THE EFFECTS OF INDIGENOUS CULTIVATION PRACTICES ON THE RECOVERY OF DRY MIOMBO WOODLAND IN CENTRAL ZAMBIA

BY

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DECLARATION

I Liywalii Kwibisa hereby declare that this dissertation represents my own work and that it has not been previously submitted for a degree at this or any other university.

....

Signature

..13/12/01..

Date

APPROVAL

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To my parents, Rose Muyunda Mwiya and Gilbert Munyindei Liywalii.

SUMMARY

Miombo is the most dominant vegetation type in Zambia and covers 53% of the country. It is dominated by species of *Brachystegia, Julbernadia* and *Isoberlinia* .

In the study area, pockets of other vegetation types like the munga may be found within the miombo, especially along drainage lines. Munga is an open decidous vegetation with scattered or grouped emergents dominated by species of *Acacia, Combretan* and *Terminalia.* The woodlands are used for agriculture, woodfuel production and timber harvesting.

Expansion of agriculture, especially crop cultivation, is degrading miombo woodlands through forest clearing and land tillage. Under such conditions, it is not known whether miombo regenerates. In other ways, is the recovery of miombo woodlands negatively affected by cultivation and other land uses?

Due to population growth in the vicinity of Lusaka city, more land is being cleared for cultivation. With increasing intensity and extensity of vegetation cover clearing, is the vegetation disappearing or regenerating after abandonment? The rationale of the study was to assess how miombo woodland responds to clearing for cultivation.

The broad aim of the study on the effects of indigenous cultivation practices on the recovery of dry miombo woodland in Central Zambia was to investigate semi-permanent cultivation practices and how this landuse affects the miombo woodland and its recovery. The specific objectives were to: describe the structure of relatively undisturbed woodland stands adjacent to cultivators' plots; describe the pattern of forest clearing and land tillage practices on cultivators' plots; describe the pattern of forest regeneration on current and abandoned cultivators' plots and; assess soil organic matter in current and abandoned cultivators' plots and adjacent relatively undisturbed woodland stands. The research hypotheses were that (1) forest clearing for agriculture and subsequent crop cultivation reduce species diversity and forest recovery in dry miombo woodland and (2) crop cultivation negatively affects soil organic matter content and the rate of recovery by abandonment.

The study was done using three different methods: farmer interviews; woody plant inventories; and soil analysis. Data were computerised using Excel spreadsheets and analysed by PC-ORD and SYSTAT Programs.

The average tree density in mature woodland plots was 1362 stems per hectare while mean height was 11 metres. Seedling/sapling density in mature woodland was 48 250 stems per hectare. The principal dominants among canopy species were *Brachystegia spiciformis* and *Julbernadia globiflora*. The tree density in the fallow plots increased with age of fallow. Seedling density was lowest in cultivated plots and highest in mature miombo.

The pattern of evenness and diversity was not readily discernible and could not be linked to age and land use type. The classification of plots using cluster analysis also revealed that occurrence of characteristic species is not associated with age or status of plot. In addition, there was no evidence that woodland recovery was impaired by cultivation. Similarly, soil organic matter content was not related to vegetation type, age and status of plot.

The hypotheses that clearing for agriculture and subsequent cultivation reduces species diversity and forest recovery in dry miombo is not supported by the findings of this study. The hypothesis that crop cultivation negatively affects soil organic matter content and the rate of recovery following abandonment is also not supported by the findings of this study. These findings indicate that present day semi-permanent cultivation can be practiced in dry miombo on a sustainable basis without negative impacts on the miombo ecosystem.

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ABBREVIATIONS

AG	Above ground
BA	Basal area
BD	Basal diameter
BG	Below ground
bh	Breast height
cm	centimetre
g	gram
gbh	girth at breast height (1.3m AG)
ha	hectare
KH	Knee height (0.3m AG)
kg	Kilogram
km	Kilometre
m	Metre
MAFF	Ministry of Agriculture, Food and Fisheries
MC	Moisture content
SD	Standard deviation
Spp	Species

CHAPTER 1

INTRODUCTION

1.1 Background

Miombo is the most dominant vegetation type in Zambia and covers 53% of the country (Chidumayo, 1997). In terms of distribution of total land cover types in Zambia, the miombo accounts for 396 920 km^2 while munga, another vegetation type found in the study area accounts for only 32 600 km^2 (Chidumayo 1997). It is also the most widespread type of vegetation in Southern Africa (Jeffers and Boaler, 1966; Malaisse 1978; Lawton ,1982). Other vegetation types are forest and grasslands. The forest component consists of dry evergreen, deciduous, montane, swamp, riparian, plantation, chipya and thicket. The savanna woodland consists of the mopane, munga, and termitaria pockets, which may be found within the miombo while grassland is divided into wetland and dambo. Munga is open deciduous vegetation with scattered or grouped emergents dominated by species of *Acacia, Combretum* and *Terminalia* (Chidumayo, 1997).

Fashawe (1971) estimates a total plant flora of 650 species in the miombo woodland. White (1983) divided the miombo vegetation into dry miombo and wet miombo characterised by a mean annual rainfall of less and more than 1000 mm, respectively. The central dry miombo found in central Zambia consist of *Brachystegia (B. boehmii – B.utilis – B. spiciformis)* woodlands with *Julbernadia globiflora* as a common dominant canopy and *Diplorhynchus condylocarpon, Lannea* spp *Ochna* spp and *Pseudolachnostylis maprounefolia* as common understorey trees (Chidumayo, 1997).

The miombo woodlands are used for agriculture, wood fuel production and timber harvesting. Miombo woodland degradation can result from fire, selective cutting, and grazing while clearing and land preparation for cultivation causes deforestation. However, conversion back to woodland is possible through proper management. This is illustrated in figure 1.1.

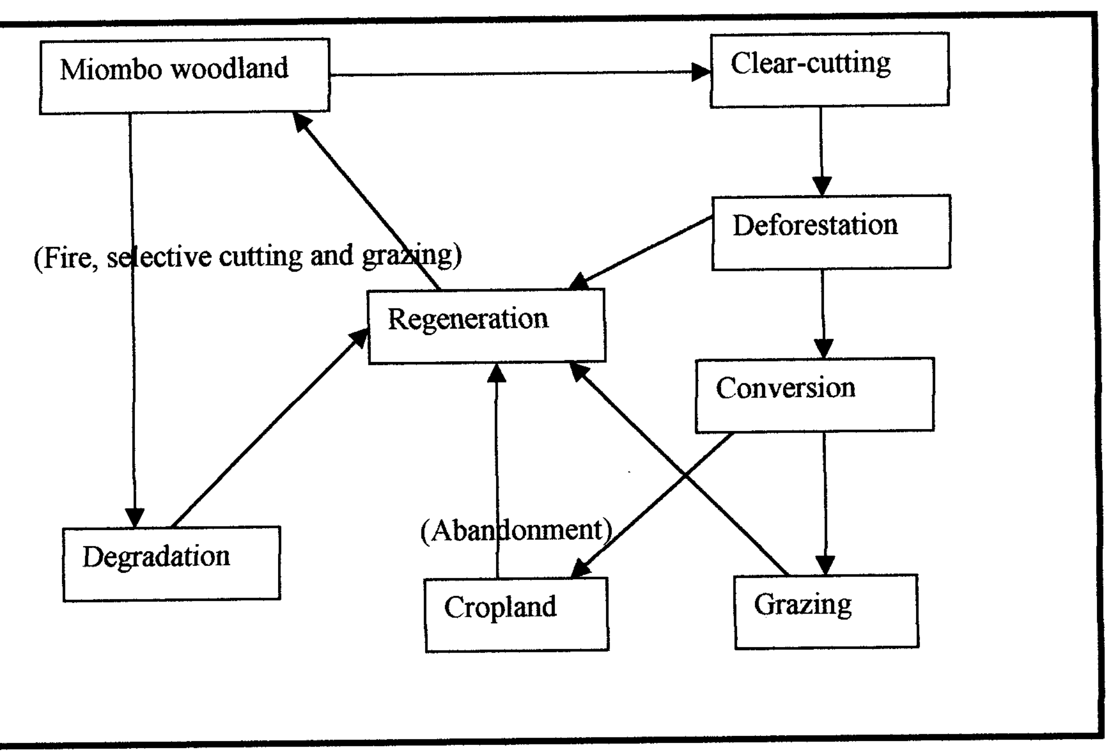

Figure1.1 Pathways of miombo degradation/deforestation and recovery.

Definitions of some terms used in the figure are given in section 1.3

1.2 Research Problem

Expansion of agriculture, especially crop cultivation, due to population growth is degrading and deforesting miombo through woodland clearing and land tillage. Under such conditions, how does miombo regenerate and revert back to woodland? Are species diversity and soil organic matter, which can affect recovery of miombo negatively, affected? This study investigated these questions. Miombo structure is considered from the view of species diversity, soil and recovery after abandonment.

