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Classification of Forests in Zambia

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ILUA II Technical Report Series

Classification of Forests in Zambia

By E. N Chidumayo

2016

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Classification of Forests in Zambia

Technical Paper prepared for the Forestry Department, the Ministry of Lands, Natural Resources and Environmental Protection and the Food Agriculture Organization of the United Nations as a part of the Integrated Land Use Assessment Phase II

by

Emanuel N. Chidumayo[1]

The Government of the Republic of Zambia as the implementing partner provided staff, office facilities and the organizational setting for the ILUA II program through the Forestry Department in the Ministry of Lands Natural Resources and Environmental Protection

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[1] Prof. Emanuel N. Chidumayo, Ecologist and Manager at the Makeni Savanna Research Project in Lusaka, Zambia

FOREWORD

Forests in Zambia form a large part of the landscape of the country. The Integrated Land-Use Assessment carried out between 2005 and 2008 revealed that almost 60% of the land area in the country was covered by forests. However, not all the forests in Zambia are alike because of geographical, environmental and other factors. In developing the forest classification for Zambia, a review of the previous classification was necessary and the classification that was adopted for the ILUA II in Zambia was based on both global and national requirements.

The classification of forests is an important aspect of forest management and land-use planning. It defines the forest communities that are available and that are supposed to be conserved or preserved. A good understanding of the forest communities through space and time helps forest managers to describe their forests in detail and generate ideas on how best the forests should be managed.

This technical paper, which is an input into the methodology adopted for biophysical data collection in the ILUA II, provides an excellent review of the different attempts at classifying the Zambian vegetation in the past. The paper also proposes recommendations for forest classification that take into account the current requirements which focus on global, national and decentralized forest area levels.

We hope that this publication will serve as a useful analytical contribution to forest classification in Zambia and will subsequently promote sustainable forest management.

Ignatius N. Makumba
DIRECTOR - FORESTRY

Bwalya Chendauka
NATIONAL COORDINATOR - ILUA II

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LIST OF ACRONYMS

AVHRR	Advanced Very High Resolution Radiometer
FAO	Food and Agriculture Organization of the United Nations
ILUA I	Integrated Land Use Assessment Phase I
ILUA II	Integrated Land Use Assessment Phase II
IPCC	Intergovernmental Panel on Climate Change
MAI	Mean Annual Increment
MSS	Multispectral Scanner
NDVI	Normalized Difference Vegetation Index
NOAA	National Oceanic and Atmospheric Administration
PFAP	Provincial Forestry Action Programme
REDD+	Reducing Emissions from Deforestation and Forest Degradation, Conservation, Enhancement of Carbon Stocks and Sustainable Forest Management
SADCC	Southern African Development Coordination Conference (from 1992 Southern Africa Development Community, SADC)

ABSTRACT

Since the 1950s, several approaches have been made to classify Zambian vegetation types. Because of the long history of human activities in the country, a clear vegetation-soil relationship has never been adequately demonstrated. The occurrence, intensity and effects of fire over a long period of time have further complicated the assessment. The eco-physiology of the majority of indigenous trees is adapted to climatic conditions and variable soil fertility and moisture status that are reflected in the deciduous habit of most species and their deep root systems. This has made it extremely difficult to prescribe a single ecological classification system based on geology, soil and climate for the Zambian vegetation. A classification method based on both global and national requirements is proposed for ILUA II purposes, based on *ecological indicators*. They are useful in the interpretation of forest dynamics in Zambia and can be applied to the ecological classification of forests, especially those that have been subjected to disturbances. It is proposed that these be used in the interpretation of the ILUA inventory data and in the development of scenarios of future trends in vegetation composition or dynamics. The following issues and recommendations for ILUA II are raised in this report.

1. Although ILUA I and II may not be the best suited for sampling rare vegetation types due to cost considerations, closed forests require to be sampled more adequately during ILUA II. Forest classification used in remote sensing mapping should also be linked to that used in field inventory at the design phase of ILUA II. This could be done by first stratifying the country into land cover types and determining proportional sampling representation for each land cover class. A detailed post-classification of the vegetation types can be done using other variables for which data will be collected during the field inventory.

