaria spp.-Pogonarthria squarrosa Guibourtia coleosperma (Chipya) Woodland/Woodland Thicket and Digitaria milanjiana-Hyparrhenia spp. Brachystegia spiciformis (Chipya) Scrub Woodland

Digitaria spp.-Hyparrhenia spp.-Hyperthelia dissoluta/Mixed spp.⁴ Fallow Shrubland to Bushland

Figure 3.1 The legend of the Landscapes and Grasslands Map of the Western Province of Zambia. The Appendix of this thesis shows colours and hatchures of the legend.

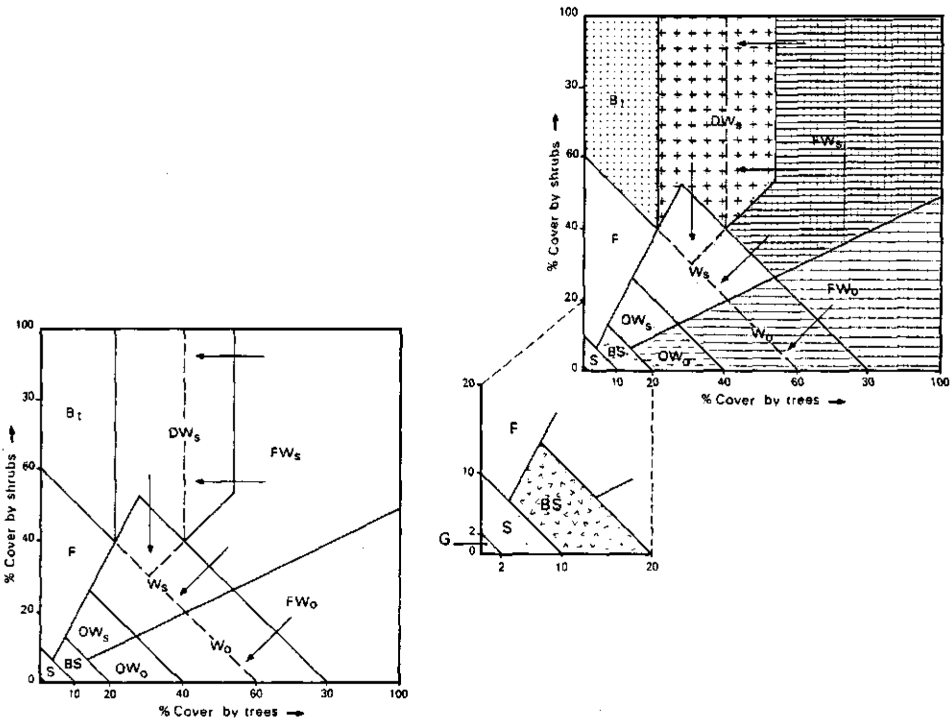

Figure 3.2 Key to the vegetation structure of the landscape and grassland map of the Western Province of Zambia.

Legend to Figure 3.2:

Tree	= a woody plant > 5 m. tall
Shrub	= a woody plant < 5 m. tall
Sub-shrub	= a woody plant < 50 cm., not included in above estimates
G	Grassland to dwarf shrub savanna
S	Tree to shrub savanna
BS	Bush group savanna
OWo	Open to bush group woodland (open)
OWs	Open to bush group woodland (scrubby)
Wo	Woodland (open)
Ws	Woodland scrubby
FWo	Forest/woodland (open)
FWs	Forest/woodland (scrub/thicket)
DWs	Degraded scrub woodland to bush land thicket
F	Fallow shrub land to bush land
Bt	Bush land thicket

Floodplains (F1 to F5)

The duration of the annual flooding is variable and depends on the area and the relative position within that area. The five floodplains delineated show different landforms and dominant grass species related to the extent of flooding. The complicated channel complex (F1) shows the *Echinochloa-Vossia-Oryza* grass association. With increasing elevation (F2), *Themeda triandra* and *Eragrostis inamoena* appear (c) among several typical wetland grasses in the lowest (wettest) areas. Further increase in elevation (F3) results in *Trachypogon spicatus* (d) next to *Themeda triandra* and *Eragrostis inamoena* (c). The highest (upper) floodplains (F4 and F5) are all dominated by *Loudetia simplex* whereas the sub-shrub *Parinari capensis* is scattered. The F4 floodplains carry several other grass species as well, unlike the F5 floodplains.

Dry plains (D1 to D4)

The dry plains, forming vast grazing areas, carry similar dominant grass species as the higher floodplains. They are also flat, but not or seldom flooded. The D1 and D2 plains are dominated by *Loudetia simplex* and *Trachypogon spicatus* respectively. The sand plains (D3) are dominated by *Tristachya nodiglumis* and *Eragrostis* spp. (c). The D4 plains, found on heavier soils (alluvial fan), carry mounds (s) and are dominated by *Eragrostis* spp.

Pans (P1 to P4)

Pans are treeless more or less rounded depressions, usually from a hundred metres to a few kilometres in diameter. P1 pans have permanent water. They sometimes have a seepage zone carrying a *Miscanthidium-Andropogon huillensis* association on the mid to lower slopes. The highest fringe is dominated by *Hyperthelia dissoluta*, which is followed by subsequent zones of *Trachypogon spicatus* and *Monocymbium* above the seepage zone. The dry pans are dominated by *Loudetia* *simplex* (P2) sometimes in association with *Trachypogon spicatus* (P3). P4 pans are, as D4, dominated by *Eragrostis* spp., *Hyperthelia dissoluta* and sometimes other common to dominant species. P4 pans are associated with relatively silty and clayey soils.

Tributaries/dambos (upper drainage lines) (V1 to V4)

The upper drainage lines show variable grass species compositions. V1 and V4 are found in the south-eastern part of the WP, whereas V2 and V3 are found in the north-eastern part. The moist V1 dambos are dominated by *Hyparrhenia bracteata* and *Trichopteryx dregeana*. The dry V4 is dominated by *Imperata cylindrica* and *Hyperthelia dissoluta*. The V2 and V3 are both dominated by *Loudetia simplex*. V2 is drier and *Trachypogon spicatus* occurs (c). The wetter V3 has several common species.

River valleys/plains (lower drainage lines) (R1 to R5)

The wettest lower drainage line (R1) is a swampy river valley dominated by sedges and *Phragmites mauritianis*. The R2 river plains have a characteristic side plain separated from the main valley by a small strip of woodland. No distinct dominant grass species are found. Typical wetland species occur (s to c). In contrast, the drier R3 and R4 river plains have dominant *Loudetia simplex* among other common species. Typical of R3 is *Tristachya nodiglumis* (c) and typical of R4 is *Themeda triandra* (c). The lowest drainage lines in Senanga West (R5) are very dry and dominated by *Eragrostis* spp.

Kalahari savannas (KS1 and KS2)

The drier KS1 savannas have large mounds, more *Burkea africana* trees than KS2 and are dominated by *Tristachya nodiglumis*, *Brachiaria dura* and/or *Elionurus muticus* grasses. The wetter KS2 savannas have small termitaria mounds, scattered *Burkea africana* trees, and *Loudetia simplex* as the dominating grass species.

Munga bush group savannas (AB1 to AB4)

The undulating Munga bush group savannas carry *Acacia* or *Combretum* spp. on the mounds. The mound tops are dominated by *Cynodon dactylon*. AB1 is very distinct in also carrying *Borassus* palms (d), which occur on saline soils. *Eragrostis* spp. are common. AB2 is associated with Mopane woodlands on heavier textured soils. The Mopane is found on the mounds (c) whereas the intermounds are dominated by *Eragrostis* spp. (as D4). The AB3 anthill based bush groups are associated with the Siloana sand plains. They have variable grass species of which *Tristachya nodiglumis* and *Eragrostis* spp. are most common. AB4, associated with upper drainage lines on high water table watersheds, is transitional between AB3 and MB and dominated by *Hyperthelia dissoluta* and *Hyparrhenia* spp.

Kalahari bush group savannas (KB)

The Kalahari bush group carry Kalahari woodland species (see K1 to K5) on the mounds. *Phoenix* palms may be present. The intermounds are dominated by *Tristachya nodiglumis*.

Miombo bush group savannas (MB)

The Miombo bush group carry Miombo woodland species (see M1 to M3) on the mounds next to *Uapaca* spp. (d). The intermounds are dominated by *Hyparrhenia* spp., *Brachiaria brizantha* and *Loudetia simplex*.

Mopane woodlands (MP1 to MP3)

The occurrence of Mopane (*Colophospermum mopane*) (d) decreases from MP1 to

MP3. MP1 is defined as woodland, MP2 as open woodland to savanna and MP3 as low woodland to savanna. The grass cover is sparse in all three vegetation types. *Aristida adscensionis* is present in MP1 and MP2 among other species (p). The grass cover of MP3 is slightly higher with several scattered species.

Munga woodlands (A1 to A3)

The Munga woodlands have a scrubby appearance. The woodland to bush group (A1) is dominated by *Acacia erioloba* among other *Acacia* spp., *Combretum* spp. and *Terminalia sericea* (c). A2 has the same tree species composition, but with a more open woodland structure than A1. A3 is an open woodland to tree savanna with *Terminalia sericea* as the dominant tree species. Due to several degrees of openness, the grass composition is variable. In all tree MU's, *Digitaria* spp., *Eragrostis* spp. among many other species are common to scattered. The more open A2 and A3 carry the sub-shrub *Parinari capensis* (s).

Teak woodlands (T1 to T3)

The Teak MU's are delineated on the degree of disturbance. The undisturbed Teak forest (T1) is dominated by *Baikiaea plurijuga* (Teak). The degraded Teak (T2) still have *Baikiaea plurijuga* (s to c) but *Acacia* spp. and shrubs as *Baphia massaiensis* are common. The fallow Teak (T3) no longer have Teak trees but shrubs of other species instead. The grass species, generally sparse, also vary between the Teak MU's. In the forest *Leptochloa uniflora* and *Setaria homonyma* are common, in the degraded woodland *Panicum kalaharense*, *Eragrostis trichopteryx* and *Urochloa trichopus* are common and the fallow MU's have a greater variety of grass species.

Kalahari woodlands (K1 to K5)

The distinct tree species of Kalahari woodland are *Guibourtia coleosperma*, *Burkea africana* and *Erythrophleum africanum*. K1 is a proper woodland, K2 is an open woodland, K3 and K4 are bush group woodlands (however, with less open plains than KB). K4 has *Terminalia sericea* (d) next to the Kalahari woodland species. K5 is fallow woodland dominated by shrubs and the typical *Brachiaria dura-Aristida stipitata* grass association. The grass species on the proper and open woodland are variable and no differences between the two MU's were found. The bush group woodlands have *Tristachya nodiglumis* (d) in the open areas (as KB).

Brachystegia spiciformis-Kalahari woodlands (BK1 to BK4)

These woodlands are characterised by dominant *Brachystegia spiciformis* mixed with Kalahari woodland species. BK1 is associated with *Burkea africana* and *Guibourtia coleosperma* in a proper woodland. BK2 is associated with *Cryptosepalum* among other Kalahari woodland species in a bush group woodland. The scattered appearance of grasses in BK1 change to a more common distribution in the open woodlands. BK3 is associated with *Brachystegia bakerana* in a thicket bush land with *Pogonarthria* as the most common grass species. BK4 is a fallow unit with *Baphia massaiensis* and *Bauhinia* spp. This latter unit also carry the *Brachiaria dura-Aristida stipitata* grass association (as K5).

Mixed Miombo-Kalahari woodlands (BK5 to BK11)

Brachystegia spiciformis is common instead of dominant in BK5 to BK11. BK5 is associated with *Dialium engleranum* and *Julbernardia paniculata* in a woodland proper. BK6 is associated with *Dialium engleranum* in a low to open woodland. BK7 and BK8 are as BK5 and BK6, respectively, but with *Erythrophleum africanum* common. BK9 is a fallow unit. The grass flora of this unit was not sampled but is expected to be as BK11. BK10 is associated with *Cryptosepalum* and *Brachystegia longifolia*. *Digitaria gazensis*, *Schizachyrium jeffreysii* and *Elionurus platypus* are the most common grass species in all MU's, although the latter two species are not seen on BK10. BK11 is fallow with *Digitaria* spp., *Aristida stipitata*, *Hyparrhenia* spp. and *Hyperthelia dissoluta* (c).

Transitional Miombo woodlands (MT1 to MT3)

This region occurs as a rim between the Mixed Miombo-Kalahari woodlands on sands to the west and the outcropping plateau landscape of the Miombo woodlands in the north-east. The woodland types retain a structure similar to that of the Miombo, with tall lightly closed (MT1) to slightly open canopies (MT2) of *Julbernardia paniculata* (d) with scattered *Brachystegia longifolia, Cryptosepalum, Burkea africana* and occasional *Pterocarpus angolensus* and *Parinari curatellifolia*. The understorey is generally quite open and sparsely grassy, with more shrubs and grasses in the open woodland. Grading from the Miombo to the west, *Hyparrhenia filipendula* and possibly additional *Hyparrhenia* (*H. hirta* and *H. bracteata*) retain a common distribution whereas species common to the coarse Kalahari sands are more frequently found. More open old fallow woodland (MT3) supports a *Digitaria* spp. cover, with or without *Hyparrhenia-Hyperthelia dissoluta* (s).

Miombo woodlands (M1 to M3)

The undisturbed woodland (M1) is dominated by *Julbernardia paniculata* and *Brachystegia* spp. (*B. spiciformis* and *B. longifolia*). The grass cover below the undisturbed Miombo woodlands is found to be *Hyparrhenia filipendula* (c). The open woodland (M2) on poorly drained soils is dominated by *Julbernardia paniculata* (overstorey) and *Uapaca* spp. (understorey) trees. With higher water tables and more open tree canopy (slopes off main watersheds), the *Hyparrhenia* retains and *Panicum juncifolium* and *Monocymbium* are found in increased frequency. *Hyperthelia dissoluta* (c) also makes appearance. Fallow land (M3) supports a mix of tree regrowth and tall grasslands of which *Hyparrhenia rufa, Pennisetum polystachion* with underlying *Pogonarthria squarrosa* and *Eragrostis* spp. are most common.

Cryptosepalum woodlands (C1 to C5)

The landscape, dominated by *Cryptosepalum exfoliatum* (sub-species *pseudotaxis*), has a broad relatively featureless watershed. There are no major dissecting river valleys, no dambos to speak of, and steep sided, narrow deeply dissecting stream valleys. C1 is closed woodland to forest, C2 closed thicket, C3 is bush group woodland, C4 is a scrubby thicket. Chipya or thicket (C2 and C4) is distinguished from woodland (C1 and C3) because it has considerable more shrubs and small trees. They vary from low and medium height woodlands with thicket understorey to tall closed canopy forests with relatively open understorey (mainly *Copaifera baumiana*, *Baphia obovata* and *Bauhinia macrantha*) and a forest floor layer of sub-shrubs. Trees common to the Kalahari and Miombo woodlands are found scattered. The grass species mixtures are not markedly different from surrounding Kalahari woodlands. However, in most cases the closed canopies of the overstorey and density of understorey trees, shrubs and sub-shrubs produce a characteristically very sparse covering of grass. Although there is little floristic detail available of the fallow unit (C5), it is expected that *Digitaria* spp., *Hyparrhenia* spp. and *Hyperthelia dissoluta* will be the common species.

Discussion

Grass floristics

According to Verboom and Brunt (1970), the WP carry a fairly uniform and distinctive grass cover, despite the wide range of associated woodlands. Indeed, variations in upland soil types seemed to have little influence on grass species groupings and little changes occurred in passing from Miombo to Kalahari woodland, and from north (wet) to south (dry). However, in the present study variable grassland floristics were found. The major influence appeared to be factors of vegetation structure, such as canopy cover, shading and density of understorey. These features often vary due to differing degrees of disturbance, or stages of regrowth, when the woodland is regenerating from fallow. With respect to dambos, pans and river plains, grass associations appeared mainly governed by water table depth, flooding height and minor textural changes in soil.

The grass floristics of the *Miombo and Mixed Miombo-Kalahari woodlands* received considerable attention in previous work (Rattray 1960, Trapnell and Clothier 1957) and correspond well with the floristics of the present study. Verboom (Verboom and Brunt 1970, Verboom 1970) had a tendency to provide grass species details predominantly for cleared or fallow regrowth sites. Subsequently, his portrayal of the grass flora of the woodlands differs from that of Trapnell and Clothier (1957) and the present study.

The *Cryptosepalum* vegetation carried grass species mixtures not markedly different from surrounding Mixed Miombo-Kalahari woodland. However, the closed canopies of the overstorey trees and the dense understorey trees, shrubs and sub-shrubs produced a characteristically very sparse cover of grass.

The past work of Rattray (1960) and Trapnell and Clothier (1957) provide no details of the grass cover of the Teak and Munga woodlands. Verboom and Brunt (1970) provided species lists, yet gave no idea of the general characteristics of the species make-up. However, the grass composition found in degraded Teak in the Sioma-Ngwezi National Park, compares well with the data of Jeanes (1985) of similar degraded Teak near the border with Angola, supporting a *Dactyloctenium* (c), *Panicum* (c), *Eragrostis* (s), *Digitaria* (s) grass cover.

The grasslands of Western Zambia are placed into the broader framework of *Loudetia* grassland type associated with woodlands as also found in eastern Angola and south-western Zaire, with the exception of Miombo woodland associated with the *Hyparrhenia* grassland type (Rattray 1960). Beyond the headward point of the Zambezi river (south-east), Rattray described *Aristida* grasslands associated with the *Acacia*/Mopane savannas of the lower valleys and basins.

To the south-west, Rattray (1960) and Verboom (1970) grouped these dry savannas into the *Loudetia*/Barotse Sand grasslands. Apart from the affinities of the sand plain grasslands and woodlands on higher sandier ridges to the *Loudetia* grassland, the remaining vegetation on heavier textured sands, showed more affinities to the *Eragrostis* grasslands of the drier savannas of Namibia (Müller 1984), northern Botswana (Rattray 1957, Skarpe 1986) and south-west Angola. Thus the Transvalian Savanna/Angolan Sector boundary delineated by Rattray (1960) should be drawn further north, in such a way that the drier Munga and Teak woodlands of the south-west are classified as *Eragrostis* rather than *Loudetia* grasslands.

The landscapes and grasslands map

The scale of the final map (1:500,000) permitted mapping of Land Regions, Land Systems and Land Units (levels 1 to 3) as described in part 1 of this study (Baars and Jeanes 1996a). It did, however, not always permit mapping of Land Facets (level 4), especially not for lowland facets.

Woodland clearing practices, mainly for cassava cultivation, have produced a mosaic of fallow land, at various stages of succession back towards mature woodland. WP woodlands show widespread influences of this process. An attempt was made to take this feature into account by including fallow MU's.

The Soil Map of Zambia at 1:4,000,000 (Soil Survey Unit 1983) is the only recent attempt at re-mapping the soils of the whole province. Many of the boundaries are delineated in terms of landscape and vegetation type (Veldkamp 1984). When accompanying the Soil Survey Unit on field trips, correlations between vegetation and soil were difficult to make.

The present map enables users to obtain an inventory of natural resources of the WP. Consequently, the map is a suitable tool to assist personnel of the Departments of Agriculture, Natural Resources, Forestry, Veterinary and Tsetse Control Services, and Land Use Planning in present and future activities.

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Table 3.2 Botanical description per Map Unit (code) of the landscapes and grasslands map. d = dominant, c = common, s = scattered, p = present.