1.3 Rationale

The rationale of this study is based on the recognition that due to population growth in the vicinity of Lusaka City more and more land is being cleared for cultivation. This raises the question of whether vegetation cleared is disappearing or regenerating after abandonment of cultivation. This was the focus of the present study.

1.4 Aim and research objectives

The broad aim of the study was to investigate semi-permanent cultivation practices and how this land use affects the miombo woodland and it's recovery. As stated in section 1.1, there are patches of other vegetation types, such as grassland and munga savanna within miombo woodland and this situation occurs in the Chakwenga area where the study was conducted. Because of this, investigations were extended to munga woodland patches found along drainage lines within the Chakwenga area. The two woodland types found in the area are cleared principally for cultivation.

The specific research objectives were to:

i) Describe the structure of relatively undisturbed woodland stands adjacent to cultivators' plots.

ii) Describe the pattern of forest clearing and land tillage practices on cultivators' plots.

iii) Describe the pattern of forest regeneration on current and abandoned cultivators' plots.

iv) Assess soil organic matter content in current and abandoned cultivators' plots and adjacent relatively undisturbed woodland stands.

A further objective was to use the results of this study to determine land use practices that might contribute to sustainable land and forest utilisation in the dry miombo ecosystem.

1.5 Research Hypotheses

The research aimed at testing two main hypotheses:

i) Forest clearing for agriculture and subsequent crop cultivation reduce species diversity and forest recovery in dry miombo woodland.

ii) Crop cultivation negatively affects soil organic matter content and the rate of recovery following abandonment.

1.6 Definition of Terms

The study adopted the following definitions: -

Degradation: Reduction in the quality of the woodland following disturbance by fire, cutting and grazing.

Regeneration: Woodland development on sites previously occupied by well-developed communities. Development was considered in terms of height, stem density and basal area of trees.

Recovery: Regeneration of the woodland following an external perturbation such as fire, harvesting, grazing and clearing.

Semi- Permanent agriculture: An agricultural practice where the fallow period is longer than the cultivation period.

1.7 Organisation of Work

This work is divided into six chapters. Chapter one presents the introduction and background to the study. Chapter two presents the review of literature. Chapter three describes the study area by presenting general descriptions of the study area and study sites while chapter four describes the method and approach to the study. Chapter five presents the results and chapter six the discussion and conclusion.

CHAPTER 2

LITERATURE REVIEW

The importance of plant succession studies in the lowland tropics has long been pointed out (Richards, 1952; Whitmore, 1975). Many of these early studies of tropical plant succession however were no more than lists of species and general descriptions of different succession stages. These studies have within the context of theories of plant succession, described sequences of species that invade a site. It was much later that other studies described changes in other characteristics such as biomass, productivity, diversity and niche breadth (Odum, 1969). Others, like Connell and Slatyer (1977), were concerned about species composition with the argument that changes that open up a relatively large space might be complex. These may not be necessarily big changes. Cole (1963) observed that even slight changes in the physical environment might favor some species at the expense of others. These changes may be a result of different factors, which may or may not include anthropogenic factors. Agricultural land use practices have significantly contributed to opening up of tracts of forests and/or woodlands in the tropics and both the vegetation and the soil systems become subjected to one form of change or another.

A relationship has been reported to exist between soil and vegetation components of abandoned fields (Watts, 1971; Moss, 1968). Aweto (1981) has analysed changes in both soil and vegetation components and investigated their relationship in fallow plots. This was significant in that earlier studies (Clayton, 1958; Jaiyebo and Moor,e 1964) were concerned with vegetation or soil fertility alone. Stromgaard (1984) has also illustrated the dynamics of the forest – soil ecosystem under shifting cultivation and a thorough understanding of the soil-vegetation dynamics is clearly important in managing the woodland recovery process.

Adams and Baker (1962) and Strang (1974) have described the effects of cultivation practices on vegetation and the varied factors that lead to recovery. Trapnell (1953) studied regeneration of the miombo woodland following cultivation. Soil moisture and nutrient status are important in influencing miombo recovery after cutting and a relationship may exist between productivity and soil nutrient status (Chidumayo, 1993b). It is suggested that high species richness in the miombo probably increases the probability for different strategies for nutrient retention. Högberg (1992) has observed that ectomycorrhiza species in a Tanzanian miombo had higher foliar nitrogen than vesicular mycorrhiza species. Against this scenario, it is concluded that high species diversity in miombo woodland may be important in the maintenance of nutrient cycling and ecological homeostasis. Magurran (1988), Mac Arthur (1955) Loucks (1970) and Margalef (1968) also suggested that diversity can be seen as a measure of ecosystem well being and that during succession there is a trend towards increase in biomass, stratification, complexity and diversity. This trend may be reversed following cultivation or other forms of disturbances such as fire, grazing and wood harvesting. On the other hand, however, Odum (1975) and Hurd *et.al.* (1971) argued that while diversity and stability are often correlated, it does not necessarily follow that diversity in itself produces stability. For example, Mann (1986) reported loss of large fractions of soil organic matter following agricultural use. Recently Knops and Tilman (2000) found that loss of soil organic matter (in the temperate regions) caused by agricultural practices might range from 16-77%. However, it is also reported in studies of abandoned agricultural fields, that soil organic matter also increases after cessation of farming (Prince *et al.* 1988). In this case the loss of carbon and nitrogen were attributed to decreased plant organic matter inputs and by increased decomposition and erosion associated with agriculture. On the other hand, it has been reported that carbon and nitrogen accumulations were also significantly influenced by plant species composition. Ovington (1965) cited woodland age, site conditions and other operations like pruning and thinning, as factors that affect the build-up and distribution of organic matter in the soil.

In the miombo ecosystem, soil moisture and nutrient status are important in influencing recovery after cutting (Chidumayo, 1993a). It is worth noting however that miombo soils are inherently infertile because they contain low levels of nutrients and organic matter (Chidumayo, 1997; White 1983; Cole, 1963). As a result, traditional cultivation systems depend on natural fallow in order to allow for the restoration of the soil nutrient pool. In wetter miombo of northern Zambia, for example, fertility of the soil is enhanced by a form of shifting cultivation called chitemene, which relies on ash fertilisation of the soil. But even then, the soils degenerate after an average of five years of cultivation (Oyama, 1996). Traditionally, a new ash garden is made every year where trees are lopped, heaped, dried and burnt to provide the required fertility. This is then followed by a period of natural fallow. Changes in the vegetation and soil nutrient store (N, P, K, Ca, and Mg) have been followed under chitemene (Strongmgaard, 1984) while sustainable options for agricultural intensification in the wet miombo, under chitemene shifting cultivation, have been assessed and both optional and ecological fallow periods have been recommended (Araki, 1992; Oyama, 1996).

These studies, including Stromgaard (1986), have attempted to study the regeneration process at abandoned chitemene fields in northern Zambia. Evidence emerging from these and other studies point to the fact that increased population density and reduced fallow periods threaten the sustainability of the chitemene (Chidumayo, 1987; Araki, 1992; Oyama, 1996). Similar observations have been reported elsewhere (Toshiyuki, 1999). No such work has been done in the dry miombo where semi-permanent cultivation practices are employed.

In the miombo, there are inter-specific differences in seed production, dispersal and germination rates, seedling survival and regeneration, especially in the first year. Generally, seedling mortality rates decline during subsequent years (Chidumayo, 1993b). Munyanziza (1994), has observed that seeds that readily germinate, for example, *J. globiflora, Brachystegia* spp. possess limited dormancy while others like those of *Pterocarpus angolensis* seeds may not germinate for several months. Otherwise for most species, seeds germinate within a period of three weeks once supplied with water. Chidumayo (1994) found that seed germination rate, as determined by seedling emergency, was higher in charcoal soil than in undisturbed soil. This was attributed to increased pH of the soil resulting from burning. Whilst acknowledging the fact that seedling survival during and immediately after germination is hampered by periodic and unpredictable droughts, Munyanziza (1994) also contends that survival may hinge on quick integration of seedlings in ectomycorrhizal network under mother trees or neighbouring trees of the same type of symbiosis. In *B. spiciformis,* for example, Ernst (1988) found that seedlings depended on cotyledons for their initial establishment. This may also be true for other miombo species.

Kieland–Lund as reported in Munyanziza (1994) identified that bush fires heavily damage most seedlings. Depending on the intensity of the fire, this may also be true for mature trees (Trapnell, 1959). Similar observations have been made by Cole (1974), Fanshawe (1971), Knapp (1973), and Rutherford (1978) who consider that fire strongly influences the structure and floristic composition of savanna vegetation. Often the time of burning and amount of fuel available influence fire intensity: the more reason why foresters prefer to burn early in the dry season as opposed to late dry season burning.