2. The interpretation of the inventory data should include the use of ecological indicators so that trends can be described and scenarios made from the current distribution of key indicators of forest dynamics. The identification of tree species in the field during ILUA II should be improved. The use of the *Check list of vernacular names of the woody plants of Zambia* by D.F. Fanshawe (1965), which also contains the corresponding scientific plant names, should improve the identification of tree species.

3. The collection and analysis of soil samples can be costly. However, soils data, especially that of soil organic matter and carbon, are required for REDD+ implementation in the country. It is therefore proposed that limited soil samples be collected per land cover type for the determination of organic matter and carbon to meet REDD+ requirements.

4. Given the longstanding impact of human activities on the Zambian vegetation structure, it is not necessary to use climate zones for determining the sampling design for ILUA II. However, the growing concern about impacts of climate change on trees and forests demands that the analysis of ILUA II data be done based on the 1961–1990 climate reference period, and the use of climate change scenarios for 2020 and 2050. This, together with a literature review, should enable the analysis of potential responses of trees and forests to climate change in the country.

1. BACKGROUND TO VEGETATION CLASSIFICATION IN ZAMBIA

1.1. The vegetation-soil classification approach

Various ecological classifications have been applied to Zambian forests, starting with Trapnell and Clothier (1957) and Trapnell (1953) who attempted to classify Zambia forests using soil and topographic features based on the indigenous knowledge of local people. This soil-vegetation relationship was demonstrated by the following quote from Trapnell and Clothier (1957):

"*The correlation between vegetation and soil type is an extremely close one in North-Western Rhodesia* [now Zambia]*. This fact is widely, if not universally, utilised by the native, who selects his land by the type of woodland or grassland cover which it carries and knows the different cropping potentialities and possible duration, of cultivation in each type of bush. The soil types by themselves not always readily recognisable, can be more easily differentiated by their type of bush, especially where native assistance is available.*"

However, even at this early stage of vegetation classification in the country, both Trapnell and Clothier (1957) and Trapnell (1953) acknowledged that the dominant tree species have a wide soil tolerance and that, within one climatic zone, a single soil type may carry two or more types of vegetation, and they therefore did not attempt to demonstrate the ecological significance of the soil-vegetation relationship (Lees 1962). In 1956, Fanshawe (quoted in Lees, 1962) classified woodlands on the basis of soil colour and tree height, but when this was applied to Misaka Forest Reserve in Copperbelt Province, it was found unsuitable for detailed application. Therefore, Lees (1962) developed an ecological classification of woodlands in the Copperbelt area for forestry purposes that was referred to as the "1960 Woodland Classification", and that tried to match floristic associations with geology and soil. This classification is summarized in Table 1.1.

Table 1.1 *Description of the 1960 woodland classification for the Copperbelt area by Lees (1962).*

Class type	Floristic association	Geology and soils
1: Museshe	*Marquesia macroura*	7.5 YR and 5 YR soils and with biotite schists
2: Musaka	*Brachystegia utilis*	Granite and quartz gravels
3: Muwombo-Muputu	*Brachystegia longifolia* or *Brachystegia spicifomis* with *Julbernardia paniculata*	Deeper soils on limestone and dolomite and sandy soils derived from quartzites and sandstone
4: Musompa	*Brachystegia floribunda*	2.5 YR shallow soils over laterite
5: Mixed Mutondo	*Julbernardia paniculata* and/or *Brachystegia boehmii*	On wide range of soils
6: Munkulungu	*Brachystegia bussei*	Rock outcrops
7: Chipya	*Brachystegia spiciformis-Erythrophleum africanum*	Colluvial and loose sandy soils on almost any geology
8: Chipya scrub	*Acacia*	Colluvial and loose sandy soils on almost any geology but poorer sites
9: Scrub	*Brachstegia-Uapaca*	Pallid shallow soils over laterite

In spite of the attempt to develop an ecological classification of the woodlands of Copperbelt area, Lees (1962) identified some major difficulties in establishing vegetation-soil-geology relationships. Firstly, the occurrence, intensity and effects of fire over a long period of time is difficult, if not impossible, to assess. The type, age and effects of traditional cultivation and effects of past exploitation have also radically altered the development and structure of the forests and woodlands. Secondly, the assessment of the soil-geology relationship is complicated by past erosion and sedimentary processes and the subsequent development, *in situ*, of other soils, to the extent that adjacent soils may have different origins and chemical/structural characteristics. In addition, the eco-physiology of the majority of indigenous trees is adapted to climatic conditions and variable soil fertility and moisture statuses that are reflected in the deciduous habit of most species and their deep root systems (Savory, 1962). All these processes and factors make it extremely difficult to prescribe a single ecological classification system for the Zambian vegetation based on geology, soil and climate.