Code	Topography	Grass vegetation	Tree vegetation
F1	Ox-bows Shallow channels Levee banks	Echinochloa colonum (c) Echinochloa pyramidalis (c) Echinochloa stagnina (c) Vossia cuspidata (c) Oryza barthii (c) Phragmites mauritianus (p)	Absent
F2	Low plains Floodways Higher than F1 Lower than F3	Themeda triandra (c) Eragrostis inamoena (c) Trachypogon spicatus (s) Loudetia simplex (s) Typical wetland species: Acroceras macrum (s) Echinochloa spp. (s) Hemarthria altissima (s) Leersia hexandra (s) Sacciolepis typhura (s) Panicum repens (s) Paspalum scrobiculatum (s) Sorghastrum nudipes (s) Setaria sphacelata (s) Vetiveria spp. (s) Vossia cuspidata (s)	Absent
F3	Low plains Mounds (s) Higher than F2 Lower than F4	Trachypogon spicatus (d) Themeda triandra (c) Eragrostis inamoena (c) Setaria sphacelata (c) Brachiaria arrecta (s) Wetland species as F2	Acacia spp. (p) Borassus spp. (p) on mounds
F4	Low plains Termitaria (c) Higher than F3	Loudetia simplex (d) Themeda triandra (c) Trachypogon spicatus (c) Eragrostis inamoena (s) Brachiaria humidicola (s) Eragrostis lappula (s) Panicum subalbidum (s) Panicum dregeanum (p) Setaria sphacelata (p) Tristachya nodiglumis (p)	Savanna patches Diplorhynchus condylocarpon (s) Burkea africana (p) Parinari capensis (c)
F5	Upper plains	Loudetia simplex (d)	as F4
D1	Dry plains Small termitaria (s) Man-made mounds	Loudetia simplex (c-d) Tristachya nodiglumis (c) Trachypogon spicatus (c) Andropogon eucomus (c) Monocymbium sp. (c) Loudetia lanata (s) Sporobolus subtilis (s) Eragrostis stapfii (p) Eragrostis lappula (p)	tree savanna Diplorhynchus condylocarpon (s) Parinari capensis (s)
D2	Dry plains Mounds (s-c)	Trachypogon spicatus (d) Tristachya superba (c) Hyparrhenia rufa (c) Hyparrhenia filipendula (c) Hyperthelia dissoluta (c) Elionurus sp. (muticus ?) (c) Eragrostis spp. (s) Pogonarthria squarrosa (s) Loudetia spp. (s)	
D3	Sand plains	Tristachya nodiglumis (d) Eragrostis spp. (c-d) Diplachne fusca (c in pans) Digitaria monodactyla (s) Diheteropogon grandiflorus (s) Elionurus platypus (s) Trachypogon spicatus (s) Brachiaria humidicola (s) Loudetia lanata (s) Aristida stipitata (s)	Parinari capensis (c)
D4	Delta plains Mounds (s)	Eragrostis pallens (d) Eragrostis rigidior (d) Panicum dregeanum (c) Aristida meridionalis (c) Aristida stipitata (s) Hyparrhenia spp. (s)	Acacia spp. (p) Combretum spp. (p) Palms (p) on mounds
P1	Wet pans Sometimes seepage zone	Hyperthelia dissoluta (c) Miscanthidium sp. (c) Andropogon huillensis (c) Trachypogon spicatus (c) Monocymbium sp. (c) Brachiaria dura (c) Aristida stipitata (c) Eragrostis spp. (s-c) Panicum dregeanum (s-c) Pools: wetland species as F2 (p)	
P2	Dry pans	Loudetia simplex (d) Panicum dregeanum (p) Eragrostis spp. (p) Trachypogon spicatus (p) Sporobolus subtilis (p) Setaria sphacelata (p) Monocymbium sp. (p)	Parinari capensis (p)
P3	Dry pans Allied to V3 Mounds (s)	Loudetia simplex (c-d) Trachypogon spicatus (c-d) Themeda triandra (s-c) Hyperthelia dissoluta (d on mounds)	
P4	Dry pans Soils with more silt and clay	Hyperthelia dissoluta (c-d) Hyparrhenia filipendula (c-d) Tristachya superba (c-d) Eragrostis heteromera (c-d) Eragrostis lappula (c-d) Eragrostis stapfii (c) Diplachne fusca (c) Panicum repens (c) Setaria sphacelata (s) Cymbopogon caesius (s) Brachiaria humidicola (s) Willkomia sarmentosa (s) Deepest pans as F2	
V1	Moist tributary valleys	Hyparrhenia bracteata (d) Trichopteryx dregeana (d) Imperata cylindrica (d) Hyperthelia dissoluta (c) Andropogon eucomus (s) Setaria sphacelata (s) Aristida spp. (s) Pogonarthria pyramidalis (s) Sedges (s)	Wooded upper slopes
V2	Plateau transitional dambos	Loudetia simplex (d) Trachypogon spicatus (c) Hyparrhenia gazensis (s) Hyparrhenia bracteata (s) Hyparrhenia filipendula (s) Hyparrhenia rufa (s) Sporobolus subtilis (s) Aristida meridionalis (s) Andropogon schirensis (s) Panicum juncifolium (s) Monocymbium ceresiiforme (s) Eragrostis lappula (s) Bottoms: wetland species (s) as F2	Parinari capensis (c) on upper slopes

Table 3.2 (cont)

Code	*Topography*	*Grass vegetation*	*Tree vegetation*
V3	Moist plateau dambos	Loudetia simplex (s-d) Hyparrhenia spp. (s-d) Hyperthelia dissoluta (s-d) Trachypogon spicatus (s-d) Tristachya superba (s-c) Panicum dregeanum (s-c) Trichopteryx dregeana (s-c) Monocymbium (s-c) Brachiaria humidicola (s) Lower plains/bottoms as F2	
V4	Drier tributary valleys	Hyparrhenia diplandra (d) Hyperthelia dissoluta (d) Themeda triandra (d) Trachypogon spicatus (d) Imperata cylindrica (d) Panicum dregeanum (p) Eragrostis lappula (p) Sporobolus macranthelus (p) Wet bottoms as F2 (p)	
R1	Riverine swamps	Phragmites mauritianis (d) Sedges (d) Wetland grasses as F2	
R2	Wet river plain Side plain (c)	Loudetia simplex (c) Monocymbium ceresiiforme (c) Andropogon eucomus (c) Trichopteryx dregeana (c) Sporobolus subtilis (c) Sedges (c) Hyparrhenia bracteata (s) Miscanthidium (s) Eragrostis capensis (s) Wetland grasses as F2	
R3	Dry river plain	Loudetia simplex (d) Monocymbium ceresiiforme (c) Tristachya nodiglumis (c) Hyparrhenia spp. (c) Hyperthelia dissoluta (c) Themeda triandra (p-d) Wetland grasses as F2	Parinari capensis (p)
R4	Dry river plain plateau (Kaoma) Mounds on slopes	Loudetia simplex (d) Monocymbium ceresiiforme (c) Themeda triandra (c) Echinochloa spp. (d in pools) Wetland grasses as F2 Upper catchment as R1	Acacia spp. on mounds
R5	Dry river plain	Eragrostis pallens (d) Eragrostis inamoena (d) Eragrostis rigidior (s) Aristida meridionalis (c) Tristachya nodiglumis (s) Paspalum scrobiculatum (s) Brachiaria sp. (rugulosa?) (s) Hyperthelia dissoluta (s) Hyparrhenia spp. (s) Phragmites australis (c in channels)	
KS1	Kalahari bush group savanna Higher/drier than KS2 Large mounds	Tristachya nodiglumis (c-d) Brachiaria dura (c-d) Elionurus muticus (c-d) Digitaria sp. (c) Pogonarthria squarrosa (c) Uryletrum agropyroides (c) Trachypogon spicatus (c) Loudetia spp. (s)	Parinari capensis (c) Burkea africana (c) Diplorhynchus condylocarpon (c)
KS2	Kalahari bush group savanna Lower/wetter than KS1 Low termitaria mounds	Loudetia simplex (d) Loudetia lanata (c) Aristida meridionalis (c) Trachypogon spicatus (c) Monocymbium ceresiiforme (s) Sporobolus subtilis (s) Tristachya nodiglumis (s) Diheteropogon grandiflorus (s) Panicum fluviicola (p)	Parinari capensis (c) Annona stenophylla (c) Diplorhynchus condylocarpon (c) Burkea africana (s)
AB1	Palm bush group savanna	Cynodon dactylon (d on mounds) Chloris virgata (d on mounds) Tristachya nodiglumis (c) Eragrostis stapfii (c) Eragrostis lappula (c) Eragrostis rigidior (c) Lower level also as F3	Acacia spp. (c) Borassus spp. (c)
AB2	Munga/Mopane bush group savanna Related to D4 and MP1 Higher than MP1	Eragrostis pallens (d) Eragrostis rigidior (d) Panicum dregeanum (c) Aristida meridionalis (c) Aristida stipitata (c) Digitaria sp. (c) Dactyloctenium giganteum (s) Diplachne fusca (c in pools) Setaria sphacelata (c in pools) Brachiaria sp. (c in pools)	Acacia spp. (c) Combretum spp. (c) Colophospermum mopane (c) on mounds
AB3	Munga bush group savanna	Sandy treed mounds as A1 Loamier mounds/intermounds: Panicum coloratum (c) Urochloa sp. (c) Chloris gayana (c) Cynodon dactylon (c) Dactyloctenium giganteum (c) Eragrostis spp. (c) Hyperthelia dissoluta (c) Brachiaria spp. (c) Aristida meridionalis (c) Tristachya superba (c)	Acacia spp. (c) Combretum spp. (c) Burkea africana (c)
AB4	Drainage line bush group savanna	Cynodon dactylon (d on mounds) Hyparrhenia spp. (d) Hyperthelia dissoluta (d) Pogonarthria squarrosa (s) Themeda triandra (s) Imperata cylindrica (s)	
KB	Kalahari bush group savanna	Tristachya nodiglumis (c-d) Hyparrhenia filipendula (c) Trachypogon spicatus (s) Andropogon schirensis (s) Digitaria spp. (s) Eragrostis spp. (s) Aristida transvaalensis (s) Pogonarthria squarrosa (s) Perotis vaginalis (s)	Burkea africana (d) G. coleosperma (d) P. curatellifolia (p) Phoenix palms (p) Erythrophleum (p)
MB	Miombo bush group savanna to bush group woodland	Hyparrhenia rufa (c) Hyparrhenia filipendula (c) Brachiaria brizantha (c) Loudetia simplex (c) Trachypogon spicatus (c) Hyparrhenia newtonii (s) Hyperthelia dissoluta (s) Andropogon schirensis (s)	Julbernardia paniculata (c) Brachystegia longifolia (d) P. curatellifolia (c) Uapaca spp. (d)
MP1	Woodland Lower than AB2	Aristida adscensionis (p) Chloris virgata (p)	Colophospermum mopane (d)
MP2	Open woodland to tree savanna	Aristida adscensionis (p) Heteropogon contortus (p) Various unidentified spp. (p)	Colophospermum mopane (d)

Table 3.2 (cont)

Code	Topography	Grass vegetation	Tree vegetation
MP3	Low woodland to tree savanna	Panicum phragmitoides (s) Eragrostis rotifer (s) Tristachya lualabaensis (s) Dichanthium annulatum (s) Setaria sphacelata (s) Diplachne fusca (s) Echinochloa colonum (s) Brachiaria humidicola (s)	Colophospermum mopane (d)
A1	Scrub woodland to bush group woodland	Digitaria milanjiana (c) Urochloa trichopus (p-c) Panicum (c) Dactyloctenium giganteum (c) Eragrostis pallens (c) Eragrostis trichophora (c) Schmidtia pappophoroides (p-c) Brachiaria dura (c) Aristida stipitata (c) Panicum dregeanum (s) Panicum kalaharense (s) Brachiaria serrata (s) Cynodon dactylon (s) Eragrostis superba (s) Tristachya superba (s) Hyperthelia dissoluta (s)	Acacia erioloba (d) Acacia spp. (c) Combretum spp. (c) Terminalia sericea (c)
A2	Scrub woodland to open woodland	Digitaria milanjiana (c) Urochloa trichopus (c) Panicum maximum (c) Eragrostis trichophora (c) Schmidtia pappophoroides (c) Aristida stipitata (c) Eragrostis spp. (s)	Acacia erioloba (d) Acacia spp. (c) Combretum spp. (c) Terminalia sericea (c) Parinari capensis (s)
A3	Open woodland to tree savanna	Digitaria gazensis (s) Digitaria brazzae (s) Eragrostis cimicina (s) Tristachya superba (s) Brachiaria nigropedata (s) Schizachyrium jeffreysii (s) Elionurus platypus (s) Aristida stipitata (s) Brachiaria dura (s) Uryletrum agropyroides (s) Rhynchelytrum rhodesianum (s) Tristachya nodiglumis (s) Tristachya rehmannii (s) Ischaemum afrum (s)	Terminalia sericea (d) Acacia spp. (s) Combretum spp. (s) Parinari capensis (s)
T1	Scrub woodland to forest	Leptochloa uniflora (c) Setaria homonyma (c) Panicum kalaharense (s) Panicum dregeanum (s)	Baikiaea plurijuga (d)
T2	Degraded scrub woodland to bush land thicket	Panicum kalaharense (c) Eragrostis trichopteryx (c) Urochloa trichopus (c) Dactyloctenium giganteum (s) Eragrostis curvula (p) Aristida stipitata (p) digitaria sp. (p)	Baikiaea plurijuga (s-c) Acacia erioloba (c) Baphia massaiensis (c) Acacia spp. (s)
T3	Fallow shrubland to bushland	Cenchrus biflorus (c) Eragrostis curvula (c) Eragrostis trichophora (c) Aristida stipitata (c) Cynodon dactylon (c) Eragrostis heteromera (s) Dactyloctenium giganteum (s)	Bauhinia spp. (d) Baphia massaiensis (d)
K1	Woodland	Digitaria gazensis (c) Tristachya nodiglumis (c) Elionurus sp. (c) Elymandra grallata (c) Aristida stipitata (c) Brachiaria dura (c) Andropogon schirensis (c) Pogonarthria squarrosa (c) Tristachya superba (c) Brachiaria nigropedata (c) Loudetia lanata (c) Uryletrum agropyroides (c) Aristida meridionalis (c)	Burkea africana (d) Guibourtia coleosperma (d) Erythrophleum africanum (c) Copaifera bauminia (s)
K2	Open woodland	As K1 and: Tristachya rehmannii (s) Rhynchelytrum nerviglume (s) Schizachyrium jeffreysii (s) Loudetia simplex (s) Panicum juncifolium (s) Sporobolus subtilis (s) Digitaria brazzae (s) Schmidtia pappophoroides (s) Eragrostis cimicina (s) Setaria sphacelata (s) Hyperthelia dissoluta (s Hyparrhenia filipendula (s) Ischaemum afrum (s)	Burkea africana (d) Erythrophleum africanum (d) Guibourtia coleosperma (c) Parinari capensis (c)
K3	Bush group woodland	Tristachya nodiglumis (c) Brachiaria dura (c) Elionurus muticus (c) Digitaria sp. (s) Uryletrum agropyroides (s) Pogonarthria squarrosa (s) Trachypogon spicatus (s) Loudetia simplex (s) Loudetia lanata (s)	Burkea africana (d) Guibourtia coleosperma (d)
K4	Bush group woodland	Tristachya nodiglumis (c) Tristachya superba (c) Elionurus muticus (c) Hyperthelia dissoluta (s) Digitaria sp. (s)	Burkea africana (d) Terminalia sericea (d)
K5	Fallow shrubland to bushland	Aristida stipitata (c) Brachiaria dura (c) Digitaria spp. (c) Hyparrhenia spp. (s) Hyperthelia dissoluta (s) Aristida meridionalis (s) Eragrostis spp. (s)	Baphia massaiensis (c) Bauhinia spp. (c)
BK1	Woodland	Brachiaria dura (s) Digitaria gazensis (s) Digitaria gayana (s) A. schirensis (s) P. squarrosa (s) Aristida stipitata (s) Tristachya spp. (s) Rhynchelytrum nerviglume (s) Sartidia angolensis (p)	Brachystegia spiciformis (c) Burkea africana (c) Guibourtia coleosperma (c)
BK2	Bush group woodland	Andropogon schirensis (c) Digitaria milanjiana (c) Digitaria diagonalis (c) Tristachya nodiglumis (c) Brachiaria dura (s) Elionurus sp. (s) Uryletrum agropyroides (s) Sartidia angolensis (p) Panicum juncifolium (p)	Brachystegia spiciformis (c) Cryptosepalum exfoliatum (c)
BK3	Scrubby woodland and thickets allied to C2/C4	Pogonarthria squarrosa(s) Brachiaria dura (p) Digitaria gayana (p) Aristida stipitata (p)	Brachystegia spiciformis (c) Brachystegia bakerana (c)

Table 3.2 (cont)

Code	Topography	Grass vegetation	Tree vegetation
BK4	Fallow shrub- and bushland	Aristida stipitata (d) Brachiaria dura (c) Hyperthelia dissoluta (s) Hyparrhenia spp. (s) Aristida meridionalis (s) Digitaria spp. (s) Eragrostis pallens (s) Pogonarthria squarrosa (s) Rhynchelytrum nerviglume (s)	Baphia massaiensis (c) Bauhinia spp. (c)
BK5	Woodland	Digitaria gazensis (s-c) Schizachyrium jeffreysii (s-c) Tristachya superba (s-c) Pogonarthria squarrosa (s-c) Aristida stipitata (s) Triraphis schinzii (s) Urelytrum agropyroides (s) Andropogon schirensis (s) Setaria sphacelata (s) Eragrostis cimicina (s) Digitaria brazzae (s) Brachiaria nigropedata (s) Brachiaria dura (s) Panicum coloratum (s) Schmidtia pappophoroides (s) Elionurus platypus (s)	Brachystegia spiciformis (c) Dialium engleranum (c) Julbernardia paniculata (c)
BK6	Low to open woodland	As BK5 and: Schizachyrium jeffreysii (c-d) Elionurus platypus (c) Hyperthelia dissoluta (s) Rhynchelytrum rhodesianum (s) Tristachya nodiglumis (s) Tristachya rehmannii (s) Ischaemum afrum (s)	Dialium engleranum (c) Brachystegia spiciformis (c)
BK7	Woodland	Digitaria gazensis (c) Schizachyrium jeffreysii (s-c) Elionurus platypus (s-c) Pogonarthria squarrosa (s) Tristachya superba (s)	Brachystegia spiciformis (c) Erythrophleum africanum (c) J. paniculata (c)
BK8	Low to open woodland	Schizachyrium jeffreysii (c) Elionurus platypus (c) Tristachya superba (s) Pogonarthria squarrosa (s) Digitaria spp. (s)	Brachystegia spiciformis (c) Erythrophleum africanum (c)
BK9	Fallow shrubland to bushland	Hyparrhenia spp. (c-d) Hyperthelia dissoluta (c-d) Aristida stipitata (c-d)	Shrubs
BK10	Woodland	Digitaria gazensis (s-c) Digitaria milanjiana (s-c) Andropogon schirensis (s-c) Diheteropogon amplectens (s-c) Tristachya superba (s-c) Pogonarthria squarrosa (s-c)	Brachystegia spiciformis (c) B. longifolia (c) Cryptosepalum (s)
BK11	Fallow shrubland	Digitaria eriantha (d) Digitaria gazensis (d) Digitaria gayana (d) Tristachya superba (c) Hyperthelia dissoluta (p-c) Hyparrhenia spp. (p-c) Other spp. of BK10 (p)	Shrubs
MT1	Woodland	Hyparrhenia filipendula (c) Hyparrhenia hirta (c) Hyparrhenia bracteata (c) Tristachya superba (c) D. amplectens (c) Digitaria spp. (c) Eragrostis nindensis (s) Pogonarthria squarrosa (s) Brachiaria serrata (s) Anthephora elongata (s) Tristachya rehmannii (s)	Burkea africana (c) Brachystegia spiciformis (c) Julbernardia paniculata (c)
MT2	Open woodland	As MT1	Julbernardia paniculata (c)
MT3	Fallow shrub- to bushland	Digitaria gayana (c) Digitaria eriantha (c) Hyparrhenia spp. (s) Hyperthelia dissoluta (s) Tristachya spp. (s) Eragrostis spp. (s) Aristida meridionalis (s) Pogonarthria squarrosa (s)	Shrubs
M1	Woodland	Hyparrhenia filipendula (c) Andropogon schirensis (s) Hyparrhenia hirta (s) Diheteropogon amplectens (s) Panicum juncifolium (s) Monocymbium ceresiiforme (s) Digitaria sp. (s) Schizachyrium sp. (s)	Julbernardia paniculata (d) Brachystegia spiciformis (d) Brachystegia longifolia (d)
M2	Open woodland	Hyparrhenia filipendula (c) Panicum juncifolium (c) Monocymbium ceresiiforme (c) Hyperthelia dissoluta (c) Hyparrhenia spp. (s) Tristachya spp. (s) Trachypogon spicatus (s) Brachiaria brizantha (s)	Julbernardia paniculata (d) Uapaca spp. (d)
M3	Fallow shrub- to bushland	Hyparrhenia rufa (c) Pennisetum polystachion (c) Pogonarthria squarrosa (c) Eragrostis spp. (c) Hyparrhenia spp. (s)	Shrubs
C1	Woodland	Digitaria milanjiana (s) Hyparrhenia filipendula (p-s) Anthephora elongata (p) R. nerviglume (p) Pogonarthria squarrosa (p) Melinis ambigua (p) Sporobolus cordofanus (p) Brachiaria brizantha (p) Andropogon schirensis (p)	Cryptosepalum exfoliatum (d) Brachystegia spp. (c) Guibourtia coleosperma (c) common shrubs: Copaifera bauminia Baphia obovata Bauhinia macrantha
C2	Woodland thicket	As C1	Cryptosepalum (d) Brachystegia spp. (c) J. paniculata (c)
C3	Bush group woodland	Digitaria milanjiana (s) Digitaria diagonalis (p) Anthephora elongata (p) R. nerviglume (p) Pogonarthria squarrosa (p) Andropogon schirensis (p) Tristachya superba (p) Elionurus muticus (p) Loudetia lanata (p) Monocymbium ceresiiforme (p)	Cryptosepalum (d) Burkea africana (c) Erythrophleum africanum (c)
C4	Woodland thicket (Chipya) allied to BK3	Anthephora elongata (p) Digitaria gazensis (p) Digitaria diagonalis (p) R. nerviglume (p) Megastachya mucronata (p) Hyparrhenia spp. (p) Pogonarthria squarrosa (p)	Brachystegia spiciformis (c) Guibourtia coleosperma (c)
C5	Fallow shrub- to bushland	Hyperthelia dissoluta (s) Hyparrhenia spp. (s) Digitaria spp. (s)	Shrubs

Chapter 4

Carrying capacity

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Tropical Grasslands (accepted)

Chapter 4

Carrying capacity

Abstract

A land evaluation was conducted with the overall objective to estimate the total number of cattle which could theoretically be carried on natural grasslands. Grazing management systems were surveyed. Calculations of grazing capacities were designed to simulate forage selection by cattle.