In terms of structural development, which is a function of woodland recovery, seedlings of miombo trees show very little growth during 3-5 years because they allocate more photosynthetic biomass to root growth during early seedling development (Chidumayo, 1993b; Munyanziza, 1994). This can be viewed as a process of resource allocation, which may explain differential tolerance among species (Pickett and Mc Donnel, 1989). Celander (1983) has observed that tap roots expand yearly while shoots produced each year die back during the dry season and this can go on for 8-10 years in species such as *P. angolensis* until the tap root has accumulated enough energy and nutrient reserves to allow the shoot to grow some three metres in a single season, thus reducing its chances of being killed by fire. Savory (1962) has observed that a well-developed taproot may well be an adaptation against damage from fire.

On the whole, poor seedling growth has a negative impact on early regeneration. Chidumayo (1994) suggested that poor seedling growth on charcoal spots in *Isoberlinia angolensis* and probably other related species contributed to lack of regeneration. Coppicing from stump is equally important in accelerating regeneration. Boaler and Sciwale (1966) have reported rapid growth of regrowth miombo in abandoned cultivated plots. Strang (1974) reported similar findings and observed that incomplete removal of rootstocks and large roots resulted in the rapid formation of shrub tending towards woodland. This was however not the case when long continued cultivation or mechanical cultivation was employed.

This study was an attempt to describe the indigenous cultivation practices in dry miombo of central Zambia from an ecological standpoint and examine their effects on woodland regeneration. Although Trapnell and Clothier (1996) described similar cultivation practices in the 1930's, these have changed overtime and so has population density. To date, there has been no recent description of these cultivation practices from an ecological perspective. Central to this study was the question of whether or not recovery of these woodlands follows patterns observed elsewhere under different cultivation systems, for example, in the chitemene. The focus was on both spatial and temporal aspects and explored the linkage between these on the one hand and the integrity of the woodland ecosystem on the other.

CHAPTER 3

STUDY AREA

3.1 General Description

Chakwenga area is located about 90 km along Great East Road in Chongwe district, central Zambia. Chongwe district lies between latitudes 14° 45' and 15° 30' South and longitudes 28° 31' and 29° 31' East. The terrain of the area comprises diverse topographical situations (Chidumayo, 1993b), which include hills and interfluves. Simpson (1967) describes the geology of the area as being underlain by granitic basement rocks that are deformed by quarzites, gneisses and schists. The mean annual rainfall, at Lusaka – which is the nearest weather station in 792 mm and is distributed from November to March/April and 75% of this occurs from December to January (Chidumayo, 1997). A large annual variability in rainfall is exhibited. The soils of Chakwenga area have been mapped by the Soil Survey Unit of the Department of Agriculture as a mixture of Alfisols and Ultisol. Generally, the soils are sandy loam at 0-30 cm depth and sandy clay at 31-100 cm depth, with a pH 5.0 – 6.0 (Chidumayo, 1993b).

The area is dominated by hill miombo, with strips of munga along drainage lines. The area has in some places been cleared for cultivation. In the miombo, the most dominant species are *Brachystegia boehmii* Taub, *Julbernadia globiflora* (Benth). Troupin, *Isoberlinia angolensis* (Welw. ex Benth) Hoyle and Brenan *Uapaca* spp. *Acacia* *polyacantha* Willd and *Combretum* spp. are the most common species in the munga patches. The herbaceous vegetation is dominated by species of *Hyparrhenia, Andropogon, Brachiaria* and *Cyperus.*

There are village settlements in the area, with Sinjela village being probably the oldest and the largest. Small family homesteads are also becoming common in the area. Chidumayo (1993b) reported that until the 1970's, this area was virtually uninhabited and village settlements have mushroomed only in the 1980's. The inhabitants of the area are actively engaged in crop cultivation, in both miombo and munga.

3.1.1 Study Sites and Plots

The study sites were located within an area of approximately 27 km^2 between latitudes 15° 15' 6" and 15° 17' 24" South and longitudes 29° 10' 54" and 29° 8' 30" East. This was delimited using 1:30 000 aerial photographs taken in 1990 and 1:50 000 topographical maps for the area as shown in Figure 3.1. A total of 34 study plots were established in cultivated and fallow fields in both miombo and munga vegetation. Choice of plots for the study was based on existence of the required plot characteristics in terms of age and status, hence the unequal distribution of study plots in different categories. An additional 4 plots were also established in relatively undisturbed mature miombo woodland. No similar sites could be found for munga vegetation. The distribution and description of the study plots by vegetation type and status are shown in Table 3.1.

Table 3.1. Distribution of sample plots by vegetation and landuse type in the study site

Study plots	Category	Status
1-10	Miombo	Cultivated
11-15	Munga	Cultivated
16-28	Miombo	Abandoned
29-34	Munga	Abandoned
35-38	Miombo	Mature woodland

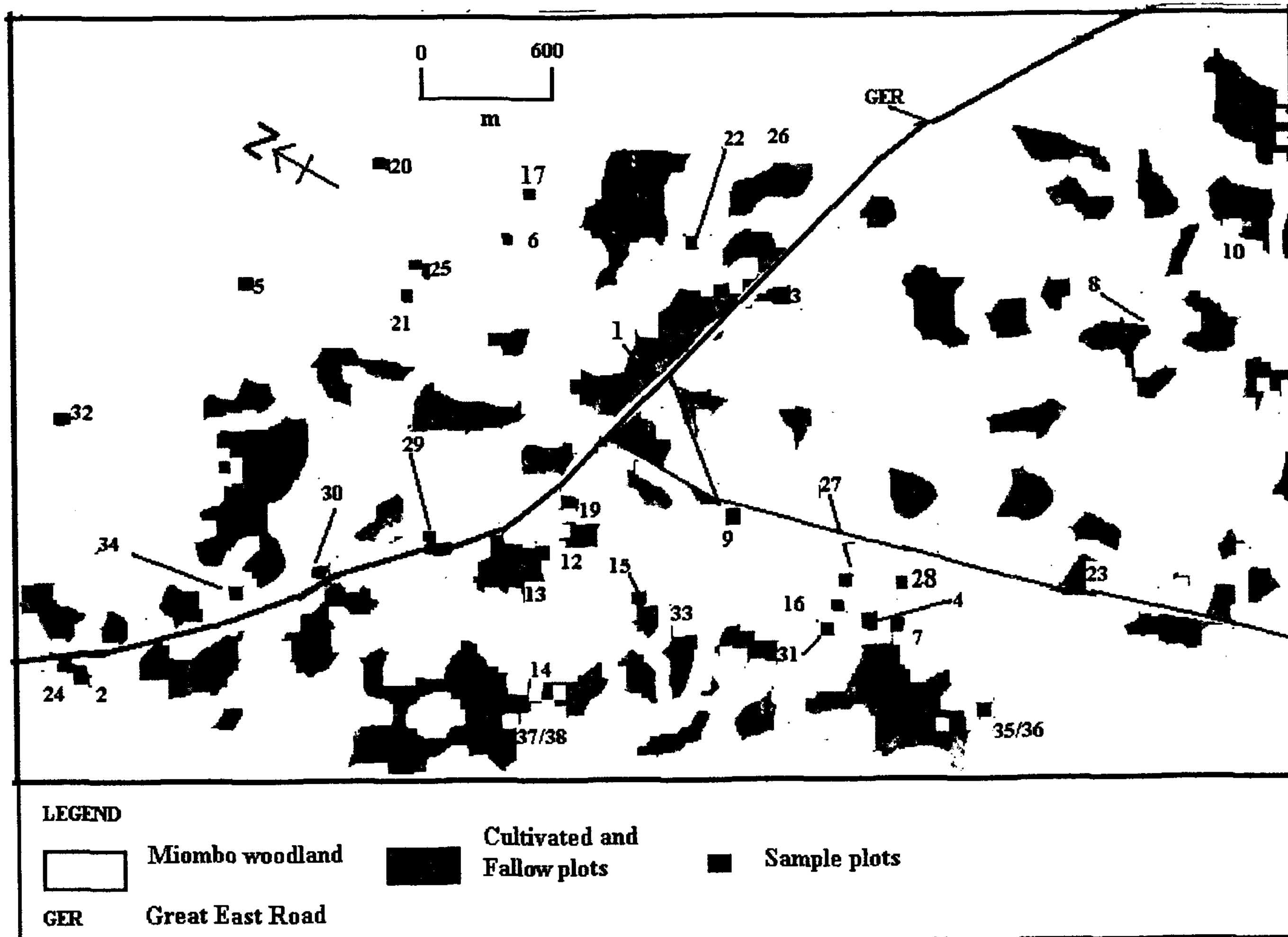

Figure 3.1 Distribution of sample plots in the Chakwenga study area.

CHAPTER 4

METHODOLOGY

4.1 Research Methods

The study on the effects of indigenous cultivation practices on regeneration of the woodland was done by three different methods:

i) farmer interviews,

ii) woody plant inventories and

iii) soil analysis

These methods are described below. Fieldwork was conducted from October to November 1999.