1.2 The species approach to vegetation classification

Using inventory data from the 1982–1985 miombo woodland survey, Chidumayo (1987a) undertook spatial modelling to compare outputs based on three ecological variables: (i) density of miombo species (*Brachystegia*, *Isoberlinia* and *Julbernardia*), (ii) total woody genera and (iii) basal area (m^2) per 0.4ha sample plots in Copperbelt, Central, Luapula, Lusaka, Eastern, Northern, North-Western and Western Provinces. The spatial outputs for each variable used were different (Figure 1.1), implying that different approaches generate contrasting results. Thus, forest species' structure and richness are not necessarily correlated with stocking rates, at least in Zambian miombo woodland types.

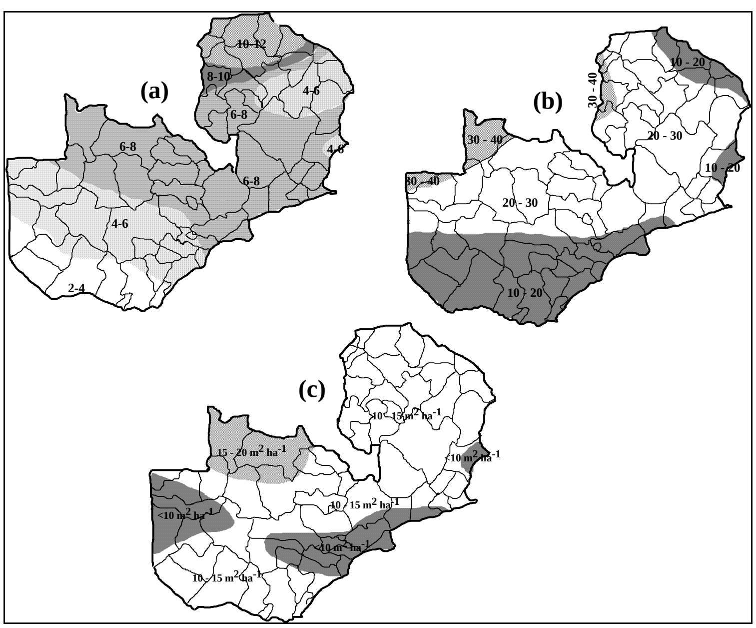

Figure 1.1 *Spatial patterns in major miombo species' richness (a: species per 0.4ha plot), total woody genera*

1.3. Previous approaches to vegetation classification

Table 1.2 summarizes the main approaches that have been used to classify vegetation types in Zambia. These approaches are described in detail in Section 3.

Table 1.2 *Outline of the different approaches that have been used to classify Zambian vegetation types.*

Source	Objective	Geographical coverage	Classification approach
Trapnell and Clothier (1957)	Vegetation and soil mapping for agricultural planning	North -Western Zambia (Copperbelt, North-Western, Southern, Western Provinces and parts of Central and Lusaka Provinces)	Vegetation classification based on landscape units and soil types
Trapnell (1953)	Vegetation and soil mapping for agricultural planning	North-Eastern Zambia (Eastern, Luapula, Muchinga and Northern Provinces and parts of Central and Lusaka Provinces	Vegetation classification based on landscape units and soil types
Lees (1962)	Forest management planning	Copperbelt Province	Vegetation classification based on stocking rates and site quality
Fanshawe (1969)	Vegetation description	Country-wide	Structural and ecological classification
Schultz (1974)	Land use assessment and planning	Country-wide	Land use classification
Mansfield et al. (1976)	Land use assessment and land resources management	Luapula and Northern Provinces, and Muchinga Province, except Chama district	Vegetation classification based on site quality and ecological groups
Edmonds (1976)	Production of vegetation map at 1:500,000 scale	Country-wide	Classification based on Fanshawe (1969)
Millington et al. (1986)	Wood biomass assessment and management planning	Country-wide	Classification based on biomass stocking rates
Chidumayo (1987)	Description of miombo woodland types	Country-wide except Southern Province	Classification based on dominant species
Provincial Forestry Action Programme	Forest and land cover mapping	Luapula, Copperbelt and Central Provinces	Classification based on land cover

Source	Objective	Geographical coverage	Classification approach
(1996 - 1998)			
Integrated Land Use Assessment (ILUA) 1 (2005 – 2008)	Forest cover and land use assessment and planning	Country-wide	Classification based on the FAO (global) system

2. SCOPE OF THE STUDY

According to the Terms of Reference, the objectives of this study were:

(i) To identify and study existing information on forest classification in Zambia, both in written and map format, including the work that has been implemented under ILUAI.