Two transhumance and two sedentary grazing management systems were described. The calculated carrying capacity (CC) of one transhumance system was close to the actual number of cattle present. In the other systems, the calculated CC's greatly exceeded actual stocking rates. The total provincial CC was estimated at 1,075,000 Tropical Livestock Units.

There is room to increase cattle numbers by about 500,000 head. Surface water development could further increase the CC by about 200,000 head. Furthermore, increasing the grazing time to more than 9 hours per day and more transhumance could increase the CC even more.

Introduction

The Kalahari sands of western Zambia represent both a unique environment in Central Africa and unique development problems for Zambia. Of the latter, those pertaining to agriculture stem largely from the nature of the soils, which are generally infertile sands of low moisture and nutrient holding capacity. Combined with climatic difficulties such as frosts, unreliable rainfall distribution, flooding and waterlogging, most of the land area is unsuitable for arable agriculture. On the other hand, the potential for livestock production is much greater.

In terms of regional and national economic significance, the livestock sector constitutes the major income earner for the region. The Western Province (WP) of Zambia in 1990 had 547,000 head of cattle (Cattle census 1991). Also, from the point of view of the 607,000 inhabitants of the WP (Census 1990), the socio-economic importance of livestock cannot be overstated. Although not all families own cattle, milk provides an important nutritional input; oxen the only affordable draft power; kraal manure the only fertilizer; and cattle sales the only readily available year round source of cash.

Given the importance of livestock in the region, an appraisal of rangeland resources was deemed necessary. The overall objective of the study was to estimate the theoretical carrying capacity (CC) of grazing cattle on the rangelands of the WP and to identify areas which have exceeded or are approaching the calculated CC.

The study covered two parts. Firstly, a land classification was conducted (Baars and Jeanes 1996a) including a detailed vegetation description (Jeanes and Baars 1996). The results of the second part of the study, an assessment of the prevailing grazing management systems and their CC's, are presented in this paper.

Materials and methods

Precipitation

The year to year variation in the amount of rainfall in the WP is small compared to (semi-)arid regions. The 1986/87 wet season preceding the survey period was quite dry throughout the WP as compared to average data (Table 4.1). The rainfall pattern was normal with rains occurring between October and April. The wet season is followed by 3 months cold-dry season which is subsequently followed by a 3 months hot-dry season (Verboom and Brunt 1970).

Table 4.1 Rainfall (mm/yr) of 4 district capitals for the 1986/87 season and long term averages (Av) (>54 yrs).

District	*1986/87*	*Av*
Kaoma	703	941
Mongu	766	947
Senanga	430	781
Sesheke	554	695

Source: Dpt. Meteorology, Mongu

Land Classification

The Land Systems approach (Dent and Young 1981), which utilizes a hierarchical system of Land Regions, Land Systems, Land Units and Land Facets, was carried out using mid- to late-wet season false colour Multi-Spectral Scanner Landsat images of 1986. Clarification of details was assisted through reference to Landsat images of various previous years. The resulting 1:500,000 draft map was utilized together with existing maps to plan and position survey sampling sites. Areas of Land Regions and Land Systems were calculated (Baars and Jeanes 1996a).

Grazing Management Systems

A questionnaire survey was conducted among Veterinary Assistants to find out whether cattle are taken elsewhere due to: flooding of the lowlands; cropping; burning; availability of drinking water at the end of the dry season.

Four grazing management systems (GMS) were assessed (Figure 4.1). GMS 1 and 2 were transhumant systems with annual movements up to 40 km away from the main villages. In the dry season the floodplains and during the wet season the surrounding woodlands were grazed. Sedentary systems, GMS 3 and 4, were found in the greater part of the WP. Nevertheless, some herds in the transhumant zones were sedentary while in sedentary systems movements of cattle over short distances occurred.

Grazing on the floodplain of GMS 1 was restricted from around January to June, due to flooding. During the floods almost all cattle grazed on the upland woodlands, pans, river plains, tributaries and plain edge. During the dry season cattle were rarely found outside the floodplain. In GMS 1 shortage of feed supply was most evident at the end of the floods.

In GMS 2, transhumance of a smaller but substantial number of cattle occurred due to water shortages on the uplands: herds were forced to shift to better watered floodplain areas in the dry season. In GMS 2 shortage of forage was most evident during the dry season.

In GMS 3 dry season grazing concentrated on pans, treeless depressions called dambos and river valleys, whereas in GMS 4 dry season grazing was found on large plains. The sedentary systems 3 and 4 had poorest feed supply during the dry season.

Figure 4.1 Grazing Management Systems of the Western Province of Zambia: transhumant 1 + 2, sedentary 3 + 4.

Quantity and quality of DM

The vegetation was sampled from early June through to early August 1987, at a stage when some patches of grass still revealed the initial ungrazed standing crop and late enough to record the lower levels of fodder quality in the dry season. At all the 137 detailed sample sites and 85 descriptive sample stops, the landform and woody vegetation, classified in overstorey trees, understorey trees, shrubs and sub-shrubs were described.

The characteristic grass cover of the WP is one of medium height grasses (1.0 to 1.5 m) with sward density chiefly influenced by landscape position and tree/shrub density. To estimate available dry matter (DM) of relatively uniform grass covers, a set of portable reference samples was taken along to enable estimations (3 to 7 per site). The set comprised samples of 12.5, 25, 50 and 100 g DM and referred to 0.5, 1, 2 and 4 t DM/ha respectively. For sites in which different vegetation types occurred, estimates were made using the Comparative Yield Method (Haydock and Shaw 1975). The samples were split into standing crop (SC) and green pluck samples of standing crop (GP) (simulated bites).

In case the vegetation was burnt, 0.25 m^2 quadrats were randomly placed and clipped to estimate phytomass of regrowth after burning (RE). Areas of burnt vegetation were estimated visually.

Forage samples for chemical analysis, 148 for N and 49 for *in-vitro* digestibility and P, were designed to sample the most frequently occurring grass associations and/or grass species.

Level of DM consumption in relation to quality

The level of consumption of DM depends largely on palatability (Roberts 1987), the availability of green leaf within a grass sward ('t Mannetje 1984) or sward structure, availability of leaf and density of leaf (Stobbs 1973). Selection of green leaf within a sward canopy can be extreme (Chacon and Stobbs 1976). A simple model (Figure 4.2), relating crude protein (CP) concentration of forage with level of consumption, was assumed, in the knowledge that cattle rely on selective grazing to survive the conditions of sub-maintenance feed offered. The model assumes that the better the quality of the forage, the higher the proportion of forage that can be consumed.

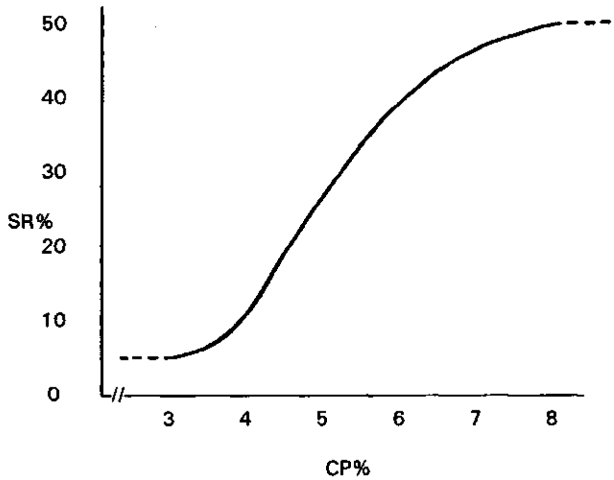

Figure 4.2 Selection rates of DM (SR) in relation to crude protein levels of grass. For $CP<4.25$: $Y=6.4X^2-38.4X+62.6$ and for $CP\geq4.25$: $Y=-2.5X^2+39.8X-109$.

The model was validated using data from the most common land units, as reported by Verboom and Brunt (1970) and Jeanes (1985). The CP concentration of 3% of a particular SC, resulted in a selection of 5% of the DM and the CP concentration of RE in 50%. The maximum utilization was set at 50% based on consumption levels reported for good quality forage in arid regions (de Leeuw and Tothill 1993).

Grazing and carrying capacity

Grazing capacity (GC) was defined as the maximum stocking rate that a range can support without deterioration. CC was defined as the maximum number of animals that can survive the greatest period of stress each year on a given land area (FAO 1991). The definitions pertained to cattle as this is the main livestock type kept in western Zambia.

The calculations of GC's were based on CP requirements and availability during the mid-dry season. In woodlands, the contribution of browse in the diet was assumed to be 10% with a CP concentration of native browse of 12.5% (Bayer 1990). For each Land Unit (60 in total)[1], the assessed DM and CP of both SC and GP and their respective selection rates (Figure 4.2) resulted in available CP per ha. Similarly, the amount of CP per ha of RE was assessed.

Results were expressed in terms of Tropical Livestock Units (TLU) weighing 250 kg with a daily DM intake of 2.0% of live weight (FAO 1991). The assumed CP concentration of 6.5% required in feed DM accounted for a slight weight loss. Phosphorus requirements were not considered.

CC's were calculated per Grazing Management System in order to account for cattle movements and different periods of range utilization. To assess the areas without surface water at the end of the dry season, data were obtained from District Veterinary Officers, from maps of ground water levels and aerial photographs. Areas more than 8 to 10 km away from water sources were considered out of reach for cattle and therefore to have a zero CC (FAO 1991). Due to the grazing management practised, where cattle graze for only 9 hours per day, a limit of 8 km was used in this study.

About 7% of the WP is dedicated to National Parks, and cannot be grazed by cattle and consequently has a zero CC.

Results

Grazing capacities

The SC on the upland woodlands ranged from 0 to 2.0 t DM/ha. As the vegetation in the woodlands showed no green material in the mid-dry season and as there was no regrowth after burning, there were no values of GP and RE (Table 4.2).

The SC on the lowlands ranged normally from 1.5 to 4.0 t DM/ha but occasio-

[1] These Land Units refer to the 66 Map Units described in Figure 3.1. The 11 BK units have been lumped to 5.

Table 4.2 Ranges of DM (t/ha) of standing crop (SC), green pick (GP), regrowth after burning (RE) and mid-dry season grazing capacities (TLU/ha) of the main land units (LU) of the WP.

LU category	*LU/ category*	*SC*	*GP*	*RE*	*Grazing Capacity*
flood plains	5	2.0-6.0	0.4-1.8	0.0-0.2	0.11-2.13
dry plains	4	2.0-3.5	0.0-0.7	0.0-0.4	0.08-0.31
pans	4	1.5-3.0	0.0-0.9	0.1-0.2	0.06-0.22
dambos	4	2.0-4.5	0.1-1.4	0.0-0.3	0.10-0.83
river plains	5	2.5-4.0	0.1-1.2	0.0-0.2	0.14-0.67
tree savannas	2	1.5-2.0	0.1-0.2	0.1-0.1	0.10-0.26
bushgroup savanna	6	1.5-4.0	0.1-0.3	0.0-0.1	0.10-0.29
normal woodland	10	0.2-1.0	-	-	0.03-0.07
open/fallow wdl	15	0.2-2.0	-	-	0.02-0.15
forest/thicket	5	0.0-0.2	-	-	0.00-0.03

nally a much higher quantity occurred, especially in floodplain channels with the floating mass of *Echinochloa* spp. and *Vossia cuspidata* (up to 40 t DM/ha). The percentage GP of various SC's on the lowlands was quite variable. The range was from 0% in a dry *Eragrostis* spp. sward to 30% in wetter dambo/river plain bottom swards. The regrowth available after burning of the more elevated *Tristachya nodiglumis* dominated plains was up to 0.4 t DM/ha RE. All other land units yielded less.

There was a significant difference ($p<0.01$) between CP concentrations of SC, GP and RE (Table 4.3) during the mid-dry season. Within the SC there was also a significant difference ($p<0.05$) between grasses growing in the lowland (2.5-3.0%) as compared with grasses of the upland woodland (3.0-3.5%). However,

Table 4.3 Mid-dry season quality (as % of DM) of standing crop (SC), green pick (GP) and regrowth after burning (RE). Means of all land units. In brackets standard deviation and number of observations respectively (sd/n).

	SC	*GP*	*RE*
Crude protein	2.9 (1.1/91)	5.1 (1.6/37)	8.3 (2.4/20)
Digestibility	38 (6.9/23)	45 (9.7/18)	57 (4.9/8)
Phosphorus	.08 (.04/23)	.11 (.05/18)	.16 (.04/8)

the overall quality of forage on the lowland was better because in the woodland the GP and RE after burning were negligible.

In Table 4.2, land units with the lowest and highest GC of a particular category are shown. Floodplain GC's ranged from 0.1 TLU/ha on *Parinari capensis* (sub-shrub) upper plains to 2.1 TLU/ha in the channels (with the palatable *Echinochloa* spp.-*Vossia cuspidata* grass association). The GC's of the other lowland land units were less and ranged from 0.1 (driest pans) to 0.8 TLU/ha (wet dambos).

Upland (woodland) GC's were low and ranged from 0.0 to 0.2 TLU/ha. *Cryptosepalum exfoliatum* forest/thicket had, in general, GC's too poor to support grazing cattle.

Burning the lowlands changed their GC's only slightly. Burning the woodlands, however, decreased their GC's considerably.

Carrying capacities

A CC of 1,075,000 TLU was calculated for the entire WP of unburnt vegetation and 889,000 under conditions of uncontrolled burning (Table 4.4).

The uplands covered 68% of the WP, whereas lowlands (dambos, pans, plains, valleys) covered the remaining 32%. However, these lowlands could carry 70% of the total calculated capacity.

For the entire WP, about 36% (4.3 million ha) was found to have a zero CC due to a lack of drinking water for cattle.

Table 4.4 Actual cattle numbers in 1990 (1), calculated carrying capacities without (2) and with (3) control of burning and potential average stocking rates (SR) per grazing management system (GMS). 1, 2 and 3 in TLU*1000.

GMS	*(1)*	*(2)*	*(3)*	*Area (ha *1000)*	*SR (TLU/ha)*
1 Bulozi Plain System	196	267	288	1,900	0.152
2 Sesheke System	39	33	37	500	0.074
3 Eastern Valley System	137	397	528	5,700	0.093
4 Western Plain System	175	192	222	4,000	0.056
Total	547	889	1075	12,100	0.089

Discussion

Equilibrium versus disequilibrium

The traditional concept of CC, as used in the present study, only applies to systems in equilibrium (Behnke *et al.* 1993). Systems having less than 400 mm of annual rainfall are under abiotic control in relation to water (Noy-Meir 1973). Under these conditions, primary production and livestock populations, fluctuate widely, and non-equilibrium dynamics will predominate (Ellis and Swift 1988). Above 400 mm of annual rainfall the most limiting factor in growth of grasses will be the nitrogen content of the soil and not so much the rainfall (de Ridder and Breman 1993). In the relatively stable environment of the semi-arid Borana system in southern Ethiopia, with 400-800 mm of annual rainfall, the fundamental pattern is one of equilibrium, and equilibrium concepts such as CC are therefore analytically useful in the context of these environments (Coppock 1993). Over a long time perspective, the semi-arid conditions of southern Zimbabwe resulted in both non-equilibrium and equilibrium conditions at different times (Behnke *et al.* 1993). The WP of Zambia with relatively high annual rainfall, 700 to 1200 mm, is considered to be a system in equilibrium.

There are other factors indicating the equilibrium status of the WP. Large fluctuations in stock numbers due to periods of prolonged drought as in southern Zimbabwe (Scoones 1993) did not occur in the WP, large fluctuations due to rinderpest, however, did. Annual grasses are insignificant, unlike in regions of disequilibrium, and in the WP no livestock other than cattle is present in significant numbers. Although transhumance over short distances occurs, mainly due to flooding of plains, nomadism and true transhumance as in arid regions, is absent in the WP.

Grazing capacities

The GC vary throughout the year. In the WP, the lowest GC's are encountered in the mid- to late-dry season. Areas with good regrowth might in the late-dry season have a higher GC than in the mid-dry season. Burning in areas with poor regrowth will reduce the GC. Due to the narrow time frame of the present study, the results do not reveal how the GC's of the different land units vary throughout the dry season and among years. Results of such short term studies can be useful guidelines for planning purposes (de Leeuw and Tothill 1993).

To calculate appropriate GC's, the proportion of total herbage that livestock can harvest, the forage loss, and the maximum proportion of forage that can be grazed without deterioration should be known (de Leeuw and Tothill 1993). In practice, a single multiplier that combines these adjustments lies in the range of 30 to 50% for good quality grasses (de Leeuw and Tothill 1993). The present study used this range for grasses with more than 5% CP (GP and RE). Grasses of poor quality (SC) had low multipliers of 5 to 10%.

In moving from north to south within the WP, within similar vegetation/soil types, the assessments revealed no difference in the SC of grass despite the difference in annual rainfall of 1200 mm in the north and 700 mm in the south.

The CP levels of SC were extremely low, which is in agreement with Verboom and Brunt (1970).

There are few reports on GC's of the WP (Verboom and Brunt 1970; Jeanes 1985) which were used to validate the model presented in Figure 4.2. No other data were available. The Bulozi floodplain, an important grazing area, was not sampled in the present survey, but data of Verboom and Brunt (1970), where they used a value of 0.25 TLU/ha, were used for our calculations. It is, however, likely that within this floodplain, GC's also range from about 0.1 to 2.1 TLU/ha, as found in the present study for other (flood)plain areas.

Carrying capacities

The sampling of available DM and CP percentage of forage was carried out in the mid-dry season. However, the bottle-neck period of GMS 1 appeared to be at the end of the flood season. A calculation of the wet season CC of GMS 1, using data of de Bie (1991), resulted in a flood season CC of about 260,000 TLU, which is similar to the dry season CC of around 288,000 TLU.

GMS 2 was the only region in which the calculated CC was close to the actual number of livestock.

Forty-four per cent of the provincial herd was transhumant and the remaining 56% was sedentary (Cattle census 1991). The highest cattle densities were found in the transhumant regions (GMS 1 and 2). The east bank of the Zambezi river (GMS 3) had, in general, a low potential for grazing, although the actual cattle numbers were far below the calculated ones. On the west bank (GMS 4), however, good grazing areas existed with a low cattle population.

Development of water ponds in GMS 4 would increase the calculated CC by about 200,000.

A change in grazing management, be it more hours grazing per day or more transhumance in presently sedentary areas, would increase the CC as well. To move cattle over large distances to thinly stocked rangelands would also solve the problem of currently densely stocked rangelands. This, however, would involve many socio-economic and political difficulties.

The total area infested with tsetse flies is about 3.6 million ha, which is 30% of the WP. A failure of tsetse or trypanosomiasis control programmes would result in zero CC's in infested areas, and would reduce the calculated CC of the WP by 24%.

Implications for further development

The total calculated CC of the WP was 1,075,000 TLU. The number of cattle present in 1990 was 547,000 head (Cattle census 1991). Thus, doubling the Provincial herd seems possible. The likelihood of ecological damage due to cattle grazing is not considered high at present. The level of the cattle population would most likely be constrained by poor nutrition, low management levels, and factors such as drought and disease, before reaching a level high enough to have any lasting widespread effect on the rangelands of the WP.