4.1.1 Farmer Interviews

A questionnaire was developed to facilitate interviews with local farmers (Appendix I). A total of 23 farmers were interviewed. Information generated from the interviews was used to define cultivation practices, in terms of land preparation practices and crops grown. For the purpose of the study, the number of farmers interviewed was considered adequate because subsequent interviews did not yield different responses. Farmer interviews were also used to identify required plots for the study. In addition, the interviews were also used to identify and establish the age of field plots, both cultivated and fallow although prior identification of possible location of sample plots was done using 1990 aerial photographs. The photographs were useful to the extent that they showed land use pattern in the study area, as it was 10 years previously. At the time of the study new areas of the woodland had since been opened, which were absent on the aerial photographs. These were delineated accordingly on the aerial photographs.

Plot age determination was done for plots under cultivation and fallow. The year of opening and the expected year of abandonment were established for the cultivated plots. Similarly, the year of abandonment and expected year of re-opening were provided by the farmers, although this was in most cases difficult to verify.

The distribution of the plots by age and vegetation type is shown in Table 4.1. Ten and 5 cultivated plots were located in miombo and munga vegetation types respectively. In the abandoned or fallow plot category, 13 of the plots were in miombo and 6 were in munga.

Table 4.1 Distribution of sampled cultivated and abandoned plots according to period of cultivation and fallow in miombo and munga woodland types in Chakwenga study area, central Zambia.

CULTIVATED PLOTS			ABANDONED PLOTS		
Period of cultivation (Years)	**Plots/Vegetation type**		**Period after abandonment (Years)**	**Plots/Vegetation type**	
	Miombo	**Munga**		**Miombo**	**Munga**
0	1	0	1	2	0
1	1	0	2	2	1
3	1	1	3	0	1
4	1	1	5	2	0
5	2	0	6	2	2
7	1	0	7	1	0
8	1	2	10	1	1
10	0	1	13	1	0
12	1	0	14	0	1
14	1	0	19	1	0
-	-	-	20	1	0
Total(s)	**10**	**5**		**13**	**6**

In addition, 4 relatively undisturbed plots were established in mature miombo woodland bringing the total number of plots to 38. Relatively undisturbed plots refer to those plots established in areas, which have not been subjected to clearing and/or cultivation in the recent past. There were no such plots identified in the study area to represent undisturbed munga woodland type.

4.1.2 Woody Plant Inventories

The shape and size (i.e., length and breadth or circumference) of each cultivated or abandoned plot was determined prior to setting up a 20 m x 10 m (200 m^2) plot at the centre of each field. The plots in the mature woodlands were systematically located within the woodland. Within each 20 m x 10 m (large) plot, a small 5 m x 2 m (10 m^2), plot was established. The large plot was used to enumerate stumps and trees (any woody plant with girth at breast height (GBH) of > 2 cm). The nested small plot was used to enumerate seedlings and saplings that were < 1 meter in height.

4.1.2.1 Survey of cultivated plots

The method of land preparation was recorded for each sample field. Individual trees on each sample plot were numbered, identified (to species or genus level) and their height estimated visually and recorded and GBH measured. For stumps, the height and top diameter were measured and if coppiced, the origin of the suckers/shoots recorded. In addition, the status (dead/dry or live) of both trees and stumps was assessed .

On the nested small plots, seedlings and/or saplings of < 1 metre were numbered, identified, and basal diameter and height measured and recorded for each individual seedling or sapling.

4.1.2.2 Survey of relatively undisturbed plots.

The relatively undisturbed plots were located close to the oldest fallow plots (i.e. 19 and 20 years old). The large plots were marked out and individual trees on each sample plot were numbered, identified and measured as described above for cultivated plots. Similarly, the nested small plots were established at the centre of the large plot and measurements on seedlings and saplings were done as described for cultivated plots above.

4.1.3 Soil Organic Matter Content

4.1.3.1 Soil Samples

Soil samples for analysis of soil organic matter content were collected from all the sample plots at a depth of 0-30 cm using an augur: a sample from each large and each nested small plot. This gave a total of 76 soil samples. Given limited resources in terms of time and the fact that the size of the plots was small (20 x 10 m for larger plots and 5 x 2 m for the nested small plots), the sample size of two was considered to be adequate.

Table 4.2 shows the distribution of the soil samples from large plots in relation to vegetation type, age and land use type of plot.

Table 4.2 Distribution of soil samples collected from cultivated and abandoned plots of varying period of cultivation and fallow in miombo and munga woodland types in the study area.

CULTIVATED PLOTS			ABANDONED PLOTS		
Period of cultivation (Years)	Samples/Woodland type		Period after abandonment (Years)	Samples/Woodland type	
	Miombo	Munga		Miombo	Munga
0	2	0	1	4	0
1	2	0	2	4	2
3	2	2	3	0	2
4	2	2	5	4	0
5	4	0	6	4	4
7	2	0	7	2	0
8	2	4	10	2	2
10	0	2	13	2	0
12	2	0	14	0	2
14	2	0	19	2	0
-			20	2	0
Total(s)	**20**	**14**		**26**	**12**

In addition, 8 more soil samples were obtained from 4 plots in relatively undisturbed mature miombo.

4.1.3.2 Soil Sample Analysis

Soil samples were air dried in the laboratory by spreading them on paper for a period of two weeks. Possible contamination by dust was avoided through ensuring that windows were closed all the time. These were then crushed to evenness and sieved through a 2 mm sieve. Soil organic matter was then determined by the combustion method: a sub sample of 10-20 grams of soil was put in a pre-weighed crucible and burnt in a furnace at 450° C for 2 hours in order to burn the carbon. After burning, the crucible and the contents were cooled in a dessicator prior to weighing.

Organic matter content was determined using the equation below:

$$O.M = [(Swt_1 - Swt_2)/ Swt_2] \times 100$$

O.M = organic matter content in %

Swt_1 = Weight of soil before combustion

Swt_2 = Weight of soil after combustion

4.2 DATA ANALYSIS

Data were computerised using Excel spreadsheets and analysed by PC – ORD (Mc Cunner and Mefford, 1995) and SYSTAT (SPSS 1997) programs. This was necessary in order to run cluster analysis using the k-means splitting technique. The plots were clustered in order to assess plot characteristics, specifically tree species evenness, richness, diversity, and organic matter in different land use types.

CHAPTER 5

RESULTS

5.1 VEGETATION STRUCTURE

The mature miombo plots adjacent to old fallows were relatively undisturbed although both dead and live stumps were evident in these plots. Tree density, height and basal area were determined for these plots in order to describe vegetation structure.

5.1.1 Tree Density, Height and Basal Area

Mean values and standard deviation figures for tree density and height were calculated. The average tree density (mean ± 1 SD) in mature woodland plots was 1362± 469 stems per hactare (ha) with a mean height in metres of 11 ±1.2. Seedling/sapling density was 48250± 14315 stems per ha. Basal area at basal area at breast height was used to mean the proportion of stem cover in terms of area on a given plot calculated from gbh measurements.

5.1.2 Species Composition, Evenness and Diversity

The principal dominants among the canopy species were *Brachystegia spiciformis* Benth and *Julbernadia globiflora*. The understorey was made up of the following: *Combretum* spp, *Ochna schweinfurthiana* F. Hoffm, *Pseudolachnostylis maprouneifolia* Pax, *Dychorhynchus condylocarpon* (Muell. Arg.) Pichon, *Dichrostachys cinerea* (L.) Wight and Arn *Terminalia* spp and *Burkea africana* Hook.

Evenness (H'/log S), where E is the evenness and S the total number of species in the sample and Shannon-Wiener Index of diversity (H, = P_i log (P_i) where P_i is the number of individuals of all the species in the sample mature woodland stand were calculated. The mean values (mean± 1SD) were 0.9± 0.04 and 1.5± 0.8, respectively. Species richness refers to the number of tree species found on a given plot.

5.2 CULTIVATION PRACTICES

5.2.1 Forest Clearing and Tillage Practices

Land preparation for cultivation in Chakwenga area starts with tree cutting at different levels above ground (stumping) and only rarely are trees uprooted. In some cases however, both stumping and uprooting are combined. Out of 18 interviewed farmers, 78% cleared woodland by stumping, 16% cleared by both stumping and uprooting and only 6% cleared by uprooting only. Observations on 34 cultivators' plots revealed that stumping was at knee height (0.3m above ground) on 68% of the plots and 9% and 3% at ground level and breast height (1.3m above ground), respectively. Of the remaining 20% trees were either uprooted or cleared by both uprooting and stumping at knee height. Trees are normally cut with a hand axe and in addition hoes are also used during uprooting. Once cut, the stems and branches are cross-cut. Some of the biomass is removed from the fields while the rest is piled in heaps and/or strips, dried and later burnt in *situ,* apparently to improve soil fertility. In some cases, the woody biomass is piled around stumps and burnt, resulting in death of stumps. This is also done on the surviving stumps in subsequent years. Biomass clearing is followed by hoeing, ploughing and in some cases ridging: 83% of the farmers interviewed used hoes and the rest used ploughs, while 38% of the farmers made ridges prior to planting.