As far as the growth of the cattle population and overgrazing are concerned, the limits of the CC for the WP would be reached in 30 years. However, such a simplistic interpretation neglects to take into account the impacts of uneven livestock distribution. Moreover, it is doubtful whether a fixed CC is a feasible parameter due to long term climatic fluctuations. A range of potential CC's would be more appropriate (Geerling and de Bie 1987). It would therefore be advisable to focus attention on the monitoring of potential overgrazing or overstocking situations. A vegetation monitoring programme, initiated in 1991 in relatively densely stocked grazing areas, did not reveal overstocking nor overgrazing (Baars *et al.* 1996a).

Aside from the risk of livestock loss in GMS 1 in years of prolonged floods and the fact that GMS 2 has reached its calculated stocking rate, there is scope to increase the cattle population within most regions of the WP. Care should be taken, however, to spread the impact of this expansion as widely as possible. To this end, attempts to develop presently under-utilized grazing resources should begin now. Otherwise, the stagnation of livestock production, the deterioration of grazing areas and an unacceptable risk of livestock death will be inevitable.

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Chapter 5

Rangeland condition in high cattle density areas

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Tropical Grasslands (accepted in shorter version as technical note)

Chapter 5

Range condition in high cattle density areas

Abstract

A range condition appraisal was initiated as part of a vegetation monitoring programme. Ten transects were established and the condition of the rangelands was assessed at three to five sample sites along each transect.

The condition assessment was based on grass species composition, basal cover, litter cover, number of seedlings, age distribution of grasses and soil condition. Age distribution of dominant grasses and soil condition were generally good to excellent whereas litter cover and the number of seedlings were generally poor. Grass composition and basal cover scores were moderate. The overall rating ranged from poor to good, the extremes excellent and very poor were not encountered. Signs of overgrazing in high cattle density areas were not detected.

Introduction

The Western Province (WP) of Zambia covers an area of 122,000 km^2 and has over half a million head of cattle (Baars and Jeanes 1996a; DVTCS 1992). The poor sandy soils (northern part of the Kalahari desert) and a marked seasonal rainfall pattern provide limited potential for crop cultivation. Livestock, almost exclusively cattle, rely on the natural vegetation for their nutrition.

A carrying capacity study revealed that the WP as a whole is not overstocked but local overstocking may occur due to the uneven distribution of cattle (Baars and Jeanes 1996b). At the same time the provincial cattle population continues to grow by about 2.5 percent per year (DVTCS 1992). Therefore, a vegetation monitoring programme was initiated in high cattle density areas in the WP, the initial results of which are presented.

Materials and methods

A vegetation monitoring exercise was initiated in the 1991 wet season. The first year, the transects were established and the methods verified. The initial assessments of range condition reported here cover 1992 and 1993.

The average annual precipitation in the WP ranges from about 700 mm in the south to 1200 mm in the north (Verboom and Brunt 1970).

The assessments were executed during the late wet season, late March or early April, because during this period most grasses were in full bloom which greatly assisted their identification. Most unidentified grass species were collected and sent to the herbarium of Harare in Zimbabwe for identification.

Selected transects and sample sites

Ten transects, from 3 to 13 kilometres in length, were established in areas with relatively high cattle densities and away from homesteads or fields for cultivation. The average provincial stocking rate was about 0.083 Tropical Livestock Unit of 250 kg per hectare (TLU/ha), the stocking rate in the study areas was approximately 0.25 TLU/ha (Jeanes and Baars 1991). Vegetation maps, aerial photographs and compasses were used to select transects and to find them in the field.

Each transect had 3 to 5 sample sites. At each sample site, a central site in a representative area was assessed by 3 or 4 observers, who radiated out to about 100 metres away from the central point for individual assessments resulting to a total of 4 or 5 assessments per sample site.

The transects and sample sites were selected in such a way as to cover both the plain (dry season grazing) and the woodland (wet season grazing), both transhumance and sedentary grazing systems (based on Jeanes and Baars 1991; MacLaurin 1990) and different levels of grazing pressure (nearby and further away from water sources).

Range condition assessment factors

The factors considered and the criteria for scoring, adapted from Ivy (1969) and Tainton (1981), are shown in Table 5.1. The maximum possible score was 50 points. The rating should be interpreted as excellent (41 to 50 points), good (31 to 40), fair (21 to 30), poor (11 to 20) or very poor (3 to 10).

Grass species composition (1-10 points). Grasses were divided into desirable species likely to decrease with heavy grazing pressure (decreasers), intermediate species likely to increase with heavy grazing pressure (increasers) and non-desirable species likely to increase with heavy grazing pressure (pioneers), according to the succession theory (Dyksterhuis 1949). Classification of grasses into decreasers, increasers and pioneers was adapted from Ivy (1969) and Tainton (1981). The adaptation was based on the vigour and the opinion of herdsmen and other experienced people on palatability of particular species.

The proportion of each species was assessed visually in an imaginary circle with a 5 m radius of a representative area.

Basal cover (0-10 points) and litter cover (0-10 points). A representative sample area of 1 m^2 was selected for detailed assessments of both basal and litter cover. The surface of basal cover of tufted grasses (quantitative) and their distribution (qualitative) were assessed as follows. The m^2 was divided into halves, one of these was further divided into quarters one of which was divided into eighths. All plants in the selected 1 m^2 were removed and transferred to the eighth in order to facilitate visual estimations. Only basal cover of living parts was considered. The rating of basal cover for tufted species was considered excellent when the eighth was completely filled (12.5%) or very poor when the cover was less than 3%. Creeping grasses were encountered twice. Although no system was developed for creepers, both were given the maximum score because of abundance of cover.

The rating for litter cover within the same m^2 was considered excellent when it exceeded 40% and poor at less than 10% litter cover.

Table 5.1 Criteria for the scoring of the different factors determining range condition.

Score	*Grass composition*	*Basal cover*	*Litter cover*	*No. of seedlings*	*Age distribution*	*Soil erosion*	*Soil compaction*
10	91-100% decreasers	>12% no bare areas	>40%				
9	81-90% decreasers						
8	71-80% decreasers	>9% evenly distributed	11-40% evenly distributed				
7	61-70% decreasers	>9% occasional bare spots					
6	51-60% decreasers	>6% evenly distributed	11-40% unevenly distributed				
5	41-50% decreasers	>6% bare spots		>4 seedlings on A4 paper	young, medium, and old	no soil movement	no compaction
4	10-40% decr ≥30% incr	>3% mainly perennials	3-10% mainly grasses	4 seedlings on A4 paper	two size categories present	slight sand mulch	isolated capping
3	10-40% decr <30% incr	>3% mainly annuals		3 seedlings on A4 paper	only old	slope-sided pedestals	>50% capping
2	<10% decr ≥50% incr	1-3%	3-10% weeds/ tree leaves	2 seedlings on A4 paper	only medium	steep-sided pedestals	>75% capping
1	<10% decr <50% incr	<1%	<3%	1 seedling on A4 paper	only young	pavements	almost 100% capping
0		0%	0%	no seedlings		gullies	

Number of seedlings (0-5 points) and age distribution (1-5 points). The number of seedlings was counted using three areas equal to the size of an A4 sheet of paper (30 x 21 cm) chosen ad random.

When all age categories, young, medium aged and old plants of the dominant species were present, the maximum score of 5 points was applied. Young and medium aged plants were defined as having respectively up to 20% and up to 50% of the biomass of old and mature plants of the dominant species. When there were only young plants, the minimum score of 1 point was applied.

Soil erosion (0-5 points) and compaction (1-5 points). Soil erosion was based on the amount of pedestals (higher parts of soils, held together by plant roots, with eroded soil around the tuft) and in severe cases the presence of pavements (terraces of flat soil, normally without basal cover, with a line of tufts between pavements). Soil compaction was based on the amount of capping (crust forming).

Results

Grass species composition

There was a significantly higher score (P=0.008) for grass composition of the woodland sample sites, 6.2 on average (n=22, sd 2.1), as compared to the average of the plain sample sites, 4.3 on average (n=16, sd 2.0) (Table 5.2).

Common or dominant grass species found in the woodlands were the palatable *Andropogon schirensis, Hyparrhenia filipendula, Digitaria* (*D. diagonalis, D. milanjiana, D. brazzae*) and *Brachiaria* (*B. dura, B. pungipes*) decreaser species; *Tristachya* (*T. nodiglumis, T. superba*), *Parinari capensis* increaser species; and *Aristida stipitata* and *Pogonarthria squarrosa* pioneer species.

The same common or dominant grass species, except for *B. dura* and *P. squarrosa*, were found on most plains although the amount of decreasers was less. Additional common species encountered on the plains were the less palatable *Loudetia simplex, Eragrostis* (mainly *E. pallens, E. rigidior, E. lappula*) and sedges.

Table 5.2 Results of the 1992/93 range condition scoring. Data are averages of 4 sub-stations, except Kasaya (av. of 5). P = plain, W = woodland, L = length of transects (m) from the starting point, GC = grass composition, BC = basal cover, LC = litter cover, NS = no. of seedlings, AD = age distribution, SC = soil condition.

Sub-station		*GC*	*BC*	*LC*	*NS*	*AD*	*SC*	*Total score*	*L*
Munkuye/1	P	6	6.75	2.25	1.5	4.75	9.5	30.75	300
Munkuye/2	P	4	5.75	1.5	1.25	4.75	5.75	23	800
Munkuye/3	W	7	3.5	3.75	0.5	4.25	8	27	1300
Munkuye/4	W	9	5	3.75	0.5	4.75	9	32	2500
Ushaa/1	W	7	2	6	2	1.75	8.25	27	0
Ushaa/2	W	6	2.75	4.75	3.5	2.75	8	27.75	400
Ushaa/3	P	4	7	6.5	4.75	3.75	7.75	33.75	1500
Looma/1	W	5	2.75	1.25	1.25	4	7.75	22	0
Looma/2	P	4	4.25	1.25	5	5	7	25.5	350
Looma/3	W	4	3.25	3.25	2.25	4.25	7.25	24.25	1500
Lwafuzu/1	P	8	5.25	1.25	1.25	5	5.75	26.5	500
Lwafuzu/2	W	3	4.5	1.75	1.5	4.75	7.25	22.75	1500
Lwafuzu/3	P	3	3.75	4	1	4.5	5	21.25	2000
Lwafuzu/4	W	7	7.75	2.25	1.25	5	6	29.25	2500
Lwafuzu/5	P	3	3.5	2.5	1	4.5	6.25	20.75	3500
Mahongo/1	P	5	4.75	0.75	1	4	5.5	21	300
Mahongo/2	P	3	4.25	1	1	4.25	4.5	18	6000
Mahongo/3	W	6	5.25	2.25	1	4.5	6.25	25.25	9000
Mahongo/4	P	5	5	1	1	4.25	4.25	20.5	11000
Mahongo/5	W	4	3.5	1.5	1	5	8.25	23.25	13000
Loanja/1	W	9	3.25	1.25	2	4.75	8	28.25	600
Loanja/2	W	7	3.5	3.75	3.5	5	5.5	28.25	2600
Loanja/3	P	3	3	1.75	2.5	5	8.25	23.5	3700
Loanja/4	W	4	3.25	1.75	1.25	5	9	24.25	5200
Kasaya/1	P	8	6.2	1.6	4	5	10	34.8	0
Kasaya/2	W	6	5.6	1.4	4	5	9.75	31.75	1500
Kasaya/3	W	5	4.6	2.4	2.4	3.8	8.25	26.45	3600
Kasaya/4	P	6	5	1.2	3.4	4.8	10	30.4	5200
Kasaya/5	W	7	6.4	3.8	1.6	1.8	4	24.6	6000
Nalikwanda/1	W	8	3.5	3	0.5	4.5	9.75	29.25	500
Nalikwanda/2	W	3	2	2.5	0.5	4	9.75	21.75	1000
Nalikwanda/3	W	3	2	2	0.75	4.5	8.25	20.5	2500
Liangati/1	P	1	2.5	3	2.5	4.25	6.75	20	500
Liangati/2	P	2	4.25	3	3.75	4.75	6.75	24.5	2500
Liangati/3	W	8	4.25	2.25	4.75	4.75	6.5	30.5	3500
Kamuni/1	P	4	4.75	2.75	5	4.5	6.75	27.75	500
Kamuni/2	W	10	3.75	2.25	4.75	4.25	6.25	31.25	1000
Kamuni/3	W	8	4.75	3.25	4.25	4.25	6.75	31.25	3000

Factors other than grass species composition

For basal cover the woodland sample sites scored 4.0 (sd 1.4) on average and the plain sample sites scored 4.7 (sd 1.3) on average, reflecting poor to fair basal covers. The differences in basal cover between woodland and plain sample sites was significant ($P = 0.090$). The Loanja and Nalikwanda transects sample sites had poor scores (range from 2 to 3.5), the scores of the other transects sample sites were poor to good (range from 2 to 7.75).

Litter covers were in general poor. The average score was 2.5 (sd 1.3) with no significant difference between woodland and plain sample sites. The variation between the different transects was considerable. The Mahongo transect sample sites ranged from 0.75 to 2.25 whereas the sample sites of the Ushaa transects ranged from 4.75 to 6.5.

The average score of the number of seedlings was 2.2 (sd 1.5) with no significant difference between the woodland and plain sample sites. The scores were low in the Munkuye, Lwafuzu, Mahongo and Nalikwanda transects (range from 0.5 to 1.5) as compared to the other transects.

For age distribution no difference between the woodland and plain sample sites was found. The average score was 4.4 (sd 0.8). Only the Ushaa transect scored lower than 4 on average (out of 5 points).

The soil condition of all transects was generally good and often excellent. In the Lwafuzu, Mahongo, Liangati and Kamuni transects the score was moderate. No difference between the woodland and plain sample sites was found.

Total score

The majority of the ratings per sample site fell into the category "fair" (Table 5.2). None of the sample sites fell into the categories "excellent" or "very poor". There was no significant difference found between the woodland and plain sample sites. The average was 26.1 points (sd 4.3).

The total score of the first sample sites of the transects was not significantly different from sample sites further away from the starting point within the same transects. This applied to both plain (P=0.21) and woodland (P=0.52) sample sites.

Discussion

Grass species composition

The grass cover below the undisturbed Miombo woodlands, as reported by Jeanes and Baars (1991) consisted mainly of *Hyparrhenia filipendula* with a mixture of scattered *Andropogon schirensis*, *Diheteropogon amplectens*, *Panicum juncifolium*, *Monocymbium ceresiiforme*, *Hyparrhenia hirta*, *Digitaria* sp. and *Schizachyrium* sp. Although the areas sampled in the present study were closer to villages and fields, the grass composition was similar to that reported by Jeanes and Baars (1991).

The sand plain areas have been described as *Tristachya* dominated (Trapnell and Clothier 1957; Verboom and Brunt 1970). *Tristachya nodiglumis* appears to be the dominant species in higher, better drained sand plain sites commonly associated with the legume shrub *Parinari capensis* among other characteristic sand plain grass species (Jeanes 1985). *Parinari capensis* is relatively unpalatable but cattle eat it after the vegetation has been burnt (personal observation). The crude protein concentration of this species is high (Jeanes and Baars 1991) and therefore, might be one of the key species for survival of cattle in these plain areas. On lower lying areas of sand plains (higher water tables, more frequently flooded) *P. capensis* disappeared, *Tristachya* spp. became less frequent and species such as *Eragrostis lappula*, *T. spicatus* and *B. humidicola* (more flood tolerant species) became more frequent (Jeanes and Baars 1991). In the present assessment *Tristachya* spp. have been reported (at Lwafuzu and Mahongo) but not as a dominant species. It is possible that, because it is tall and erect, it attracts the eye and is therefore easily judged as dominant. Other species mentioned (Jeanes 1985; Jeanes and Baars 1991), correspond well with present findings.

The decreaser species assessed along the Loanja transect have not been reported by others. According to Jeanes and Baars (1991) the sandier intermounds and plains carried an *Eragrostis* (*E. pallens, E. rigidior*) dominated flora. The Loanja Acacia woodlands carried the more frequent woodland patches present in typical sandier Acacia woodland grass flora (*Digitaria-A. stipitata-Schizachyrium*).

In the Mopane (*Colophospermum mopane*) open woodlands, a scattered mixture of species, similar to the ones found in the present study, has been reported. *Panicum phragmitoides, Tristachya lualabaensis* and *Eragrostis rotifer* were possibly unique to the Mopane clays. The higher, denser woodlands carried a very sparse cover of unknown species (Jeanes and Baars 1991). The results of the present study revealed no clear difference between the woodland and plain sample sites of the Kasaya transect which can be explained by the fact that the Mopane woodlands are very open.

In the Kalahari woodlands, the palatable *Brachiaria dura* was common (Verboom 1966a) among species such as *Andropogon schirensis, T. nodiglumis, T. spicatus* and a scattered mixture of *Loudetia lanata, Tristachya superba, Monocymbium, Pogonarthria* and *Rhynchelytrum* spp. *P. capensis* may be present in lower lying areas (Jeanes and Baars 1991).

An appraisal of range condition does not allow conclusions on how the composition of the rangelands has changed due to stocking, but it is recognised that changes occur (Pantis and Mardiris 1993). However, a comparison of sample sites near by and further away from roads or water sources did not reveal differences.

Factors other than grass species composition

In contrast to the description of vegetation, little research has been done in the WP with respect to aspects of basal and litter cover, grass condition, and soil erosion and compaction.

Basal and litter cover play an important role in the dissipation of raindrop energy and thus in the control of erosion (Scott 1981). The results of basal cover (moderate) and litter cover (poor) in the present study do therefore not explain the high score for soil condition. However, the WP is relatively flat and the higher woodlands are very sandy (Soil Survey Unit 1983). Sandy soils are not susceptible to compaction and flat terrain is only susceptible to wind erosion and not particularly to water erosion. The high scores for soil condition can thus partly be explained by the natural features of the landscape instead of basal and litter cover. The two transects which presented a fair instead of a good score for soil condition were both located in the sand plain areas of the Senanga District. These areas have a finer soil structure and, in contrast to their name, relatively more clay particles.

Studies in Zimbabwe in different soil/vegetation types, and rainfall zones (Kennan 1962; 1969) revealed that the extent and speed of impact of heavy grazing were lower in lighter textured soils in higher rainfall areas compared to heavier textured soils in low rainfall areas. In the former, 15 years of continuous heavy grazing produced little significant change in terms of grass species composition or basal cover.

Implications for development

Many African rangelands are deteriorated (Mabbutt 1985). It is, however, not clear whether climatic changes, human and animal impact or the combination of these cause deterioration or how they interact, especially in areas with unreliable rainfall (Westoby *et al.* 1989). Taking into account that rangelands can have a range of equilibria or carrying capacities (Geerling and de Bie 1987, Tausch *et al.* 1993), the results of the present study show that the rangelands in the WP in high cattle density areas away from homesteads are not overgrazed nor deteriorated. This is probably due to the low grazing pressure as compared to many other rangelands in Africa. Data of Southern Mali (Leloup 1994) compared to the WP, showed a similar area (both 122,000 km^2) and amount of rainfall (range of 500-1300 vs range of 700-1200 mm p.a.) but a seven-fold cattle population (3,359,00 vs 479,000 head in 1986).

Deterioration due to cropping, on the other hand, should be more of a concern considering the large and increasing areas under fallow. Areal photographic interpretations indicated a high percentage of fallow around settlements (Jeanes and Baars 1991) and future areal photographs should be analyzed to assess the increase in fallow areas. The fallow areas have a poor value in terms of grass species composition due to unpalatable species such as *Aristida* spp., and they need a long time to regain their initial soil fertility. Moreover, the occurrence of frequent crop failure implies a non-sustainable farming system.

The intensification of cattle husbandry (in numbers and efficiency) will increase access to markets because of fewer financial constraints. Increased purchases of cereals for home consumption produced elsewhere in more reliable rainfall areas, will reduce the pressure on rangelands because of a reduction of areas under fallow. It will also improve welfare because of reduced dependence on the unreliable crop sector. Also, more outputs of cattle, manure and draught-power, would become available for the crop sector resulting in safer cereal production (manure improves the water holding capacity of the soils, ploughing leads to fields which can be ready in time).

The economic importance of the cattle industry for the WP will remain a feature in the future (Mwafulirwa and Moll 1991) and cattle production could even be expanded on the poor sandy soils where commercial crop production is limited. There is room to expand cattle numbers (Baars and Jeanes 1996b). There will, however, always be a need to monitor the rangelands and to avoid eventual overgrazing and deterioration. Livestock holders will continue to expand numbers because of the high rate of return from livestock as an investment and the need for security (Livingstone 1991). Cattle growth in the WP is about 2.5% annually (DVTCS 1992). Deterioration processes occurring in other regions of Africa can serve as examples of how to deal with rangelands in an economically, ecologically and sociologically sustainable manner (see also Breman and de Wit 1983; Dodd 1994).