5.2.2 Shape and Size of Fields

Generally , fields in the Chakwenga area are rectangular in shape. Out of the 34 fields studied, only 1 was triangular and another circular while the rest were rectangular. The average size of plots under cultivation and fallows was 1.64± 1.6 ha and 0.79 ± 0.6 ha, respectively.

5.2.3 Crops and Cropping Patterns

Maize is the major crop grown in Chakwenga. In 40% of the plots, maize was the exclusive crop grown since the fields were opened. In the rest of the plots maize was the first crop to be planted in the first year of opening the fields, with other crops grown in subsequent years. These included groundnuts, beans, sweet potatoes, and sorghum, but with no evidence of distinct cropping sequence. Although these crops are not grown on a relatively large scale, these are introduced in the second and third year prior to reverting to maize in the fourth year. In 50% of the fields where other crops are grown, these were intercropped with maize with no definite crop rotation patterns.

5.2.4 Cultivation and Fallow Periods

The number of years over which any given field is continuously cultivated was not defined. Once a field has been opened, there is no projected year of abandonment because farmers prefer permanent cultivation of a plot. Enhancement or restoration of soil fertility is effected through annual coppice re-clearing and burning, and use of fertilisers. In some cases, crop rotation and inter-copping are used. Out of the 15 fields under cultivation in the study, only 2 were expected to be abandoned after an average of 4.5 ± 0.7 years of cultivation. The average fallow periods for the fields in the study were 3. ± 5.7 years. Out of the 15 cultivated plots in the study, 86% of the plots were opened after 1990. On the other hand, only 32% of the 19 fallow plots were more than 10 years old. In all the cases plots were rested due to lack of fertilisers.

5.3 WOODLAND RECOVERY

In this study the terms recovery and regeneration have been used interchangeably. They refer to woodland development through stem suckering, root suckering, increase in the seedling pool and soil organic matter. It was based on measurements of tree height, girth, tree and seedling density and soil organic matter.

Woodland recovery in fallows was studied from the view point of coppice regrowth, root suckering and seedlings. In abandoned plots, an average of 38% of all live stumps showed evidence of coppicing and 17.5% of these regenerated by root suckering. Similar proportions were observed on the cultivated plots, although death through fire was high on cultivated than on abandoned plots. Stump mortality was 37% and 19.5% in a cultivated and abandoned plots, respectively. Seedling density was used as a measure of regeneration through seedlings and is discussed in section 5.3.1.

5.3.1 Vegetation Structure

Tree density, height and basal area were calculated for all the 18 fallow plots.

Tree density for the 18 fallow plots of varying age is shown in Table 5.1. Tree density was highest in a 6-year-old munga plot. Generally, there was a steady increase in tree density in the miombo plots up to the age of 13 years. This was also observed in the small plots. Average seedling/sapling density, was 11133.3 ±11891.6 and 33421.1 ±33017.4 in cultivated and fallow plots, respectively.

Table 5.1. Tree density in miombo and munga fallow plots with SD for average values of density.

Age	Density per hectare	
	Miombo	**Munga**
1	300	
2	1200 ±530.3	0
3		1300
5	1275 ±671.7	
6	1475 ±1308.1	3125 ±2439.5
7	2900	
10	1750	2000
13	4500	
14		750
19	1400	
20	500	

The tree height for different age classes is shown in Figure 5.1. Generally, tree height increased with age of fallow. In fallow plots of the same age class, average height of trees was higher in munga than in miombo.

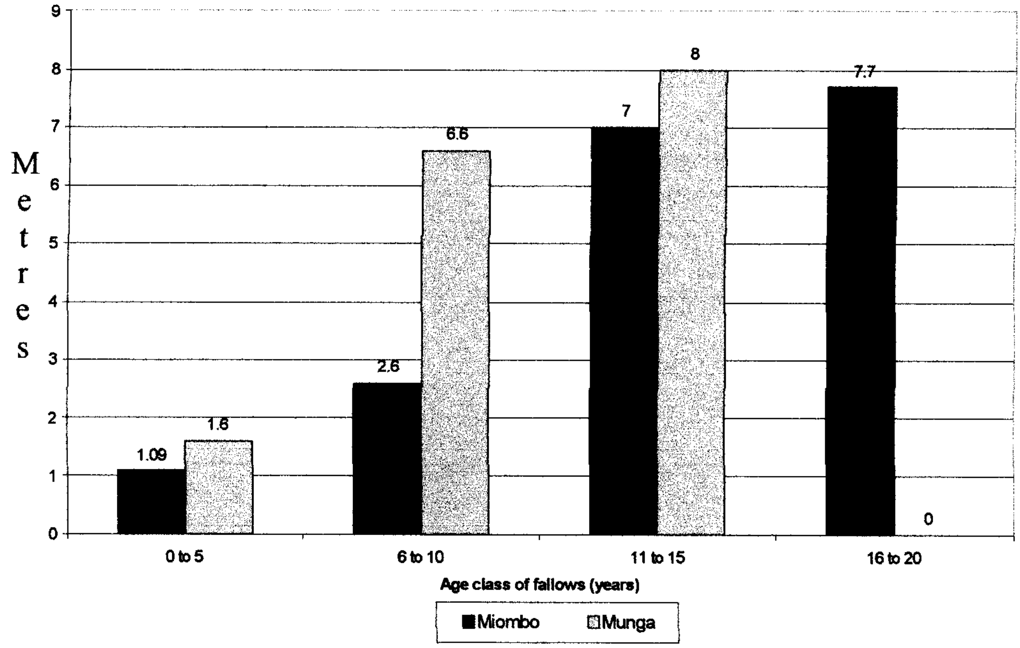

Figure 5.1Average stem height (in metres) of trees in miombo and munga wooland plots by plot age-class in Chakwenga.

Tree basal area at breast height (metre square/ha) in fallow plots of different age classes is shown in Figure 5.2. Basal area tended to increase with age of fallow. Generally, for plots of the same age group, basal area was higher in munga than in miombo plots except for the 11-15 years age group.

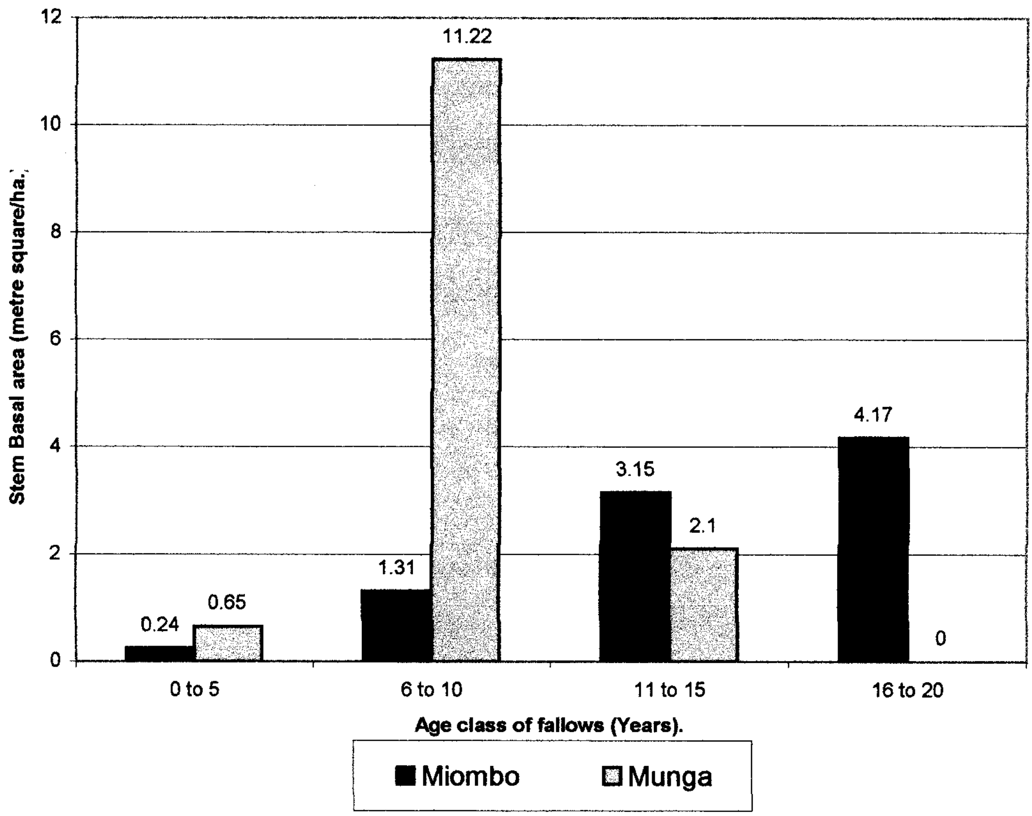

Figure 5.Basal area of trees in miombo and munga woodland plots by age-class in Chakwenga.

5.3.2 Species diversity

A total of 39 species was found among all the 38 plots. Species richness was highest at 9 species in the miombo in a 13-year-old fallow plot. There was a steady increase in the number of species up to this stage after which it fell to 1 in a 1-year-old fallow plot. Mean values with SD for species richness in abandoned miombo plots was 5.5 ± 2.8. It was also observed that species richness in the 13-year-old fallow plot was higher than the average species richness in the four mature woodland plots, 7.3 ±1.5. Similar observations in the munga plots revealed that, species richness was highest in 6-year-old fallows at 10 species and was thereafter characterised by a decline in older fallows. Mean values for species richness in the abandoned munga plot was 3.8 ±3.3.

Evenness (H'/ log S), and diversity, using the Shannon-Wiener Index ($H' = P_i \log (P_i)$) were calculated for both cultivated and fallow plots. However in this regard, only those of abandoned and mature plots are reported here and are shown in Table 5.2. There was no vegetation in some of the cultivated plots.

Table 5.2 Evenness and diversity indices in abandoned miombo and munga cultivators' plots (Standard deviation is shown in brackets).

Plot Type	Evenness (mean values)	Diversity
Fallow Miombo	0.614 (0.33)	1.088 (0.64)
Fallow Munga	0.620 (0.42)	1.782 (0.25)

Although the pattern of evenness and diversity was not readily discernible, the highest evenness in miombo fallow plots was in a 1-year old plot. In the Munga plots this was found in a 3-year old plot. In terms of diversity, the highest diversity was found in a 10-year miombo fallow plot while in the munga this was observed in a 6-year-old fallow.

5.3.3 Classification of plots

Large Plots Survey

Cluster analysis, using the k-means (SPSS 1997) technique was used to classify study plots using species inventory data (Appendix 4). The analysis generated four clusters with their characteristic species (Table 5.3). The cluster groups could not be distinguished by status (cultivation, abandonment and mature) and age.

Table 5.3 Classification of plots among the 38 plots using the k-means splitting technique into 4 groups based on Eucleidean distance.

Cluster **variable**	**Mean value per cluster**				**F- ratio**
	1	**2**	**3**	**4**	
A. polyacantha	4.50	8.00	4.00	1.50	19.11
B. boehmii	3.33	77.00	1.67	12.67	119.05
B. spiciformis	19.00	11.00	4.67	3.00	19.52
D. cinerea	20.00	2.25	1.00	1.50	144.66
J. globiflora	1.00	12.00	3.00	11.50	21.35
Unidentified spp 3	32.0	1.33	2.00	-	372.27

Cluster 1 is characterised by high mean values for *B.spiciformis, D. cinerea* and unidentified spp 3. This cluster comprised of cultivated and abandoned plots. In cluster 2, characteristic species were *B. boehmii,* with the highest value, followed by *J.globiflora, B spiciformis* and *A.polyacantha.* This group was made up of a total of 6 plots which included both cultivated and abandoned plots. *A.polyacantha* and *B. spiciformis* were the characteristic species in cluster 3 which had a total of 8 plots. Three out of the 4 mature woodland plots were placed in this group. *B.boehmii* and *J.globiflora* were the characteristic species in cluster 4. This group comprised a total of 9 plots that included one mature woodland plot. In terms of floristic similarities, *B. spiciformis* and *B.boehmii* were characteristic species in clusters 1, 2 and 3 and clusters 1 and 4 respectively.

Small plots survey

Cluster analysis was also used in the classification of the small plots based on species inventory data (Appendix 5). As in the large plots above, the cluster groups could not be distinguished by status and age. The results of the cluster analysis are shown in Table5.4.

Table 5.4 Classification of plots among the 38 small plots using k-means technique splitting into 4 groups.

Species variable	Mean value per cluster				F-ratio
	1	2	3	4	
B. boehmii	2.60	6.50	7.00	13.00	20.02
B.manga	4.00	15.00	4.00	1.67	28.94
B.spiciformis	2.00	16.50	9.00	34.00	251.21
D.cinerea	1.00	1.00	1.00	4.33	41.67
J.globiflora	4.00	6.50	30.00	7.50	5.79

In cluster 1, comprising 17 small plots, *B. manga* and *J.globiflora* were the characteristic species. In cluster 2 with 8 plots, *B. manga and B.spiciformis* were the characteristic species. *B.spiciformis* and B.boehmii characterised cluster 3, which had 3 plots and the only one without a mature woodland plot. The major characteristic species in cluster 4 were *B.boehmii* and *B.spiciformis.* On the basis of floristic similarities, *B.manga* was a dominant characteristic species in cluster 1 and 2, *J.globiflora* in clusters 1 and 3. *B.spiciformis* was a dominant characteristic species in cluster 2, 3 and 4.

Further analysis of species richness, evenness, and diversity by plot status was done. An ANOVA for species evenness and diversity showed no significant differences for species evenness ($F = 1.36_{5,25}$, $p > 0.05$) and species diversity ($F = 2.60_{5,25}$, $p > 0.05$). The difference was only significant for species richness ($F = 6.21_{5,32}$ $p < 0.05$).

The differences were among abandoned, cultivated, and undisturbed woodland plots.

5.4.1 Soil organic matter content, species richness, evenness and diversity

Cluster analysis using the k-means technique was used as in 4.3.3 above. This was based on results of soil organic matter content, species richness, evenness and diversity (Appendix 6). The analysis generated four clusters and is shown in Table 5.5.2

Table 5.5 Classification of 38 plots using the k-means splitting technique into 4 groups

Variable	Mean value per cluster				F- ratio
	1	2	3	4	
Organic matter	1.32	1.32	2.81	1.50	8.98
Species richness	0.67	8.88	8.00	4.64	137.44
Evenness	0.21	0.81	0.89	0.78	12.08
Diversity	0.14	1.76	1.83	1.17	39.01

Cluster 1 was characterised by relatively low species richness, evenness and diversity. It comprised plots that were either under cultivation or recently abandoned. It had a total of 15 plots with a mean standard deviation of 1.2. Cluster 2 with 8 plots was characterised by high species richness, evenness and diversity. Plots in this group were mostly fallows of intermediate age and mature woodland. Cluster 3, made up of only 4 plots had relatively high organic matter content. Species richness, evenness and diversity were very similar to those in cluster 2. This group was made up of abandoned munga plots and mature miombo woodland. Cluster 4, with 11 plots was characterised by high evenness and diversity. This group comprised cultivated, abandoned and mature plots. On the whole, the levels of soil organic matter content were not different among clusters 1, 2 and 3. Generally, the groups could not be distinguished on the basis of age, status and woodland type using soil organic matter as a discriminating variable. An analysis of variance for organic matter by status for all the plots was not significant ($F = 0.92_{5,32}$, $p > 0.05$).

Chapter 6

DISCUSSION AND CONCLUSION

6.1 Discussion

Tree felling, stumping, uprooting, and burning are part of the agricultural systems currently obtaining in the dry miombo of central Zambia. The effect of this on species diversity, recovery of woodland and how the practice affects soil organic matter content are discussed below.

6.1.1 Species Diversity

The pattern of evenness and diversity was not readily discernible although generally, the former was relatively higher in mature miombo; the diversity was in fact highest in fallow munga plots. Diversity could not be linked to age and even status of the plots. Within fallows of varying age, no distinct pattern of diversity associated with age was observed. In some cases diversity was found to be higher in cultivated plots. (Details of species richness, evenness and diversity of study plots are shown in Appendix VIII).

The classification of plots using cluster analysis also revealed that occurrence of dominants or characteristic species is not associated with age or status of plot. The hypothesis that clearing for agriculture and subsequent cultivated reduces species diversity and woodland recovery in dry miombo is therefore not supported by the findings of this study.

The lack of distinct landuse categories based on age in terms of diversity and evenness is contrary to the findings of Aweto (1981) on fallows in tropical West Africa. On the other hand, these agree with observations of Uhl *et al* (1981) in the Amazon forest that age may not necessarily be the most important determinant of site floristics and even structure. Other factors may need to be considered; these include dispersal strategies, initial floristic composition and other site related factors like cultivation history (Toshiyuki, 1999; Uhl *et al* 1981; Pichet and McDonnel, 1989; Finegan, 1984; Cody, 1975). These findings have also shown that even among the seedling/sapling pool, it is the dominant species that are abundant.