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Chapter 6

Fire management in communal rangelands

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Chapter 6

Fire management in communal rangelands

Abstract

Farmers burn rangelands during the dry season, mainly to obtain the regrowth of a high nutritive value. However, fires are not controlled. Cattle farmers were subjected to a questionnaire survey to elucidate their practices and ideas with regard to the management and control of fires. Seventy-eight percent considered fires beneficial because they provided green grass (80% of the positive respondents), they reduced the number of ticks (14%) or for other reasons (6%). On the other hand, 15% of the farmers complained about a shortage of grass due to burning. A follow-up study monitored the regrowth of grasses during the most critical part of the dry season. The DM yield 3 weeks after burning was 0.12 t/ha as opposed to 1.3 t/ha before burning and did not increase further unless re-clipped. The CP concentration was higher in regrowth (8.7%) than in unburnt grass (3.3%). P levels were influenced more by the site than by burning. Heavier textured soils had a relatively high soil moisture concentration. There was a correlation of 0.68 between soil moisture and the amount of regrowth. The strategic burning of areas with potential regrowth (loamy soils) is necessary to obtain high quality forage. However, due to limited amounts of regrowth, burning should be avoided on approximately 25% of the land area to obtain an optimal balance between the poor quality standing crop and a limited quantity of good quality regrowth.

Introduction

Annual dry season fires are widespread in the Western Province (WP) of Zambia. Among other reasons, fire is used to provide a green flush for grazing cattle. Burning results in high quality regrowth, but also reduces the standing crop due to poor regrowth (Tainton 1981). Whether the use of fire is justified, therefore, depends on the balance of the advantage of increased quality and the disadvantage of decreased quantity of low quality forage.

It can be argued that the sustained use of fire, despite official disapproval and publicity against burning, indicates that the users of fire in the WP currently consider the benefits to outweigh the disadvantages (Frost 1992). Technical arguments against the use of fire are not clear cut. The adverse effects of fire may be due more to the outcome of an inappropriate burning regime than of the fire itself (Frost 1992). If burning is not desirable, how can it be restricted? Conversely, if there are valid reasons for its use, how can it be carried out responsibly and with greater control? A prohibition on the use of fire is not enforceable, especially if the responsibility for policing such a ban is not vested in local authority and institutions (Bromley and Cernea 1989). It seems more practical to seek ways of promoting controlled burning among the users of fire rather than to try to ban it outright.

Range management in the WP is characterized by low inputs. Fire management is probably the only practice which manipulates forage availability and quality. Recent collaboration on range management between farmers and technical extension staff, however, was limited due to a lack of technical knowledge, both on the part of the extension staff and farmers, which resulted in an imperfect execution of fire management. For this reason a fire management programme was initiated with the aim of developing a policy on fire management. The objective of the present study was firstly to assess the farmers' perception of fire management and secondly to assess the regrowth of grasses after fire. The second objective resulted from the study on farmers' perception.

Materials and methods

Study area

The rangelands of the WP are communally grazed. Subdivision of grazing areas is absent and the only individually owned land is crop fields, which are grazed after the harvest.

The average annual precipitation in the WP ranges from about 1200 mm in the north to 700 mm in the south (Verboom and Brunt 1970). The wet season runs from November to April.

Farmers' perception of grazing management

The cattle farmers' perception was surveyed by way of a questionnaire during the dry season of 1991 among 56 cattle owners in four high cattle density areas of the Province. The distance between the homesteads of each individual participant was at least 15 kilometres.

Assessment of the regrowth of grass

Vegetation types. In two grazing areas with perennial natural grasslands, representative of the WP, the regrowth of grasses was monitored during the months of June to August, the most critical period of the dry season. One area was a flood plain (FP), the other a sand plain. The sand plain area consisted of two vegetation types: 1) treeless plains (SP), dissected by 2) elevated woodlands (WL). In the FP there were no woodlands.

In the FP area, the most important grass species were *Hyperthelia dissoluta*, *Aristida* spp., *Monocymbium ceresiiforme* and *Panicum repens*. In the SP area *Tristachya nodiglumis* and *Tristachya superba* dominated grasslands were associated with *Aristida congesta*. The WL of the SP region was characterized by *Andropogon brazzae*, *Eragrostis* species and *Digitaria milanjiana* (Jeanes and Baars 1991).

Burning history. The areas were selected after they were burnt (in May 1992) by farmers. Interviews with the farmers revealed that they were burnt to stimulate regrowth (FP and SP) or to clear the area (WL).

Experimental design. In each of the three vegetation types, four plots of 3 by 3 meters were fenced to protect them from grazing and fire. The distance between plots was at least 100 m. Three out of four plots were used to measure regrowth after burning, the fourth one was a control plot in nearby unburnt vegetation.

Each plot was divided into four sub-plots. Sub-plot A was used to measure the heights of undisturbed growth; sub-plot B was clipped 3, 7 and 11 weeks after burning, sub-plot C was clipped 7 weeks after burning; sub-plot D was clipped 11 weeks after burning. The re-clipping of sub-plot B was undertaken to simulate grazing cattle. The cutting height was 5 cm.

Analyses. Dry matter (DM) content was determined after drying at 105 °C for 24 hours. Forage analyzed to estimate nitrogen (N) and phosphorus (P) concentrations was dried at 60 °C. Two samples from each clip were analyzed for N and P. The height of the grasses was measured to verify how long it takes for grass tillers to grow to about half their length when fully expanded in the case of a green flush, as recommended (Frost 1992).

Five soil samples of 30 cm deep were collected with a soil auger in each plot which was clipped. Thereafter, they were mixed and a sub-sample was dried in an oven (24 hours, 105 °C) to estimate the soil moisture concentration. The soil texture of all plots was assessed once.

The one-way analysis of variance (ANOVA) has been used to test for statistical differences.

Grazing behaviour

In the months of June to July, grazing behaviour was monitored in five herds of the SP/WL region. All herds were monitored one day per week with a total of 41 observation days. Every 15 minutes, the activity and the type of forage grazed were recorded of five ad random selected animals. The proportion of the area burnt at that time was approximately 50%. All herds had a herdsman but cattle were normally left free to roam around.

Results

Farmers' perception of fire management

Ninety-eight percent of the farmers reported burning in their grazing areas. This took place throughout the dry season, but mostly within the first three months of the dry spell (April to June in the dry areas, June to August in wetter areas). The grazing areas in the vicinity of the interviewees were burnt in their entirety every year (94%) and in some cases they were partially burnt (6%).

The majority of cattle farmers thought burning was beneficial (69%), some thought it to be destructive (22%) and a few considered both to be true (9%). As the principal advantage of burning was reported the regrowth of grass (80%), the killing of ticks (14%) and some farmers saw other advantages in burning rangelands (6%). As the principal disadvantage of burning was reported the resultant shortage of forage (49%), the proportion of the area burnt was too small (5%), and other reasons (12%) while some farmers saw no disadvantages in burning (34%).

Most farmers (88%) acknowledged that burning could be either good or bad. Bad burning was defined as uncontrolled (53%), carried out at the wrong time (35%) or for reasons not related to the regrowth of grass (12%). Fires were considered beneficial when applied at the proper time (55%), when the application was coordinated (14%), when the vegetation was partly burnt (14%), when the thatching grass, used to roof houses, was not burnt (9%), or for other reasons such as hunting and clearing (9%).

Most respondents (82%) thought it was possible to control fires. However, the majority of the fires were unplanned and uncontrolled, and it was not known who started the fires. Even in the case of planned fires, it was not very clear who decided when or where fires should be started. The influence of tradition or traditional leaders was still obvious. The control of fires was considered feasible if people were prepared to organize themselves (53%), if the government would provide help (29%), if the use of fire breaks was implemented (9%) or through

Table 6.1 DM yields (t/ha), CP and P concentrations (% of DM) (first, second and third block respectively) of unburnt grass (UB) and regrowth (RE). ** = no data due to negligible regrowth.

Weeks post burn	*Bulozi floodplain*		*Siloana sand plain*		*Siloana woodland*	
	UB	*RE*	*UB*	*RE*	*UB*	*RE*
Dry Matter						
3	1.0	0.12	0.8	0.13	0.6	0
7	1.8	0.11	1.4	0.11	0.8	0
11	1.4	0.14	1.4	0.11	0.6	0
7reclip	0.2	0.13	0	0.03	0	0
11reclip	0.2	0.08	0.2	0.05	0	0
Crude Protein						
3	2.9	10.5	2.6	8.8	3.6	**
7	2.3	7.4	2.9	6.3	3.6	**
11	2.5	8.3	3.8	7.6	3.5	**
7reclip	2.7	8.5	**	9.7	**	**
11reclip	5.4	9.0	6.2	10.8	**	**
Phosphorus						
3	0.12	0.19	0.01	0.09	0.01	**
7	0.16	0.17	0.01	0.07	0.01	**
11	0.15	0.16	0.01	0.06	0.01	**
7reclip	0.16	0.16	**	0.09	**	**
11reclip	0.12	0.18	0.03	0.10	**	**

other methods (9%).

Observations on the regrowth of grass

Availability of forage. The height of grasses in the SP was homogeneous while the height of grasses in the FP varied considerably, depending on the species present. The average height of unburnt grasses in the SP and FP regions stayed the same throughout the period of measurements. Three weeks after burning the height of regrowth was 20% whilst seven and 11 weeks after burning it was 25% of that before burning. In the WL there was negligible regrowth.

The available DM of regrowth remained the same 3, 7 and 11 weeks after burning. The re-clippings, of unburnt and regrowth together, resulted in lower yields than in plots clipped for the first time at 7 or 11 weeks ($P<0.05$) (Table 6.1). However, the cumulative yields of regrowth in the FP and SP areas, at 11 weeks, were respectively 275% and 161% of the yields of the plots clipped for the first time.

Quality of forage. There was a significant difference between the crude protein (CP) concentration of unburnt grass (3.5%) and of regrowth (8.7%) ($P<0.001$). The CP levels of regrowth 3, 7 and 11 weeks after burning were the same (Table 6.1). No difference in CP concentrations was found between the two regions.

There was no significant difference in the P concentrations of unburnt grass and regrowth on the FP ($P=0.15$). However, there were significant differences between the grasses of the FP and SP regions ($P<0.001$). The P levels of regrowth 3, 7 and 11 weeks after burning were the same.

Relationships between soil texture, soil moisture and regrowth. There were three soil texture classes: loamy soil, fine sand and coarse sand. The water concentration of the texture classes differed significantly ($P<0.01$), with the highest concentration of water in loamy soil. There was more water in the soils 3 weeks after burning as compared to the same locations 7 weeks after burning ($P<0.01$) (Table 6.2). The correlation between soil moisture and the amount of regrowth over all observations was 0.68 ($n=27$). Soil texture appeared related to the amount of regrowth. Course sandy soils, as found in the WL, showed no regrowth at all whereas loamy soils showed the highest regrowth.

Grazing behaviour

The cattle were kraaled at night. They were nine hours outside the kraal (sd 0.9) and 67% of this time they were grazing. Grazing on the grassland was mainly on regrowth (Table 6.3).

Table 6.2 The relationships between soil texture, soil moisture (M in %) and regrowth after burning (RE in t/ha) in three vegetation types in the Western Province of Zambia.

Land unit	*Soil texture*	*3 weeks*		*7 weeks*		*11 weeks*	
		M	*RE*	*M*	*RE*	*M*	*RE*
Flood	sand	1.2	0.06	0	0.14	0	0.12
plain	silty loam	2.5	0.08	1.7	0.20	2.0	0.10
	loamy sand	4.8	0.22	3.5	0.16	3.5	0.19
Sand	sand	1.1	0.12	0	0.12	0	0.12
plain	sand	2.9	0.16	0	0.14	0.9	0.10
	sand	1.6	0.12	0.9	0.08	0.5	0.12
Wood	sand coarse	0	0	0	0	0	0
land	sand coarse	0	0	0	0	0	0
	sand coarse	0	0	0	0	0	0
Correlation		c=0.92		c=0.54		c=0.66	

Table 6.3 Type of forage grazed (% of time) in the Siloana sand plain region in the months of June to July 1991.

	Woodland	*Grassland*	*Fields*	*Total*
Regrowth	2	34	1	37
Unburnt area	4	25	34	63
Total	6	59	35	100

Discussion

Farmers' perception of fire management

The four major objectives of using fire in grassland management by livestock owners are (Tainton 1981): to burn off unpalatable standing crop to make green parts of tufts accessible; to stimulate regrowth; to control parasites, particularly ticks; and to control bush encroachment. The first reason mentioned appeared most important in north-eastern Australia (Tothill 1971). It is not clear whether the major advantage of burning in the WP is making green grass accessible or stimulating regrowth. However, regrowth was mentioned by 80% of the farmers and making green parts accessible was not mentioned at all. The control of bush encroachment was considered equally unimportant, probably because of the abundance of large plains in the area. However, due to the lowering of ground water levels, fringes of dambos and pans were being invaded by trees, especially *Terminalia sericea* (personal observation). There are several additional reasons for the use of fire for livestock production (Pressland 1982) but these are of minor importance in the WP.

Many non-cattle owners apply fires to: clear paths between settlements or fields for cultivation; smoke out bees for honey collection; hunt large game; and for charcoal production (Frost 1992). No control efforts seem evident. The dry climate and winds cause these fires to reach areas a long distance away from the point of ignition. Despite planned fires being uncommon, most cattle farmers considered burning beneficial because it provided green grass. They were also aware that the time and extent of the burning greatly influenced its effect and that fires did not always occur at the correct time.

According to the farmers, the control of fires seems possible but they also considered the control to be hampered by the anonymity of persons responsible for starting fires, the lack of community resolve or need to cooperate in controlling burning, the gradual disappearance of traditional rules and the inability of the government to execute a fire management programme.

Regrowth of grasses

Availability of forage. The average biomass of regrowth at 23 sites spread across different lowland land units of the WP was 0.26 t DM/ha (Jeanes and Baars 1991) as against 0.13 t DM/ha in the present study. This difference was caused by higher regrowth rates on the wetter river valleys and dambos which were not included in the present study. The amount of DM in the WL was zero. This was also reported in the other study (Jeanes and Baars 1991).

The regrowth did not reach more than 25% of the height of unburnt grass. So the proposed recommendation (Frost 1992) not to graze the regrowth until it has reached approximately 50% of the height of unburnt grass cannot be applied. The height of regrowth outside the cut plots was lower than inside, indicating that cattle did graze regrowth within the first weeks after burning.

Quality of forage. The quality of CP of both burnt and unburnt grasses found was comparable to those reported in Chapter 4. The present study found 3.5% for unburnt grass (in Chapter 4 2.9% for the yellow parts and 5.1 for the green parts) and 8.7 for regrowth and 8.1 if the re-clipped grasses are excluded (8.3% in Chapter 4). The CP concentration of regrowth was above the level required for maintenance (7%) (Milford and Minson 1966). The very low levels of CP in unburnt grass were also found in Australia (Tothill 1971).

Baars and Jeanes (1996b) found P levels of 0.08% for yellow, 0.11% for green unburnt grass and 0.16% for regrowth. The present study, however, exerted a greater effect per region rather than the effect of unburnt versus regrowth grass. All the grasses of the FP, whether burnt or not, had more than the level required for maintenance, and all the grasses of the SP area, whether burnt or not, had P levels in grass below maintenance requirements (0.12%) (Little 1980).

Relationships between soil texture, soil moisture and regrowth. The relationship found between soil texture and soil moisture seems logical as coarse sandy soils have a very limited water holding capacity and dry out easily. The lower water concentration of the soil 7 weeks after burning as compared to 3 weeks after burning can be explained by a longer period of exposure to direct sun light, resulting in high soil temperatures during the day time (Tainton and Mentis 1984).

Application of results

The combination of burning and mineral supplementation showed a positive effect on cattle performance (Winter 1987). This would most likely also be the case for cattle in the WP, especially in the SP areas where P levels are too low to support maintenance. However, calving intervals in the SP area were shorter than in the FP area (van Klink 1994). Research aimed at evaluating the effect of P shortage and supplementation seems necessary.

The proportion of burnt area required to obtain a diet of approximately 7% CP was, based on the average DM and CP data over 3, 7 and 11 weeks, 77% in the Bulozi FP and 79% in the Siloana SP. Most plains, however, have a considerable proportion of *Parinari capensis*, a shrubby legume, which to some extent is consumed by cattle. If the diet is assumed to contain 10% browse of 12.5% CP (Bayer 1990), the burnt area required would be 74% of the total area. This is also suggested by the relative large proportion of the time that cattle graze on regrowth (Table 6.3). However, if burning is carried out in areas with relatively good regrowth, for example on loamy soils not used for agriculture, the proportion of the area can be reduced considerably.

According to Tothill (1971), strategic burning coupled with the planned conservation of standing dry forage seems appropriate to those lands which have not been developed to any significant extent. He also discussed the reduced need to burn if cattle are supplemented with urea licks. This also applies to Africa, although it should be considered that fire prevention is a complicated matter in Africa.

Large areas are burnt every year. Farmers perceive this beneficial and the observations on the regrowth indicate the need to burn approximately 75% of the grazing areas to obtain a good quality diet. This suggests a control of fires to some extent which might be a very difficult task. Strategic burning on soils with good soil texture, as found in some dambos and river valleys, seems an appropriate way to burn.

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Chapter 7

Costs and returns of keeping cattle herds

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Chapter 7

Costs and returns of keeping cattle herds

Abstract

The costs and returns were analyzed to assess inputs and outputs per herd, their distribution among families, and the relation to other farm and off-farm income. Cattle sales, the increase in cattle numbers, milk production and ploughing by oxen appeared to be the most important returns (respectively 24, 20, 20 and 19% of total gross returns). Local slaughter, manure and ox-power for transport played a minor role. The kraal keepers' household (KKH), who owned 60% of the herd, accrued 65% from the total gross returns, incurred 73% of total costs and accrued 60% of the net returns. Average net returns to the KKH from cattle keeping, crops, sales of other farm produce, and off-farm income were 55, 29, 5 and 12% of the total household income. The calculated costs were about a third of the returns. The net economic efficiency was calculated at 1.4 US$ per ha per year. There is scope to increase the role of draught-power and the animal offtake.

Introduction

The Western Province (WP) of Zambia covers an area of 122,000 km^2 (Chapter 2) and is divided into 6 districts. There are over half a million head of cattle (DVTCS 1992) of the Barotse breed, a Sanga breed type (Epstein 1971). They graze on natural pastures for about nine hours daily. At night they are kraaled on fields which will be cultivated at a later date. There are four grazing management systems (GMS): two transhumance and two sedentary systems (Figure 4.1). The transhumance is over short distances (up to 40 km) when compared to that found in, for example, the Sahelian region, and occurs because people and cattle are forced to move out of the plains when flooded in the wet season (GMS 1) or because they are forced to move to the flood plains because of lack of water in the uplands in the dry season (GMS 2) (Chapter 4).

In many sub-saharan countries, the provision of veterinary services has been free of charge for livestock owners (ILCA 1988). Meeting the costs involved in the provision of these services has become increasingly difficult for most of the governments (de Haan and Nissen 1985). There is a need to rigorously restructure services through involvement of the private sector as well as the design of cost recovery measures. In the WP, the Department of Veterinary and Tsetse Control Services (DVTCS) is investigating the possibilities and requirements to restructure services (de Rooij and Wood 1989). Research activities have been initiated in order to establish the position and economic importance of cattle in the rural society (Wood 1986), of which the present study is one.

The study has three objectives: 1) to assess the economical and financial costs and returns (C&R) per cattle herd; 2) to assess the various C&R to the kraal (=herd) keeper's household (KKH) (the kraal keeper (KK) makes decisions for the whole herd but does not own all the animals) and to all other households who own cattle in the herd; 3) to assess the relative importance of cattle to the KKH in relation to other farm and off-farm income.

Materials and methods

Data sources

The unit of investigation was the herd: a group of cattle belonging to one or more owners kept in one cattle pen or kraal under the responsibility of a KK. From 1986 to 1988, the DVTCS has been monitoring 50 herds which were selected on the following characteristics: easy accessibility to enable data collection every two weeks; equal representation of transhumant and sedentary herds, as is the normal situation according to the cattle census (DVTCS 1992); and a herd size between 20 and 120 animals to avoid exceptional small or large herds (Corten 1988). The distribution of the herds in the four main cattle-keeping districts of the WP was: Kalabo 12; Mongu 12; Senanga 17; and Sesheke 9. The distribution in the GMS's was: GMS 1 18; GMS 2 7; GMS 3 14; GMS 4 11.

Production parameters from these herds (from April 1986 to April 1988), and follow-up data collected through a questionnaire survey among the same herds, were used for the economic assessment. The additional data gathered through the questionnaire, related to the price, cost, and income of ploughing, transport, milk production, livestock sales, local (emergency) slaughter and manure use. Moreover, data on income from crops, and other farm and off-farm activities were collected. If a particular herd had more than one KK, only one of them was interviewed in full. However, all the KK's (55) of the 50 kraals studied were questioned about the household composition and areas cultivated. The kraal size, the area manured through shifting the kraal, and the area ploughed, were measured.

The assessment was confined to economic and financial C&R. Social C&R, such as position in society, family relations and bride prices, were not considered. The KKH was defined as the KK and his wife or wives together with children and dependents such as parents, grandchildren etc., but excluded children living elsewhere. All others with cattle in the kraal, whether living in the village of the KK or not, were considered as the other owners.

Estimates obtained for the variables considered

Ploughing. The economic returns of ploughing were based on the amount of cultivated land, labour requirements and yields per ha obtained by ploughing as compared with hand-hoeing. This concept was used instead of the concept of "opportunity cost", because the latter was found inappropriate due to the absence of a free market caused by many social obligations and restrictions in hiring out of oxen for ploughing during the time of field preparation.

Data from an animal draught-power survey in Senanga District of the WP (Phiri 1988) estimated an average cultivated area of 5.0 ha (4.2 ha ploughed) for households owning oxen against an average area of 3.0 ha for households without oxen. Similarly, an extensive survey (Pingali *et al.* 1987) considering 48 studies in ten Sub-Saharan countries including Zambia, concluded that farms using animal traction cultivated approximately 100% more land than farms using hand-hoes (6.6 ha versus 3.3 ha). All the crops grown in the WP are cultivated on ploughed or unploughed fields of similar condition. However, cassava fields are usually only prepared by hand-hoe. The conclusions from Pingali *et al.* (1987) were applied in our study.

In eastern Burkina Faso, it was found that an average of 86 working days per ha were required from hand-hoeing to harvesting, as against 68 working days from ploughing by oxen to harvesting (Barrett *et al.* 1982). The animal draught-power survey in Senanga District in the WP indicated a similar difference of 20 days (Phiri 1988).

Data on basic yields of crops were taken from statistics for 1982 - 1987 collected by the Department of Agriculture in the WP. The increase in yield per ha was based on results of the Adaptive Research Planning Team (ARPT) in the WP (Penninkhoff 1990): ploughing boosted yields of maize, sorghum and millet by 8%, and rice by 20%, compared with yields from manually tilled fields.

Manure. The conventional way to assess the economic returns of manure is to convert it into nutrient equivalents of fertilizer. In the WP fertilizers are only used in part of Kaoma District, on relatively good soils, and the soils of the rest of the WP are too sandy to justify use of in-organic fertilizers. Alternatively, the assessment of the economic return of manure can be based on its contribution to the farming system. The effect of manure was determined to be through additions of phosphorus and potassium, in combination with increase in the soil's water holding capacity (Penninkhoff 1990). The traditional application of manure through kraaling is approximately 15 ton/ha annually, corresponding to 90 kg N, 20 kg P2O5, 75 kg K2O and 75 kg SO3 (adapted from (Penninkhoff 1990)). The results obtained by the ARPT, based on experiments at three research stations, indicated that the effect of manure on the sandy soils was to increase yields of cassava, millet and sorghum by 60%, and those of other crops by 70% in the first season after manuring. The residual effect of manure on crop yields in the second season after application was 40% compared with yields from fields without manure application. By the third season after manuring the effect had vanished. However, there was no effect on yields on the more loamy soils (Penninkhoff 1990).

Cost of land, capital and labour. No land cost has been considered in this study since there is no individual land ownership and all land with good soils for crop cultivation is allocated by the chiefs. Capital consisted mainly of cattle and of some draught-power implements such as ploughs and sledges. Cost of capital was calculated on the basis of the real interest of capital at 5%. Depreciation for implements was set at 20%. The opportunity cost of labour, as determined through the questionnaire survey, was determined at US$ 0.38 per day, based on piecework as indicated by the respondents. The reported rates ranged from $ 0.25 (Sesheke rural) to $ 1.25 (Mongu, provincial headquarters) per day. In the case of contracted herding, payments amounted to $ 0.14 per day plus an estimated value of $ 0.25 for board and lodging. A study of households growing cassava and maize in Kaoma District also found a gross margin of $ 0.38 per labour day (van der Bijl 1987).

Results

General profile

Seventy-six percent of the informants considered themselves Lozi, the mayor tribe, but in fact the majority belonged to Lozi sub-tribes. The pure Lozis accounted for 20%. The youngest KK was 35 years old and the oldest 75. Fifty-four % of the KK's were 60 years old or older, 48% were 40 to 60 years old, and 8% were less than 40 years old. Most had less than 5 years' schooling. The composition of the average KKH is shown in Table 7.1. In the village of the interviewee there were on average 6.3 households, of which 60%, including the KKH, had cattle in the kraal. The average number of herds in a village was 1.5. The area cultivated per average kraal in the survey is shown in Table 7.2. The average area cultivated by the KKH, was for the WP and for the Districts of Kalabo, Mongu, Senanga and Sesheke, 3.9, 2.5, 4.7, 3.1 and 5.2 ha respectively.

Table 7.1 Household size and composition of interviewed kraal keepers in relation to the number of wives per kraal keeper.

Number of wives	*N*	*Household size*	*16 years and over*	*< than 16 years*
0	2*	8.0	4.5	3.5
1	34	9.2	4.1	5.2
2	18	11.7	5.2	6.5
4	1	22.0	8.0	14.0
average	55	10.2	4.5	5.7

* 1 female headed household

Table 7.2 Average area (ha) ploughed and/or manured annually per kraal for various crops (average herd size 66 cattle).

Crop	*Ploughed + manured*	*Only ploughed*	*Only manured*
Maize	0.47	2.66	-
Rice	0.02	0.90	-
Sorghum	0.08	0.88	-
Millet	0.02	0.36	-
Cassava	0.02	0.38	0.078
Vegetables	0.03	0.18	0.002
Total	0.64	5.36	0.08

Outputs of cattle-keeping

Ploughing. The average herd size was 66 cattle, of which 11 were oxen. Eighty percent of the adult oxen were trained. Eleven informants used two oxen per team, and the other 39 informants worked with four oxen in a team. Occasionally, teams of more oxen were used. The average time spent on ploughing was 3.5 hours (sd = 1.4) per day for 46 days resulting in 6.0 ha ploughed on average.

The reduction of labour requirements per ha on ox-ploughing farms was offset by the greater acreage (Table 7.3). This resulted in an increased labour requirement of 150 days. Oxen were hired out on only 5% of the ploughing days, most of them for free, and rarely at the "normal" rate of $ 2.5 to $ 3.75 per day.

The average return of ploughing over hoeing was $ 285 per herd calculated at $ 341 for the increased acreage being tilled and higher yields per ha being produced, minus $ 56 for the extra labour.

Table 7.3 The costs and returns of land cultivation per kraal with full access to ploughing compared to farms without access to ploughing.

	Unit	*Access to Ploughing*	*No access (hoeing)*
Cultivated area	ha	6.0	3.0
Harvest/ha	US $	108	101
Total harvest	US $	645	304
Labour/ha	days	68	86
Total labour	days	408	258
Total labour	US $	153	97
Harvest-labour	US $	492	207

Transport. On 65% of the 33 days that oxen were harnessed for transport, it was to move firewood while 25% was to transport foodstuffs to and from the fields or markets. Other commodities transported were luggage, poles for houses or kraals, water, grass, and people. Sledges were mostly used for transport.

The average number of oxen used per team for transport was four. Ox-teams were hired out in the same way as for ploughing. Since only 13 out of 50 kraals had occasionally hired out oxen, the opportunity cost of transport was low, and assessed at $ 1.25 per transport day (based on $ 0.75 for labour of two persons and $ 0.5 for hiring of equipment), or $ 41 per year (Table 7.4).

Manure. At night most cattle were kraaled for an average period of 11 months on fallow fields which were destined for cropping the next season. In Sesheke District manuring of fields was less common: only three out of nine interviewees mentioned manuring of fields by their herds. The kraal was usually made from local poles, occasionally thorn bushes and/or barbed wire. The barbed wire had been provided free of charge in the past.

The cattle density during kraaling, including young stock, was 0.6 animals per m^2 (sd=0.44). How often the kraal was re-sited depended on the soil type and season. On average, kraals were shifted every three days in the rainy season, and every five days in the dry season, leading to an average manured area of 0.72 ha (sd=0.41). Excluding herds which were not kraaled for the purpose of manuring the field, the average area manured per herd per year was 0.81 ha. Once a field had been manured, it would be 3.3 years (sd = 1.5) before the kraal was re-sited on that field.

The total average value for increased crop yields was calculated as $ 56 in the first year after the field had been manured and $ 23 for the second year.

Milk. The average price of one litre of milk was $ 0.10. The highest price was charged in Mongu District ($ 0.13), followed by Sesheke District ($ 0.11) and Senanga and Kalabo Districts ($ 0.09). Bessell and Daplyn (1977) and the herd monitoring programme (Corten 1988) estimated a milk production of on average 122 and 211 litres per cow per year respectively. The value of the milk produced based on the average of these two figures was $ 309 per herd.

Herd development and meat production. The herd increase amounted to 5.5 animals, sales to 4.25, purchases to 1.92 and local (emergency) slaughter to 5.17 animals per average herd per year. The average price of purchased cattle ($ 39) was much lower than that of sold cattle ($ 86), because purchases often concerned young-stock. The average value of a locally slaughtered animal was $ 27. The herd increase was calculated by using the average value of animals of a herd which was $ 58 per animal.

Hides. Only 45% of the hides (3.8 per herd per year) could be sold or used, because of the lack of a market outside Mongu District, and because not all hides were accepted for processing. The average value of the hides which were used

Table 7.4 Costs and returns, cash income and expenditure per year of the average herd of 66 animals (n = 50 herds).

Gross Returns	*Physical output/ average herd*	*Amount (US $)*	*(%)*	*Cash receipts (US $)*	*(%)*
Ploughing	6.0 ha, 46 days	285	19	4	1
Transport	33 days	41	3	3	1
Manure	0.72 ha	79	5	0	0
Milk	2872 litres	309	20	77	14
Cattle sales	4.25 animals	366	24	366	66
Local slaughter	5.17 animals	137	9	103	19
Hides	3.8 hides	5	0	2	0
Herd increase	5.5 animals	314	20	0	0
Total gross returns		1536	100	555	100
Costs	*Physical input/ average herd*	*Amount (US $)*	*(%)*	*Cash spent (US $)*	*(%)*
Labour	605 days	227	44	83	45
Drugs	various	1	0	1	1
Purchases	1.92 animals	75	14	75	41
Depreciation	2 ploughs	16	3	16	9
Depreciation	1.7 cart/sledge	7	1	7	4
Interest	66 animals	191	37		
Interest	implements	1	0		
Total cost		518	100	183	100
Total net returns		1018		372	

was $ 1.29. The contribution of hides to the income derived from cattle was $ 5 per herd per year.

Costs

Labour. The average size of the KKH was 10.2 persons (Table 7.1), of whom 4.5 persons (43%) were available for work within their own household and for farm work. Most of them were 16 years and older. When persons younger than 16 years were counted as 50%, the labour availability was 5.0 persons for polygamous households and 3.5 for other households, or 4.2 on average.

On average, 2.5 people were involved per ploughing day of 3.5 hours, or 403 hours for the total ploughing period of the herd. On average two people at five hours each were engaged per day trip in transport or 330 hours in total. Kraal re-siting, 79 times per year, took on average 474 hours per kraal per year. Milking and herding took respectively 187 and 3449 hours per year for the average herd. In total, the labour required by the average herd was 4,843 hours or 605 working-days at 8 hours per day which were estimated at \$ 227.

Capital cost. The average value of the animal inventory was calculated by using \$ 86 per animal of 3 years and over (selling price), \$ 39 per animal aged 2 to 3 years (buying price) and \$ 12.5 per calf. The total value amounted to \$ 3829 with a cost

Table 7.5 Costs and returns per Grazing Management System (in US \$ per 100 cattle per year).

	Average	*GMS 1*	*GMS 2*	*GMS 3*	*GMS 4*
Number of herds	50	18	7	14	11
Herd size	66	65	96	58	60
Gross returns/100 cattle:					
Ploughing	429	506^{a}	457^{a}	432^{a}	281^{b}
Transport	62	58	63	54	76
Manure	119	143^{a}	52^{b}	129^{a}	110^{a}
Milk	465	527^{a}	$488^{a,b}$	450^{b}	370^{c}
Cattle sales	551	537^{a}	366^{b}	455^{b}	815^{c}
Local slaughter	207	208	170	214	221
Hides	7	7	5	7	7
Herd increase	473	497^{a}	692^{b}	524^{a}	219^{c}
Total gross returns	2313	2483	2293	2265	2099
Costs/100 cattle:					
Labour	342	330	346	350	349
Drugs	2	2	2	2	2
Cattle purchases	113	102	97	138	110
Depreciation	35	35	35	35	35
Interest	289	289	289	289	289
Total costs	781	758	769	814	785
Total net returns/100 cattle:	1532	1725	1524	1451	1314

Values with different superscript in a row differ significantly (ANOVA; $P<0.05$).

of $ 191 for real interest, which is the interest forgone for having money capital tied in the animal. Other costs were of minor importance (Table 7.4).

Costs and returns per Grazing Management System

To allow comparisons between GMS's, the output was also expressed per herd of 100 cattle (Table 7.5). In GMS 2, the output of manure was less compared to the other GMS's. For most outputs, GMS's 1, 2 and 3 were rather similar. In GMS 4, the outputs of milk production and ploughing were less compared to the other GMS's. The low output of herd increase in GMS 4 was explained (and compensated) by higher cattle sales.

Distribution of returns to the kraal keepers' household

The distribution of C&R of cattle-keeping to the KKH is summarized in Table 7.6. This should be seen against the ownership of cattle which was 60% for the KKH. Some of the milk accruing to the KKH (25%) and most of the meat (75%) was sold by the KKH.

Other income

Crop income of the KKH, calculated from the average of 3.9 ha cultivated land and multiplied by the average cropping pattern and yields, indicated a value of crops of $ 444. Deducting the cost of labour and seeds, estimated at $ 99 and $ 24 respectively, resulted in a net return of $ 320. The interviews gave an average sale of crops amounting to $ 102 per KKH. Other farm activities such as beer brewing, fishing, keeping shop, sales of crafts, chickens and goats provided $ 59 on average in cash. Off-farm income through salaries, pension, remittances from elsewhere generated an average of $ 131 per KKH (Table 7.7). Remittances were received by 38% of the KK's, beer brewing generated money in 63% of the KKH's, the sale of chickens in 30%, and the other activities mentioned in 2 to 14%.

Table 7.6 Distribution of total returns, cost and cash flow to the average kraal keeper's household (KKH) (sd = standard deviation).

Gross Returns	*KKH share (%)*	*Amount (US $)*	*(%)*	*Cash receipts (US $)*	*(%)*
Ploughing	60 (sd=29)	171	17	4	1
Transport	65 (sd=35)	27	3	3	1
Manure	59 (sd=38)	47	5		
Milk	78 (sd=29)	241	24	60	17
Cattle sales	54 (sd=40)	198	20	198	56
Local slaughter	85 (sd=28)	116	12	87	25
Hides	60	3	0	1	0
Herd increase	60	188	19		
Total return	65	991	100	353	100
Costs	*KKH share (%)*	*Amount (US $)*	*(%)*	*Cash spent (US $)*	*(%)*
Labour	83	188	50	83	53
Drugs	100	1	0	1	0
Cattle purchases	66	50	13	50	32
Replacement implements	100	24	6	24	15
Interest cattle	60	115	30		
Interest implements	100	1	0		
Total cost	73	379	100	158	100
Net return	60	612		195	

Table 7.7 Average distribution of returns and cash income of farm and non-farm activities per kraal keeping household.

Source of income Kraal keeping household	*Returns (US $)*	*(%)*	*Cash receipts (US $)*	*(%)*
Cattle	612	55	195	40
Crops	320	29	102	21
Other farm activities	59	5	59*	12
Off-farm activities	131	12	131*	27
Total	1122	100	487	100

* household expenditures were not collected during the survey

Discussion

The tribal composition of the KK's interviewed indicated that 20% were Lozi which are the traditional cattle keepers. This agreed with the findings of a previous study (MacLean 1965).

The population census (Census 1980) showed an average number of 1.1 wives per married man in the rural areas of the WP, against 1.4 found among KK's in our study. Similarly, the KKH (10.2) was larger than the provincial average (4.7). Possibly labour requirements and/or surplus of food, attracted dependents who were taken up in the household.

People in the study area, including some who owned oxen, generally complained of a shortage of draught-oxen. However, there are more than 46 days on which ploughing is possible in the WP (Niesten 1984) and ploughing can be increased to about 5 hours per day (Singh and Sivaneson 1981). It can be concluded that oxen ploughed fewer fields than they potentially could, and consequently there is room for improvement of the output of draught-power. Reasons for the under-employment of oxen were related to an uneven distribution of oxen both socially and topographically, the poor quantity and quality of fodder, shortage of cash, and absentee ownership.

Although manure is commonly considered to be one of the main products of cattle-keeping in the WP, it is not in general utilized fully. Mayor reasons for not using manure were a shortage of labour, lack of interest or that nearby fields were in cultivation. Even in areas where manuring was common it played a minor role (5%) in terms of gross returns, because only a limited area was manured annually, and the resultant value of crops was low. However, farmers considered reducing the risk of crop failure as an important reason for the application of manure to be essential. In Sesheke District manure was used less than in other districts, possibly because the district has more shifting cultivation, is drier, and maize is less common. The approach used in this study to arrive at the extra value of cropping obtained by using manure considered the response of the entire farming system. However, the contribution of manure (5%) to the kraal income is low. This agrees with the results of an economic study on fertilizer equivalents which found that the contribution of manure to the kraal income was low (10%) (Mwafulirwa and Moll 1991).

Outbreaks of disease in 1986 in Southern Province (East Coast Fever, Foot and Mouth Disease) led to restrictions of cattle movement. Many private traders from the Southern Province shifted their trade to the WP. Therefore the sales recorded in this report were higher than in previous years, especially in GMS 4. However, from 1987 to 1992 cattle sales remained at this higher level, a trend which is likely to continue. The cattle sales per average herd of 66 heads were 4.25 animals or 6.4%. This is low, and there is room for the increase of cattle sales, especially since the natural increase of the herd is large: 5.5 animals or 8%. If culling were more timely, the number of animals for emergency slaughter could be reduced as well. Both activities would require farmers to have improved marketing channels, and good prices. In return, an increase in offtake could result in higher income for the rural population and a larger meat supply of the local market.

The returns in the form of protein production, i.e. cattle sales, local slaughter and milk together, formed 53% of the total returns. The total costs of cattle-keeping were about a third of the returns calculated.

The KK owned 44% of all animals of the herds in the survey, their wives 3% and their children 14%. Together they owned about 60% of the cattle (Corten 1988). This might be a slight under-estimate because some KK's or their dependents may have had cattle in other herds. Thirty-two percent of the cattle belonged to relatives and 8% to others. From Table 7.6 it can be observed that in the order of 54 to 85% of the returns per kraal went to the KKH. The share of the KKH in the net return at 60% was similar to the distribution of ownership of cattle. The allocations of milk and meat to the KKH were the highest at 78 and 85%, though actual consumption was only 62 and 47% of the kraal production. Meat consumption by the KKH was low because meat usually became available after an emergency slaughter and most was then sold. Slaughter for social purposes was uncommon in village life. Milk gradually became available in small quantities every day. Milk surpluses only occurred in the wet season and scarcely, if at all, in the long dry spell. Moreover, the KK with the responsibility of keeping someone else's cow, was often rewarded in milk. Consequently, milk from cows owned by people not living near the kraal was often consumed by the KKH or partly sold.

The additional data obtained on income from crops and other farm and off-farm income, showed that cattle made a sizeable contribution (55%) to the total income of the KKH. In terms of cash, the direct contribution of cattle was much less: $ 163 or 36%. This is because most expenses incurred on cattle are paid in full by the KK. On the other hand, cash from crop sales, partly due to the use of animal draught-power and manure, was not credited to cattle. Furthermore, the labour costs were calculated at $ 0.38 per day but in actual fact amounted to much less, since herdsmen were partly paid in kind. Consequently, the cash contribution of cattle was much greater than our results would suggest.