6.1.2 Woodland recovery

In terms of woodland recovery, there was no evidence that this was impaired following cultivation and subsequent abandonment. The number of species, tree density, height and basal area tended to increase with increasing age of fallow. The degree of dominance of a few characteristic miombo species, in particular *Julbernadia* and *Brachstegia* spp. was observed, but as indicated earlier, this was not accompanied by a decrease in species richness. The same was observed in munga plots where *A. polyacantha* dominated but never eliminated other species.

The sources of regeneration were through stump coppicing, root suckering and seedlings. Sprouting from stump is common among forest species and is not restricted to the miombo: similar findings have been recorded in the Amazon basin (Uhl *et al.* 1981). A steady increase in seedling/sampling density was also observed; this was lowest in cultivated plots and highest in mature woodland plots. This is a critical factor in the recovery of the woodland, as the seedling pool represents a key potential for regeneration. These findings therefore suggest that disturbance resulting from current cultivation practices in the dry miombo is temporal, and does not necessarily impair woodland recovery. These findings do not support the hypothesis that clearing for agriculture and subsequent cultivation reduces recovery capacity of the woodland. This strongly conforms to the pathways of miombo degradation and deforestation depicted in Figure 1.1.

6.1.3 Soil organic matter content and woodland recovery

Soil organic matter content was not related to vegetation type, age and status of a plot. However, there were observed variations in classification of plots using cluster analysis, when species richness, evenness and diversity were considered. But even then, these did not necessarily show relationships with organic matter, based on age, status and vegetation type. Knoops and Tilman (2000) reported that vegetation composition had a significant influence on rates of accumulation of nitrogen and carbon. Aweto (1981) also found that character and age of fallows affect nutrient build-up in the soil. Odum (1960) and Swift *et al* (1979) suggested that this is possibly due to predominance of certain forms that may improve or restore site factors such as fertility. In older fallows and relatively undisturbed plots, with high densities and high diversity of trees, more litter may be generated or the soil is afforded greater protection against organic matter destruction and nutrient leaching and erosion. Savory (1962) observed that inter-site differences in structure and floristics might also be viewed within the light of edaphic gradients. Although this could not be generalised in this study with regard to vegetation type, portions of munga with incursions of some miombo species were found along drainage lines, suggesting a possibility of complex relationships between vegetation and soil characteristics. While the current study used the combustion method to determine soil organic matter content, the levels found are comparable to the findings by Chidumayo (1993b) for soils in the same study area using the Walkley and Black method. Mean soil organic matter content (% of dry weight) at soil depth of 0-30cm at four miombo woodland sites using the Walkley and Black method ranged from 1.2 -3.8% while the findings in the present study using the combustion method were 1.0-3.8%.On the whole, the findings of this study do not support the hypothesis that in miombo woodlands soil organic matter content and recovery are negatively affected by cultivation.

6.2 Conclusion

Recovery of miombo can be attained with proper management, even after clearing for agriculture and subsequent cultivation. Regeneration can be effected through coppice regrowth, root suckering and through the seedling pool. In practice, complete woodland recovery may not be observed in the dry miombo as cultivation practices are becoming more permanent and very few plots are left fallow for prolonged periods of time. In addition, practices like killing of stumps through biomass burning done to increase soil fertility are detrimental, as stumps are an important source of woodland recovery. For purposes of enhancing and maintaining soil fertility, alternative means need to be explored and promoted. Extended fallow periods of 16-40 years for example, observed in northern Zambia under Chitemene (Oyama 1996) can not be sustained in the miombo of central Zambia. This is due to high population density as indicated by the high number of plots opened in the recent past, and use of fertilisers especially for maize production.

Although conclusions have been made, based on the findings of this study, these should be treated with caution. Like all chronosequence studies, where time is replaced with space, the conclusions are based on the assumptions that the environment of the selected sites was similar and that the sites have a similar history. This may not be necessarily so. Therefore this needs to be considered in accepting the results obtained and the conclusions made. Reliability of the results can be increased through long term monitoring on permanent plots.

RECOMMENDATIONS

In order to increase the reliability of results on the effects of forest clearing for agriculture and subsequent crop cultivation on woodland recovery on dry miombo, long term experiments on the same plots are required.

Although the findings of this study suggest that recovery of dry miombo is possible after clearing for agriculture and crop cultivation, this however, should be treated with caution. Extended cultivation periods and other contingent factors can affect recovery.

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APPENDICES

Appendix 1: Farmer interview questionnaire

FARMER QUESTIONNAIRE

Questionnaire Number:____________

Date of Interview:______________

Name of Farmer:_____________________________

Sex:__________ Age:_________ Tribe:__________

____

1. How many plots do you have that are currently under cultivation?
2. *When were they opened and what is their expected year of rest?*

PLOT NUMBER	YEAR OPENED	EXPECTED YEAR OF REST
1.		
2.		
3.		
4.		
5.		

3. How many plots do you have that are currentlly not under cultivation?
4. When were they rested and when do you expect to reopen them?

PLOT NUMBER	YEAR RESTED	EXPECTED YEAR OF REOPENING
1.		
2.		
3.		
4.		
5.		

5. What method of tree cutting and land preparation did you use?

Tree cutting		Land Preparation		Crops	
Type	Tools	Type	Tool	Year	Main Crop
Stumping		Ploughing		1	
Uprooting		Ridging		2	
		Coppice re-clearing		3	
		Piling of waste		4	
		Clearing of waste		5	

Appendix II Survey data sheet for large relatively undisturbed plots (20 X 10m Plots)

Date:____________

Location:_________

Adjacent Cultivated/Uncultivated Plot #:________________

Name of Farmer:____

Tree number	Species name	Number of Stems	GBH(cm)	Height class	Status

APPENDIX III Survey data sheet for large cultivated plots (20 X10m Plots)

Date:____________

Name of farmer:____________________________
Active/Abandoned:__________________________
Plot number:_______________________________
Shape of plot:___________________________
Size of plot:Length(m)___Width(m)___circumference(m)_____
Method of clearing:Stumping height__Uprooting___Other____
____

Tree/ stumps	No.	Species	*Height/* height class	*Status* dead/ live	Diameter	GBH	Number of *Stems* ________ Coppicing/ root suckering	

APPENDIX IV Survey data sheet for small plots

Date:____________

Name of farmer:____________________________________

Status of plot: Active__________________________

Abandoned_______________________

Relatively undisturbed__________

Plot number:________

____

Number	Species name	Basal diameter	Height

APPENDIX V Data sheet for soil samples

Name of farmer	Status of plot	Plot number	Sample number	Date of sampling	Organic matter content (0-30cm)

APPENDIX VI Species inventory data for large (20 x 10 m) plots

Species	Frequency occurrence per plot															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Julbernadia globiflora	2			1													1
Brachystegia spiciformis																	
Brachystegia boehmii	1		1	5													3
Pericopsis angolensis												1					2
Isoberlinia angolensis																	
Diplorhynchus condylocarpon																	
Dichrostschys cinerea												1					
Pseudolachnostylis maprouneifolia												1					
Brachystegia manga					1	2											
Burkea africana																	
Ochna schweinfurthiana																	
Parinari curatellifolia	1																
Cassia abbreviata																	
Strychnos spinosa																	
Strychnos innocua																2	
Uapaca kirkiana	3																
Uapaca sansibarica																	
Bauhinia petersiana																	
Piliostigma thonningi								1			12						
Markhamia obtusfolia																	
Swartzia madagascariensis																	
Azanza garkena																	
Acacia polyacantha											5	2					
Acacia sieberana																	
Albizia harveyi											2						
Acacia spp 1.												1					
Acacia spp 2.												1					
Acacia spp 3.																	
Albizia spp 1.																	
Vitex spp 1.															1		
Combretum spp 1.																	
Syzygium guineerisis																	
Protea spp 1.																	
Ziziphus spp 1.																	
Faurea spp 1.																	
Terminalia spp 1.																	
Unidentified spp 1.			1									1					
Unidentified spp 2.																	
Unidentified spp 3.																	