The total provincial net return was 8,479,000 US$ per year. The assessed net income was 1.4 US$/ha/yr and is lower than the income from extensive grazing of 2.4 US$/ha/yr as found in east Africa (Cossins 1985). This is probably due to the low stocking rates found in the WP (Baars and Jeanes 1996b).

Gathering economic information on cattle kraal management to augment technical production data obtained by the monitoring programme provided an interesting and quantitative insight into the multi-functional contribution of cattle in providing draught-power, cash, milk and meat. The role of cattle as providers of manure appeared minor in economic terms. The study also indicated that there is room to increase draught-power and offtake of the herd. The study further led to the conclusion that cash income from cattle husbandry provided a major part of the total income of the KKH and that the C&R were related to ownership of cattle.

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Chapter 8

General discussion

Chapter 8

General discussion

The aim of this final chapter is to place the conclusions of the preceding chapters into the context of general agro-pastoral development of the Western Province (WP). The Government policy with respect to livestock development, as described in the Provincial Medium Term Development Plan for 1992-1996 (PPU 1991), comprise: improved cattle marketing; disease control at affordable costs; to realize the potential of the existing grazing areas in an ecologically justifiable way; to promote wider use and access to cattle. The Ministry of Agriculture, with assistance from the Livestock Development Programme (Chapter 1), was the agency responsible for the execution of these policies to which this thesis contributed.

Land evaluation

Land evaluation (LE) encourages the promotion of sustainable land uses which integrate land, livestock and people for their mutual benefit (FAO 1991). Extensive grazing is the predominant form of land use in the WP of Zambia. The lack of information on both the potential of the land to support cattle and grazing practices was the reason for the evaluation of this type of land use.

The evaluation of extensive grazing must take into account both the primary production (vegetation) and the secondary production (livestock). In general, the following questions need to be answered (FAO 1991): How is the land currently used? Is the land use sustainable? What improvements in management are necessary and possible? Are there alternative uses of land? What are the benefits?

These questions have been dealt with in the present study, and the following steps were considered. Step 1: a land inventory based on vegetation types and topography (Chapters 2 and 3). Data generated in this step are necessary for any land use planning. Step 2: an assessment of the potential of the land to support cattle, integrating the vegetation and cattle (Chapters 4 and 5). Step 3: an assessment of the main management practices and economic efficiency, integrating vegetation, cattle and people (Chapters 6 and 7).

It is recognized that in the WP cattle and crop production are highly integrated (Chapter 7). Alternative uses of land other than extensive grazing were not considered in this study because of edaphic and socio-economic reasons. There are basically three categories of soil. The best soils, normally found on termitaria mounds, cover a small area and are used for crop cultivation. There is no doubt that these loamy soils should continue to be used for that purpose. The second category, the large sandy to loamy plains with savanna vegetation, are used for both crop and cattle production. This category comprises about 30% of the WP and can carry about 70% of the potential cattle population (Chapter 4). Considering the sparse human population and consequently the insignificant proportion under crops, the competition through encroachment of the area under crops is not important at present. The third category, the sandy woodlands, have a limited potential for livestock as well as for crops. WP woodlands show widespread influences of clearing practices, mainly for cassava cultivation, which have produced a mosaic of fallow land, at various stages of succession back towards woodland. An attempt was made to take this feature into account by including fallow units in the land classification (Chapters 2 and 3). Encroachment of areas under crops is not high at present, unlike in regions such as the Sahel and Sudan (e.g. Leloup 1994; Ahmed 1995), and is therefore not considered in the present LE.

Similarly, the two National Parks of the WP were not considered in the LE and it is hoped that they will keep their present condition with still numerous wild animals.

In provincial land use planning, however, the crop, livestock and natural resource sectors should be integrated. In Figure 8.1 an attempt has been made to delineate boundaries of Land Use Units based on Land Regions (LR) (Chapter 2), Grazing Management Systems (GMS) (Chapter 4), Farming Systems (FS) (Muwamba 1988)

Figure 8.1a Land Regions (source Chapter 2).

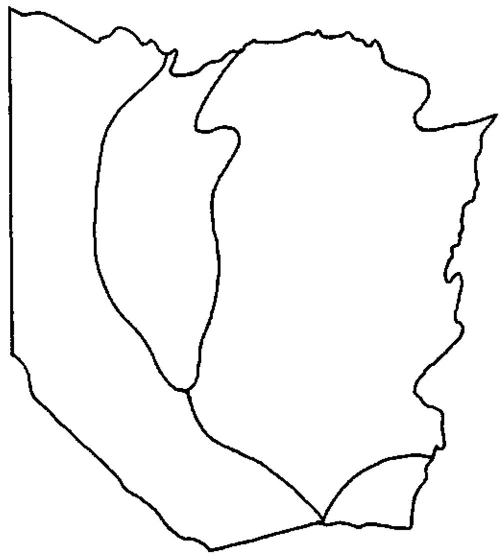

Figure 8.1b Grazing Management Systems (source Chapter 4).

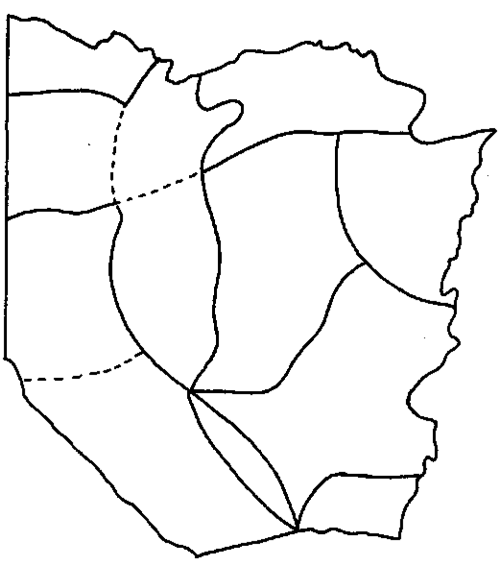

Figure 8.1c Farming Systems (source Muwamba 1988).

Figure 8.1d Land Use (combination of 8.1a,b,c).

and the National Parks, representing respectively the physical features, livestock systems, crop systems and the wildlife areas of the WP. When the boundary of a LR was close to that of the FS, the former was used, as it is easier and more accurate to delineate physical boundaries than boundaries of FS's. South of Senanga, the units of LR's, FS's and GMS's merge. Once a clear provincial land use plan has been described, LE's done at a district (or smaller) scale (Mulungushi 1986; Sikuleka and Rootselaar 1990) can be put into a better context.

The approach of the present LE had a geographical basis. It allowed a relatively rapid and accurate appraisal of the rangeland resources. An alternative approach could have been a LE on the basis of grids (as is the principle of GIS). However, such a LE would have required more data collection and thus more financial resources and man-power compared to the one used. For example, a grid size of 10 by 10 km would have resulted in approximately 1200 grids for the WP. Similar arguments apply to other approaches of LE such as on the basis of administrative boundaries.

Important range species

Over two hundred grass species were identified of which only the frequently occurring ones were reported (Chapter 3). Variations in upland soil types seemed to have little influence on grass species groupings. The major influence instead appeared to be factors of vegetation structure, such as canopy cover, shading and density of understorey. These features often vary due to differing degrees of disturbance and stages of regrowth. With respect to the lowland dambos, pans and river plains, grass associations appeared to be mainly governed by water table depth, flooding height and minor textural changes in soil.

The amount of standing crop of the *Echinochloa* spp./*Vossia cuspidata* grass association on the frequently flooded channels and plains, reached up to 40 t DM/ha as against a normal range of 1.5 to 4.0 t DM/ha (Chapter 4). It was found that cattle in the Bulozi floodplain grazed approximately 70% of their time on this particular association (Ottens and Baars, unpublished), which was in accordance with the extremely high amount of DM available. These sites, particularly those on which cattle rely during the hot-dry season, should be well protected from fire before the end of the dry season (Frost 1992).

The drier sand plain areas have been described as *Tristachya* dominated (Trapnell and Clothier 1957; Verboom and Brunt 1970). *Tristachya nodiglumis* appears to be the dominant species in higher, better drained sand plain sites commonly associated with the legume shrub *Parinari capensis* among other characteristic sand plain grass species (Jeanes 1985). *Parinari capensis* is relatively unpalatable but cattle eat it after the vegetation has been burnt (personal observation). The crude protein concentration of this species is high and therefore might be one of the key species for survival of cattle in these plain areas. On lower lying areas of sand plains (higher water tables, more frequently flooded) *P. capensis* disappears, *Tristachya* spp. become less frequent and species such as *Eragrostis lappula*, *T. spicatus* and *B. humidicola* (more flood tolerant species) become more frequent (Chapter 3). A good understanding of how *P. capensis* contributes to the diet of cattle and how this contribution interacts with burning on lower and higher plain areas is required.

In the Kalahari woodlands, the palatable *Brachiaria dura* was common (Verboom 1966a and Chapter 3) among species such as *Andropogon schirensis*, *T. nodiglumis*, *T. spicatus* and a scattered mixture of other species. *P. capensis* may be present in lower lying areas (Chapter 3). Although the study of Verboom is now 30 years old, his discussion on the potential of *B. dura* to improve the nutritive value of the rangelands of the sandy upland soils still holds.

Variability in grazing capacity

The calculation of grazing capacity (GC) (Chapter 4) was based on the amount of DM and the crude protein content of four components in the mid-dry season: the old mature standing crop (SC), the green parts of the SC (GP), the regrowth after burning (RE) and browse. However, the GC changes throughout the year and it is a limitation of the present study that no data to improve day-to-day management have been reported.

The GC is highest in the early- to mid-wet season and thereafter declines rapidly until the early-dry season due to maturation of the forage. Throughout the dry season the GC changes slightly because the balance SC:GP constantly increases. At the same time, the SC is replaced by RE after the rangeland has been burnt. A range of GC's is shown in Figure 8.2. They are estimates, based on data of the sand plain area of Senanga West. The assumptions were: SC and GC together form 2 t/ha of which 6% and 30%, respectively, is grazeable; RE is 0.2 t/ha of which 50% grazeable (Chapters 4 and 6). A piece of land is either burnt or not burnt. Thus the combinations shown in Figure 8.2 only apply at village scale where a certain proportion of the grazing area is burnt. Tentatively, the left corner represents the wet season GC's, the right corner the mid-dry season and the top the late-dry season. The GC's of the left corner (wet season) are probably heavily under-estimated but they are not relevant as the wet season is not the period of greatest nutritional stress. Figure 8.2a includes 10% browse in the diet (where applicable), whereas in Figure 8.2b there is no browse. Such simple figures should be developed for important cattle production areas. Only then is it possible to optimise range management.

In the Sahel, where much more rangeland research has been done than in the WP, a similar practical approach has been developed (Breman and de Ridder 1991). Depending on the amount and quality of data required, three levels of LE have been described: Level 1 is a global evaluation at scale 1:500,000 similar to that described in Chapters 2 to 4; level 2 is a semi-detailed evaluation of a smaller but representative area at scale 1:100,000 for the research at sub-regional scale, more or less as described in Chapter 7; and level 3 at scale 1:50,000 a detailed evaluation of selected areas for in-depth investigations as described in Chapters 5 and 6. Although the complexity of agro-pastoralism in Africa makes it difficult, if not impossible, to give a framework for development, appropriate for the whole region (Little 1984), the approach as described above for the Sahel is a good example of how future rangeland research activities in the WP should develop.

It is concluded that the results of the present study are useful for planning

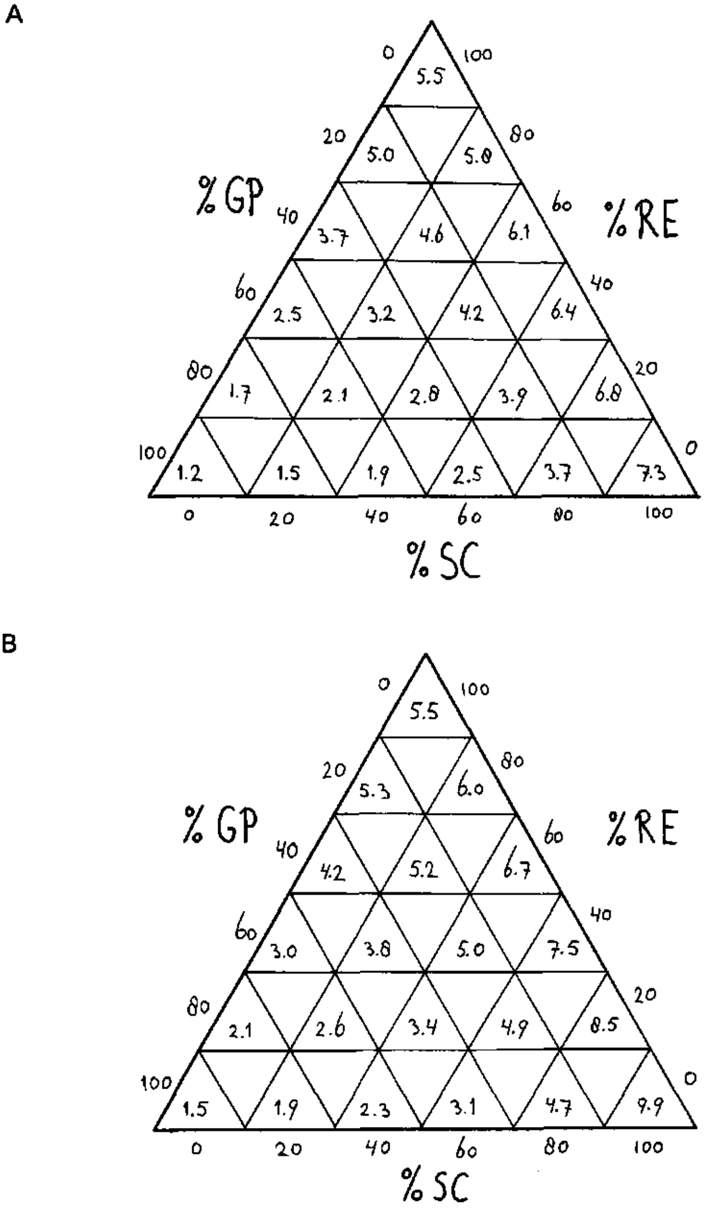

Figure 8.2 Simulated grazing capacities at village level (ha/TLU) based on the relative contribution of standing crop (SC), green pick (GP) and regrowth after burning (RE). A: browse (10%) included, B: browse excluded.

purposes. To improve range management practices at village level, additional site specific research is required.

Increase in cattle numbers

It is has been shown in these studies that vast areas of the WP rangelands are under-utilized. The conservatively calculated potential carrying capacity (CC) was 1,075,000 TLU, twice the 547,000 head of cattle present in 1990. Thus, doubling of the herd seems possible (Chapter 4). Sites near by and further away from roads or water sources did not reveal differences in range condition (Chapter 5), indicating that the areas with higher stocking rates have not deteriorated.

Aside from the risk of livestock loss in GMS 1 in years of prolonged floods and the fact that GMS 2 has reached its potential stocking rate, there is scope to increase the cattle population of the WP (Chapter 4). The east bank of the Zambezi river (GMS 3) had, despite its relatively low potential for grazing, actual cattle numbers far below the potential ones. Development of this region will be difficult because of the difficult living conditions for humans (lack of infrastructure). The west bank (GMS 4), where good grazing areas exist with a low cattle population, has the highest potential for expansion. Digging of simple water ponds in GMS 4 would increase the potential CC by about 200,000 (Chapter 4).

As a consequence of the under-utilization, the assessed net income of 1.4 US$/ha/yr was lower than the income from extensive grazing of 2.4 US$/ha/yr as found in pastoral regions of east Africa (Chapter 7). If the potential number of cattle would graze the WP, the output per ha would be slightly higher than that reported for east Africa (2.6 US$/ha). Water pond development would increase the average provincial output with 0.4 US$/ha to 3.0 US$/ha.

The limits of the CC for the WP would be reached in 30 years. However, such a simplistic interpretation neglects to take into account the impacts of uneven livestock distribution, and care should be taken to spread this impact as widely as possible. The Bulozi floodplain edge deserves special attention. Cattle often are kept close to the plain's edge because the farmers want to manure the fields or want to sell the milk, leading to a heavily stocked area during the flood season. For this reason, attempts to develop presently under-utilized grazing resources should begin now. Otherwise, the stagnation of livestock production, the deterioration of grazing areas and an unacceptable risk of livestock death will be inevitable.

The likelihood of ecological damage due to increased stocking rates, is not considered high at present. The level of the cattle population would most likely be constrained by poor nutrition, low management levels, and factors such as drought and disease, before reaching a level high enough to have any lasting widespread effect on the rangelands of the WP. There will, however, always be a need to monitor the rangelands to avoid eventual overgrazing and deterioration because cattle numbers cannot accumulate indiscriminantly. Livestock holders will continue to expand numbers because of the high rates of return from livestock and the need for security (Livingstone 1991). Deterioration processes occurring in other regions of Africa can serve as examples of how to deal with rangelands in an economically, ecologically and sociologically sustainable manner (Dodd 1994).

How static is a carrying capacity assessment

The traditional concept of CC, as used in the present study, only applies to systems in equilibrium (Chapter 4), referring to systems with sufficient rainfall to ensure substantial forage production every year. In the (semi-)arid regions, non-equilibrium dynamics will predominate (Ellis and Swift 1988) and calculations of CC are much more complicated (Behnke *et al.* 1993). The WP is considered a system in equilibrium.

Nevertheless, the calculated figure of 1,075,000 head of cattle should not be seen as a static result but rather as a guideline for planning purposes. Due to the narrow time frame of the field measurements, the results do not reveal how the GC's vary throughout the dry season and among years as discussed above. A range of potential CC's, based on good, moderate and bad years, would be more appropriate (Geerling and de Bie 1987).

However, the calculations in the present thesis have been conservative due to the poor quality of the standing crop. The crude protein concentration of dry grass in high rainfall areas is lower than in low rainfall areas (Breman and de Wit 1983). If a more simple method had been used, for example as proposed by the FAO's LE for extensive grazing (FAO 1991), a higher CC would have been found. The FAO proposed that 20% of the standing crop can be utilized irrespective of the quality. This would have resulted in an overall provincial CC of 1,560,000 head of cattle or 1,810,000 if corrections for browse had been considered.

Factors such as the expansion of areas under cultivation, supplementation, grazing and fire management can change the CC considerably. However, the expansion of areas under cultivation is not high, as discussed above. There are no home-grown supplements and it is not advisable to introduce them due to the difficult growing conditions and required inputs. The only affordable supplements are the moderate to poor quality crop residues in the early cold-dry season (Ottens and Baars, unpublished). Strategic burning coupled with the planned conservation of standing dry forage seems appropriate to those lands which have not been developed to any significant extent (Tothill 1971). The need to burn will be reduced if cattle are supplemented with urea licks. This will increase the CC because the proportion of the SC that can be consumed will then increase. Even this relatively low input is not likely to be successful in the near future of the WP.

Grazing and fire management

A survey among farmers revealed that the time of release, the time of kraaling and the milking practices determined time spent on grazing (Ottens and Baars, unpublished). There was a flexible system of grazing: the better the forage on offer the less time was allowed to graze. But the time spent on grazing was low throughout the year.

Herding efforts were mainly directed to prevent damage to crops and not to optimize the use of grazing resources. Probably, farmers will not be willing to invest much time in grazing management, because many recommendations to improve grazing management imply higher labour inputs.

A constraint to improve grazing management in the WP is that the people responsible for the entire herd are not always the owners and full beneficiaries of all cattle. The household of these kraal keepers owns about 60% of the cattle in a herd (van Klink 1994). They are normally rewarded for looking after someone else's cattle, for example by receiving every second calf of a cow (Beerling 1986). The total inputs of the kraal keepers' household to the herd of 60% equalled the total net outputs of this household (Chapter 7). Most investments leading to improved efficiency are also required for cattle not owned by the keeper and he might be reluctant to invest in other people's cattle.

The major objectives of using fire in grassland management by livestock owners were to stimulate regrowth and to a lesser extent to control ticks (Chapter 6). Many non-cattle owners apply fires also for a wide variety of other reasons. No control efforts were evident. Despite planned fires being uncommon, most cattle farmers considered burning beneficial because it provided out of season green grass.