Species	Frequency occurrence per plot												
	18	19	20	21	22	23	24	25	26	27	28	29	30
Julbernadia globiflora		9			12	1	14						
Brachystegia spiciformis		4			11					19			
Brachystegia boehmii			12	3		2	19	7	77				
Pericopsis angolensis					2								
Isoberlinia angolensis			2		12	5		7					
Diplorhynchus condylocarpon								1					
Dichrostschys cinerea			2		4			2	2		1		
Pseudolachnostylis maprouneifolia		1		2	2								
Brachystegia manga				28		1	21	7					
Burkea africana		2		1		2	2						1
Ochna schweinfurthiana							1	1					
Parinari curatellifolia													
Cassia abbreviata													
Strychnos spinosa					3				1				7
Strychnos innocua										4			5
Uapaca kirkiana									2				
Uapaca sansibarica		2							1				
Bauhinia petersiana											4		
Piliostigma thonningi													5
Markhamia obtusfolia											1		
Swartzia madagascariensis								1	1				
Azanza garkena											1		4
Acacia polyacantha				1									
Acacia sieberana													
Albizia harveyi													
Acacia spp 1.													
Acacia spp 2.													
Acacia spp 3.													
Albizia spp 1.													
Vitex spp 1.	6												
Combretum spp 1.										1	2		
Syzygium guineerisis		1						3	2				
Protea spp 1.		1											
Ziziphus spp 1.													
Faurea spp 1.			1										
Terminalia spp 1.		1								2			2
Unidentified spp 1.					1			2			1		
Unidentified spp 2.									3	1			
Unidentified spp 3.					1				1				2

Species	Frequency occurrence per plot							
	31	32	33	34	35	36	37	38
Julbernadia globiflora					4		2	5
Brachystegia spiciformis					6	2	4	3
Brachystegia boehmii								
Pericopsis angolensis	1					1		1
Isoberlinia angolensis								
Diplorhynchus condylocarpon					1	2	6	6
Dichrostschys cinerea	2	20	1	1	1		1	
Pseudolachnostylis maprouneifolia					1	1	1	
Brachystegia manga								
Burkea africana							1	1
Ochna schweinfurthiana						2	1	2
Parinari curatellifolia	1							
Cassia abbreviata								
Strychnos spinosa	1						2	
Strychnos innocua	3	2	2					
Uapaca kirkiana								
Uapaca sansibarica								
Bauhinia petersiana								
Piliostigma thonningi	4							
Markhamia obtusfolia			7					
Swartzia madagascariensis								
Azanza garkena	2	20						
Acacia polyacantha	9	4	7	4				
Acacia sieberana	3							
Albizia harveyi			4					
Acacia spp 1.		13	3					
Acacia spp 2.		1						
Acacia spp 3.		2						
Albizia spp 1.		2						
Vitex spp 1.						5		
Combretum spp 1.					4	1		
Syzygium guineerisis			2					
Protea spp 1.								
Ziziphus spp 1.		6						
Faurea spp 1.								
Terminalia spp 1.							3	2
Unidentified spp 1.			3	2			2	1
Unidentified spp 2.		3		1				
Unidentified spp 3.	2	32	12					

APPENDIX VII species inventory data for small (5 x 2 m) plots

Species	Frequency occurrence per plot																
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Julbernadia globiflora	1																1
Brachystegia spiciformis									1								
Brachystegia boehmii	1									4							7
Pericopsis angolensis	1		1														
Isoberlinia angolensis																	
Diplorhynchus condylocarpon			1														
Dichrostschys cinerea	1	5									1						
Pseudolachnostylis maprouneifolia																	
Brachystegia manga					1						2						4
Burkea africana																	
Ochna schweinfurthiana																	
Parinari curatellifolia																	
Cassia abbreviata																	
Strychnos spinosa												4					
Strychnos innocua											1		4	1	1		
Uapaca kirkiana																	
Uapaca sansibarica																	
Bauhinia petersiana																	
Piliostigma thonningi								1			3						
Markhamia obtusfolia																	
Swartzia madagascariensis																	
Azanza garkena																	
Acacia polyacantha																	
Acacia sieberana																	
Albizia harveyi		1	3														
Acacia spp 1.													1				
Acacia spp 2.																	
Acacia spp 3.															2		
Albizia spp 1.													1				
Vitex spp 1.																	
Combretum spp 1.																	
Syzygium guineerisis																	
Protea spp 1.	1																
Ziziphus spp 1.																	
Faurea spp 1.																	
Terminalia spp 1.																	
Unidentified spp 1.		1															
Unidentified spp 2.																	
Unidentified spp 3.											1						

Species	Frequency occurrence per plot												
	18	19	20	21	22	23	24	25	26	27	28	29	30
Julbernadia globiflora		30			2	2	9	1					
Brachystegia spiciformis		9			4			1		2			
Brachystegia boehmii			15	2		11		4	7				
Pericopsis angolensis													
Isoberlinia angolensis			1					1					
Diplorhynchus condylocarpon							1						
Dichrostschys cinerea		1											1
Pseudolachnostylis maprouneifolia					3								
Brachystegia manga				3	5		1	15	3				
Burkea africana							2						
Ochna schweinfurthiana			3				1		5				
Parinari curatellifolia													
Cassia abbreviata													
Strychnos spinosa													
Strychnos innocua													1
Uapaca kirkiana													
Uapaca sansibarica		2											
Bauhinia petersiana											3		
Piliostigma thonningi													
Markhamia obtusfolia													
Swartzia madagascariensis			2										
Azanza garkena													
Acacia polyacantha											5		
Acacia sieberana													
Albizia harveyi													
Acacia spp 1.													
Acacia spp 2.													
Acacia spp 3.													
Albizia spp 1.													
Vitex spp 1.	1	1							3				
Combretum spp 1.											4		
Syzygium guineerisis													
Protea spp 1.													
Ziziphus spp 1.													
Faurea spp 1.													
Terminalia spp 1.		1											
Unidentified spp 1.		2								1			
Unidentified spp 2.		1											
Unidentified spp 3.													

Species	Frequency occurrence per plot							
	31	32	33	34	35	36	37	38
Julbernadia globiflora					12		13	4
Brachystegia spiciformis					2	16	34	17
Brachystegia boehmii					2			
Pericopsis angolensis								
Isoberlinia angolensis								
Diplorhynchus condylocarpon					1			
Dichrostschys cinerea	4	4			1			
Pseudolachnostylis maprouneifolia						4		4
Brachystegia manga								
Burkea africana								
Ochna schweinfurthiana					2			
Parinari curatellifolia								
Cassia abbreviata								
Strychnos spinosa								
Strychnos innocua					1			
Uapaca kirkiana								
Uapaca sansibarica								
Bauhinia petersiana					3			
Piliostigma thonningi		1						
Markhamia obtusfolia	3		3					
Swartzia madagascariensis								
Azanza garkena		1						
Acacia polyacantha	2							
Acacia sieberana								
Albizia harveyi								
Acacia spp 1.								
Acacia spp 2.	3							
Acacia spp 3.	2							
Albizia spp 1.								
Vitex spp 1.								
Combretum spp 1.						2		1
Syzygium guineerisis								
Protea spp 1.								
Ziziphus spp 1.								
Faurea spp 1.								
Terminalia spp 1.								
Unidentified spp 1.	1	3		1				
Unidentified spp 2.		6						
Unidentified spp 3.								

APPENDIX VIII Organic matter content, species richness, evenness and diversity in study plots

Plot #	Woodland type	status	Age	Organic matter (%)	Species richness	Evenness	Diversity
1	miombo	cultivated	0	0.59	4	.921	1.277
2	miombo	cultivated	1	2.55	-	-	-
3	miombo	cultivated	3	1.22	2	1.000	.693
4	miombo	cultivated	4	1.65	2	.650	.451
5	miombo	cultivated	5	1.27	1	.000	.000
6	miombo	cultivated	5	1.05	1	.000	.000
7	miombo	cultivated	7	0.81	-	-	-
8	miombo	cultivated	8	1.54	1	.000	.000
9	miombo	cultivated	12	0.60	-	-	-
10	miombo	cultivated	14	0.68	-	-	-
11	munga	cultivated	3	2.60	3	.800	.879
12	munga	cultivated	4	1.61	8	.948	1.972
13	munga	cultivated	8	1.59	-	-	-
14	munga	cultivated	8	1.44	-	-	-
15	munga	cultivated	10	1.86	1	.000	.000
16	miombo	abandoned	1	1.24	1	.000	.000
17	miombo	abandoned	1	2.17	3	.921	1.011
18	miombo	abandoned	2	0.96	1	.000	.000
19	miombo	abandoned	2	0.71	8	.821	1.707
20	miombo	abandoned	5	1.23	4	.593	.822
21	miombo	abandoned	5	1.80	5	.470	.756
22	miombo	abandoned	6	1.31	9	.836	1.837
23	miombo	abandoned	6	0.55	5	.879	1.414
24	miombo	abandoned	7	1.00	6	.744	1.333
25	miombo	abandoned	25	1.26	9	.903	1.984
26	miombo	abandoned	13	1.27	9	.319	.701
27	miombo	abandoned	19	1.51	5	.601	.967
28	miombo	abandoned	20	1.76	6	.898	1.609
29	munga	abandoned	2	1.40	-	-	-
30	munga	abandoned	3	2.63	7	.923	1.795
31	munga	abandoned	6	3.78	10	.888	2.044
32	munga	abandoned	6	1.26	10	.805	1.854
33	munga	abandoned	10	2.41	9	.891	1.958
34	munga	abandoned	14	1.85	4	.832	1.154
35	miombo	undisturbed	mature	2.40	6	.844	1.512
36	miombo	undisturbed	mature	1.44	6	.907	1.626
37	miombo	undisturbed	mature	1.39	9	.915	2.011
38	miombo	undisturbed	mature	1.77	8	.952	1.980