Approach to improved management

External assistance to communities in grazing and fire management should be directed at developing and strengthening the managerial capacity, rather than focusing largely or solely on technical aspects. Consequently, no matter how much we know about technical improvements, it all becomes meaningless if the institutional and organizational framework in which decisions are made, do not exist or are fragmented ('t Mannetje 1996). An example is the failure of the summer grazing scheme in the seventies whereby cattle were transferred during the floods from the Bulozi floodplain edge to further into the upland. Persons other than the herd owner were in charge of the herd for a few months. Lack of trust in these 'unknown' persons, lack of manure along the plain's edge and lack of possibilities to sell milk by the herd owner caused the failure of this scheme. Similarly, to move cattle over large distances to thinly stocked rangelands, is not likely to be successful due to many socio-economic and political limitations. A more appropriate approach to improve range management seems required.

The issue of proprietary rights of a community over the resources of an area is central to the concept of communal management of natural resources, such as the control of fires (Bromley and Cernea 1989). In many cases, communities have lost the legal rights over, and the corresponding responsibilities for the natural resources of their area (Frost 1992). Common property ownership involves the rights of individuals to benefit from the use, exchange, or sale of communal assets, provided that this does not infringe the same rights of others within the group (Bromley and Cernea 1989). Viewed this way, property is not an object, such as land, but rather a right to a flow of benefits from an asset which others are legally and morally obliged to respect.

Individuals operating within a common property regime thus have both rights and duties in respect of the use and management of the resource, while the group as a whole is able to exclude outsiders from having access to the resource. The issue therefore is how these rights and obligations are defined and enforced. Crucial to the success of such an institution is a system of community-based authority able to enforce the rules governing the behaviour of individuals in the group.

Fire management plan

Any attempt to control fires must have the support of the community. This is best achieved by making fire management part of a broader community based programme of natural resource management. By institutionalizing the responsibility for burning within a community, it is anticipated that a more restrained and accountable pattern of use will emerge (Frost 1992).

Particular difficulties may arise in those grazing management systems based on transhumance. Because of the itinerancy of the livestock owners, who are probably the most frequent users of fire, it may be difficult for them to participate regularly in discussions within the community on setting up a management plan. Consequently, they may be less committed to the plan and disinclined to help fulfil its aims.

Fire management plans should be developed for selected areas by the local communities concerned, with the assistance of government officers and others. Obviously, central to this process, is the need to identify what benefits a community could expect to receive. Data as shown in Figure 8.2 may then be required.

Matthewman (1980) mentions indiscriminate burning as a serious threat to the nutritional status of cattle. Also in the WP there is a wide belief among government workers that fires should be prevented. From Figure 8.2 and from farmers' perception (Chapter 6) it appears that fire can improve the GC substantially. The proportion of burnt area required to obtain a diet of approximately 7% CP was 77% in the Bulozi floodplain and 79% in the Siloana sand plain. The inclusion of browse in the diet and burning in areas with a good regrowth potential would reduce the need to burn and more biomass would be available for cattle. But in the Bulozi floodplain, the amount of fodder from grass appears to be sufficient and cattle are reluctant to browse (Ottens and Baars, unpublished).

Livestock productivity

From Chapter 7 the following conclusions are drawn. The output of draught-power can be increased considerably. There is a limited potential to increase the output of manure because the area manured is small. The cattle sales per average herd are low, and there is room to increase cattle sales, especially since the natural increase of the herd is large. If culling were more timely, the number of animals for emergency slaughter could be reduced leading to more cattle available for sale. In short, provided there are good marketing channels and good prices, the output per head can be increased considerably.

Cattle are kraaled at night. Shifting of the kraal is done every 3 to 5 days to manure fields which are cultivated the next rainy season (Chapter 7). Manure is considered a main output by farmers (Beerling 1991). The more time spent on kraaling (and thus manuring), the less time spent on grazing. This will negatively influence the output of milk, meat, reproductive performance and draught-power.

Although attempts were made in the WP to get insight in the cattle manure application versus crop production (Penninkhoff 1990), an understanding of the soil-manure-crop processes is lacking. In the Sahel, extensive studies on this process resulted in valuable information. Application of high rates of cattle manure can give rise to leaching of organic carbon, nitrogen and phosphorus, and it is more efficient to apply small amounts of manure frequently than large amounts at longer intervals (Brouwer and Powell 1993). Because of the perceived importance of manure in the WP, an in-depth study as in the Sahel seems required. This will provide useful information on how to optimise the manure output with respect to grazing time and other outputs.

P levels found were 0.08% for yellow grass, 0.11% for green unburnt grass and 0.16% for regrowth (Chapter 4). The study on regrowth, however, exerted a greater effect per region rather then the effect of unburnt versus regrowth grass (Chapter 6). All the grasses in the floodplain region (GMS 1), whether burnt or not, had a higher P level than that required for maintenance, and all the grasses in the sand plain area (GMS 4), whether burnt or not, had P levels in grass below maintenance requirements (0.12%, Little 1980). It is known that a shortage of P in the diet can lead to a low reproductive performance. However, in GMS 1, with high P levels in the diet, the calving interval was 650 days versus 559 days in the other GMS's. Also the survival rates of calves at the age of one year were lower than those of the other GMS's (van Klink 1994). The low performance of cattle in GMS 1 is probably due to uneven cattle distribution during the upland grazing period and not to P levels in the forage. Despite the unclear role of P in the reproduction of Barotse cattle, it is emphasised not to under-estimate the possible influence of low P levels of grasses in some regions on livestock production.

The intensification of the cattle husbandry (in numbers and efficiency) will increase access to markets because of fewer financial constraints. Increased purchases for home consumption of cereals produced elsewhere in more reliable rainfall areas like the Kaoma district of the WP, will reduce the pressure on rangelands because of a reduction of areas under fallow (Chapter 5), although this effect is not obvious at present. It will also improve welfare because of reduced dependency on the unreliable crop sector. More manure and draught-power would become available for the crop sector resulting in safer cereal production (manure improves the water holding capacity of the soils, ploughing leads to fields which can be ready in time) (Chapter 7).

Realization of objectives

In the first paragraph of the discussion, the objectives of the Provincial Medium Term Development Plan for 1992-1996 (PPU 1991) were mentioned. It is obvious that the third objective "to realize the potential of the existing grazing areas in an ecologically justifiable way" has not been reached by far. The challenge to achieve this potential should also include the efficiency at herd level. These improvements will positively influence cattle marketing (objective 1), disease control (objective 2) and a wider use and access to cattle (objective 4) as there are more cattle products and investments will be cheaper per head or per unit of output both for the farmers and the Government.

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Summary

Condition and management of the rangelands in the Western Province of Zambia

In the Western Province of Zambia, concern was raised about possible overgrazing of the rangelands, due to an annual increase in cattle numbers of 2.5% over the last two decades. For that reason, a land evaluation for extensive grazing, based on FAO guidelines, was conducted, which comprised the following steps: 1) land classification, 2) floristic description of identified land units, 3) mapping of these units, and 4) the calculation of the provincial carrying capacity for cattle (CC).

A hierarchial land classification into Regions (9), Systems (32), Units (124) and Facets (415) is presented (Chapter 2). The land classification was based on woodland types, drainage patterns, and landforms. False colour MSS Landsat images, aerial photographs, existing maps and available literature were used for the initial classification. During field surveys, using 289 sites in the wet season and 222 in the mid-dry season, the landform and vegetation were identified or literature data verified. Areas were assessed within all classes. Based on the land classification and collected floristic details, map units were designed. A map of landscapes and grasslands in colour, describing 71 units, scale 1:500,000, resulted (Chapter 3). Each map unit provides data on the dominant tree and grass species and the vegetation structure. The classification of vegetation structure is based on the cover by woody species (trees >5m, shrubs <5m and grasses/sub-shrubs <0.5m).

To assess grazing capacities for the land units delineated in Chapter 2, the amount of dry matter (DM) was estimated during the mid-dry season survey. The DM was classified into 1) dry mature grass of unburnt sites, 2) green grass of unburnt sites and 3) regrowth grass after burning (Chapter 4). Crude protein concentrations were determined within these classes on 91, 37 and 20 samples, respectively. Calculations of grazing capacities were designed to simulate forage selection by cattle: the higher the crude protein concentration of grass, the higher

the proportion of DM selected.

Grazing management systems were surveyed. Two transhumance and two sedentary grazing management systems were described. The calculated CC of one transhumance system was close to the actual number of cattle present. In the other systems, the calculated CC's greatly exceeded actual stocking rates. The total provincial CC was estimated at 1,075,000 Tropical Livestock Units. There is room to increase cattle numbers by about 500,000 head. Surface water development west of the Zambezi river could further increase the CC by about 200,000 head. Increasing the grazing time to more than 9 hours per day and more transhumance could increase the CC even more.

In 1991, a vegetation monitoring programme was initiated. Ten transects were established in high cattle density areas and the condition of the rangelands was assessed at three to five sample sites along each transect (Chapter 5). The condition assessment was based on 1) grass species composition, 2) basal cover, 3) litter cover, 4) number of seedlings, 5) age distribution of dominant grasses, 6) soil erosion and 7) soil compaction. Age distribution and soil conditions were generally good to excellent whereas litter cover and the number of seedlings were generally poor. Grass composition and basal cover scores were moderate. The overall ratings were poor, moderate or good. The extremes excellent and very poor were not encountered. No differences in condition of sites nearby and further away from water points or roads within transects were encountered. Signs of range deterioration in high cattle density areas were not detected.

Farmers burn rangelands during the dry season, mainly to obtain regrowth of a high nutritive value (Chapter 6). However, fires are not controlled. Cattle farmers were subjected to a questionnaire survey to identify their practices and ideas with regard to the management and control of fires. Seventy-eight percent considered fires beneficial, because they provided green grass (80% of the positive respondents), they reduced the number of ticks (14%) or for other reasons (6%). On the other hand, 15% of the farmers complained about a shortage of grass due to burning. A follow-up study monitored the regrowth of grasses during the most critical part of the dry season. In three vegetation types, 4 plots were clipped 3,

7 and 11 weeks after fire application. The DM yield 3 weeks after burning was 0.12 t/ha as opposed to 1.3 t/ha before burning and did not increase further unless re-clipped. The crude protein concentration was higher in regrowth (8.7%) than in unburnt grass (3.3%). P levels were influenced more by the site than by burning. Heavier textured soils had a relatively high soil moisture content. There was a correlation of 0.68 between soil moisture and the amount of regrowth. Strategic burning of areas with potential regrowth (loamy soils) is necessary to obtain high quality forage. However, due to limited amounts of regrowth, burning should be avoided on approximately 25% of the land area to obtain an optimal balance between the poor quality standing crop and a limited quantity of good quality regrowth.

The costs and returns were analyzed to determine herd (kraal) input and output, the distribution of costs and returns among families, and the relation to other farm and off-farm income (Chapter 7). Cattle sales, the increase in cattle numbers, milk production and ploughing by oxen appeared to be the most important sources of income (respectively 24, 20, 20 and 19% of total returns of the herd). The returns from local slaughter, manure and ox-power for transport played minor roles. The kraal keeper's household, which owned 60% of the herd, accrued 65% from the total kraal returns, incurred 73% of total costs and accrued 60% of the net returns. Average returns to the kraal keepers' household from cattle keeping, crops, sales of other farm produce, and off-farm income were 55, 29, 5 and 12%. The calculated costs were about a third of the returns. The net economic efficiency was calculated at 1.4 US$ per ha per year. There is scope for increasing the role of draught-power and the animal offtake.

It was argued (Chapter 8) that the land classification, grazing management systems and farming systems should be integrated to develop a provincial land use plan. A practical approach to further develop grazing capacity studies and studies related to the interaction of time spent on grazing time versus herd output is presented. The main conclusions are that: the rangelands of the Western Province are under-utilized, there are no signs of range deterioration, the economic output is low and that fire management has a definite role in range management.

Samenvatting

Conditie en management van weidegronden in de Western Province van Zambia

In de 'Western Province' van Zambia nam de veestapel de laatste twee decennia 2.5% per jaar toe. Dit leidde tot bezorgdheid over mogelijke over-exploitatie van de weidegronden. Om deze reden werd een landevaluatie voor extensieve begrazing, gebaseerd op richtlijnen van de FAO, uitgevoerd. Deze evaluatie omvatte de volgende stappen: 1) een land classificatie, 2) de botanische beschrijving van geïdentificeerde eenheden, 3) het in kaart brengen van deze eenheden, en 4) de berekening van de potentiële rundveestapel die in de provincie zou kunnen grazen.

Een hiërarchische land classificatie in Regio's (9), Systemen (32), Eenheden (124) Facetten (415) wordt beschreven in hoofdstuk 2. De land classificatie is gebaseerd op soorten bos, waterafvoersystemen, en landvormen. MSS Landsat satelliet afbeeldingen, luchtfoto's, bestaande kaarten en beschikbare literatuur werden gebruikt voor de eerste voorlopige classificatie. Tijdens veldonderzoek, op 289 lokaties in het natte seizoen en 222 in het midden van het droge seizoen, werd de vorm van het landschap en de soort vegetatie geïdentificeerd of de bestaande literatuurgegevens geverifieerd. Oppervlakten werden bepaald binnen alle klassen. Kaarteenheden werden ontworpen op basis van de land classificatie en verzamelde botanische gegevens. Een 1:500.000 kaart van landschappen en gras vegetaties in kleur, die 71 kaarteenheden beschrijft, resulteerde (Hoofdstuk 3). Elke kaarteenheid beschrijft de dominante boom- en grassoorten en de vegetatiestructuur. De classificatie van de vegetatiestructuur is gebaseerd op de bedekking van de volgende categorieën: bomen >5m, struiken <5m en grassen/sub-struiken <0.5m.

Tijdens het veldwerk in het droge seizoen werden tevens droge stof (DS) opbrengsten bepaald, nodig voor het berekenen van de potentiële veedichtheid per landeenheid zoals beschreven in Hoofdstuk 2. De DS werd gescheiden in 1) droog overrijp gras (hooi) van niet gebrande lokaties, 2) groen gras van niet gebrande

lokaties en 3) hergroei van gras na branden (Hoofdstuk 4). Ruw eiwit concentraties werden bepaald binnen deze categorieën van respectievelijk 91, 37 en 20 monsters. Het berekenen van potentiële veedichtheden was zodanig ontworpen om de selectie van het gras door vee te simuleren: hoe hoger de ruw eiwit concentratie van het gras, hoe hoger het deel van de DS dat geselecteerd wordt.

De typen beweidingssystemen werden onderzocht. Twee systemen met seizoensbeweiding (transhumance) en twee met continu beweiding (sedentair) werden geïdentificeerd. De berekende draagkracht van één transhumance systeem kwam overeen met het reeds aanwezige vee. In de andere systemen overtrof de berekende draagkracht ruim de huidige aantallen vee. De totale draagkracht van de provincie werd berekend op 1.075.000 tropische vee eenheden. Het is mogelijk om de veepopulatie te verhogen met ongeveer 500.000 stuks. Constructie van drinkplaatsen ten westen van de Zambezi rivier zou de draagkracht met zo'n 200.000 stuks vee verhogen. Een toename van de beweidingstijd tot meer dan 9 uur per dag en meer transhumance zou de draagkracht eveneens kunnen verhogen.

In 1991 werden voor de aanvang van een vegetatie monitoring programma tien transects gemarkeerd, in gebieden met relatief hoge veedichtheden. De conditie van de vegetatie werd op drie tot vijf lokaties langs elke transect vastgesteld (Hoofdstuk 5). De vaststelling van de conditie was gebaseerd op 1) de samenstelling van de grassoorten, 2) de grondbedekking door levende plantbasis, 3) de grondbedekking door afgestorven organisch materiaal, 4) het aantal zaailingen, 5) de leeftijdsverdeling van de dominante grassoorten, 6) bodemerosie en 7) bodemcompactie. De leeftijdsverdeling en bodemcondities waren over het algemeen goed tot uitstekend terwijl de bedekking door afgestorven materiaal en het aantal zaailingen over het algemeen slecht waren. De samenstelling van de grassoorten en de grondbedekking door plant basis waren gemiddeld. De totale scores waren slecht, normaal of goed. De extremen uitstekend en erg slecht werden niet vastgesteld. Er werden geen verschillen in conditie gevonden tussen weiden dichtbij en verder weg van drinkplaatsen of wegen binnen de transects. Aanwijzingen van degradatie van weidegronden in gebieden met hoge veedichtheden werden niet geconstateerd.

In het droge seizoen branden de boeren de weidegronden met name om de hergroei van goede kwaliteit gras te bevorderen (Hoofdstuk 6). Echter, men beheerst het vuur niet. Veeboeren werd een vragenlijst voorgelegd om inzicht te verkrijgen in hun praktijken en ideeën m.b.t. het managen en beheersen van vuur. Zevenentachtig procent van de boeren was positief over branden, omdat het resulteert in groen gras (80% van de positieve antwoorden), omdat het teken bestrijdt (14%) of om andere redenen (6%). Aan de andere kant klaagden 15% van de boeren over een tekort aan gras als gevolg van branden. In een vervolg studie werd de hergroei van het gras na het branden waargenomen tijdens de meest kritieke fase van het droge seizoen. In drie vegetatie typen werden op vier lokaties per vegetatie monsters geknipt op 3, 7 en 11 weken na het branden. De DS opbrengst was 3 weken na het branden 0.12 t/ha tegenover 1.3 t/ha voor het branden en nam niet verder toe tenzij het opnieuw geknipt werd. De ruw eiwit concentratie was hoger in de hergroei (8.7%) dan in niet gebrand gras (3.3%). Fosfor niveaus werden meer beïnvloed door lokatie dan door het branden. Bodems met een fijnkorrelige textuur waren relatief vochtig. Er was een correlatie van 0.68 tussen bodemvocht en de hoeveelheid hergroei. Strategisch branden van gebieden met potentiële hergroei (leem bodems) is nodig om goede kwaliteit gras te verkrijgen. Maar door de beperkte hoeveelheid hergroei zou branden beperkt moeten worden tot ongeveer 75% van het areaal om een optimale balans te verkrijgen tussen de DS van slechte kwaliteit ongebrand gras en goede kwaliteit hergroei.

De kosten en baten werden geanalyseerd op kudde niveau voor het bepalen van: in- en output per kudde, de verdeling van kosten en baten onder de families, de verhouding met ander bedrijfsinkomen en extern inkomen (Hoofdstuk 7). De berekende kosten waren ongeveer een derde van de bruto opbrengsten. Veeverkoop, aanwas, melkproduktie en ploegen vormden de belangrijkste bronnen van inkomsten (respectievelijk 24, 20, 20 en 19% van de totale inkomsten van de kudde). De inkomsten uit lokale slacht, mest en trekkracht voor transport speelden een minder belangrijke rol. Het gezin van de beheerder van de kudde bezat 60% van het aantal dieren. Dit gezin kwam 65% van de totale bruto en 60% van de totale netto opbrengsten toe, en droeg 73% bij aan de totale kosten. Het gezinsinkomen was als volgt opgebouwd: het houden van vee 55%, verbouw van gewassen 29%, verkoop van andere bedrijfsprodukten 5%, en extern inkomen 12%. De netto economische efficiency van beweiding werd berekend op 1.4 US$ per ha per jaar. Er is potentie om de rol van trekkracht en de verkoop van levende have te vergroten.

In het laatste hoofdstuk (8) wordt beargumenteerd hoe de land classificatie, de beweidingssystemen en de farming systems geïntegreerd zouden moeten worden om tot een provinciaal landgebruiksplan te komen. Een praktische methode om studies m.b.t. de draagkracht verder te ontwikkelen en studies m.b.t. de interactie van beweidingstijd en de produktie van de kudde wordt gepresenteerd. De belangrijkste conclusies zijn dat: de weidegronden van de provincie onderbenut zijn, er geen tekenen zijn van weidedegradatie, de economische output laag is en dat branden een duidelijke rol speelt in het management.

Curriculum vitae

Robertus Markus Theodorus Baars was born on April 25 1962 in Culemborg, the Netherlands, where he completed secondary education in 1982. As a student of the Agricultural University of Wageningen he realised his theses in Sri Lanka and Zambia in 1985 and 1987, respectively. He graduated in 1988 with specializations in Tropical Animal Husbandry and Tropical Grassland Science. He worked for 2 years in Zambia before being employed as a Range Management Officer in the Western Province of Zambia. From mid 1993 to February 1996 he worked at the National University of Costa Rica as a cattle nutritionist in a Herd Health Project. In 1994 he started to prepare this thesis based on the studies conducted in Zambia. Later in 1996 he will be employed in the field of dairy management and milk processing at the Alemaya University of Agriculture, Dire Dawa, Ethiopia.

Appendix

The Landscapes and Grasslands Map, the Appendix to Chapter 3, has been reduced to A3-size. Chapter 3, including the map at its original scale of 1:500,000 will be published in the ITC Journal in due course.