(ii) To identify and describe key ecological indicators for forest classification in Zambia.

(iii) To propose a preliminary classification of Zambian forests using the identified key indicators.

(iv) To specify ILUA II field data to be collected for the purpose of forest classification.

(v) To prepare a section on forest classification for the field manual.

The work involved the review of published and unpublished literature and the analysis of vegetation maps for parts of, or the whole, country.

3. EXISTING APPROACHES TO FOREST CLASSIFICATION IN ZAMBIA

3.1. Classification of forests by Trapnell

The first extensive surveys of vegetation in Zambia were conducted from 1932 to 1936 by C. G. Trapnell and J. N. Clothier (Trapnell and Clothier, 1957; reprinted in 1996), and during 1937 to 1942 by C. G. Trapnell (Trapnell, 1953; reprinted in 1996). The 1932–1936 survey covered central and western regions of the country (i.e. Copperbelt, North-Western, Southern and Western Provinces and parts of Central and Lusaka Provinces); the rest of the country was covered by the 1937–1942 survey. Both surveys focused on soils, vegetation and traditional agriculture, and therefore aimed at establishing a soil-vegetation classification that could be used for assessing the agriculture potential in the country. Trapnell and Clothier (1957) used vegetation main classes, landscape units and soil types to derive vegetation floristic associations for central and western Zambia (Table 3.1) and produced a provisional vegetation-soil map for the region. An example of such a map is given in Figure 3.1 for Southern Province, while the floristic associations for the map units are summarized in Table 3.2.

Table 3.1 *Classification of vegetation of central and western Zambia by Trapnell and Clothier (1957).*

Main vegetation Class	**Land system unit**	**Main soil type**	**Floristic association**
Forest (Livunda)	Plateau	Upland central sands in Zambezi and Mwinilunga	*Cryptosepalum*
		Southern transitional sands	*Baikiaea* and *Acacia-Combretum-Terminalia* thicket
Woodland	Plateau	Northern plateau on clay soils	*Brachystegia*
		Northern plateau on variable soils	*Brachystegia-Julbernardia*
		Northern plateau on sandy soils	*Julbernardia -Brachystegia*
		Southern plateau on sandy loams	*Julbernardia globiflora-Brachystegia*
	Kalahari	Northern Kalahari on contact sands	*Brachystegia*
		Upland and contact sands	*Julbernardia paniculata-Brachystegia*
		Western sand plains	*Burkea* & *Diplorhynchus* shrub-grassland
		Low-lying sands to southwest of the northern plateau	*Cryptosepalum-Guibourtia-Burkea*
		Central sands	*Baikiaea-Guibourtia*
		Bush in Western Kalahari region and on Kalahari contact soils	*Acacia-Terminalia* with *Burkea*, *Brachystegia*, *Isoberlinia* & *Uapaca*
	Valley	On transitional soils	*Combretum* with *Pericopsis*, *Dalbergia*, *Pterocarpus*, *Ostryoderris*
		On thorn soils	*Acacia*
		Thicket on lower valley chestnut sands	*Commiphora* with *Combretum* & *Pterocarpus*
		On brown lower valley soils and grey alluvial clays	*Colophospermum mopane* (Mopane)
Grassland	Plateau		*Hyparrhenia-Loudetia-Schizachyrium*
	Kalahari		*Tristachya* with *Loudetia* & *Schizachyrium*
	Valley		*Hyparrhenia-Brachiaria*

Main vegetation Class	Land system unit	Main soil type	Floristic association
		Sand plain and dambo	*Loudetia simplex –Monocymbium-Tristachya*
		Black clay and floodplain	*Hyparrhenia-Setaria*
		Seepage, streamside and lagoon	*Hyparrhenia-Trachypogon*; *Scleria-Miscanthidium* & *Phragmites*

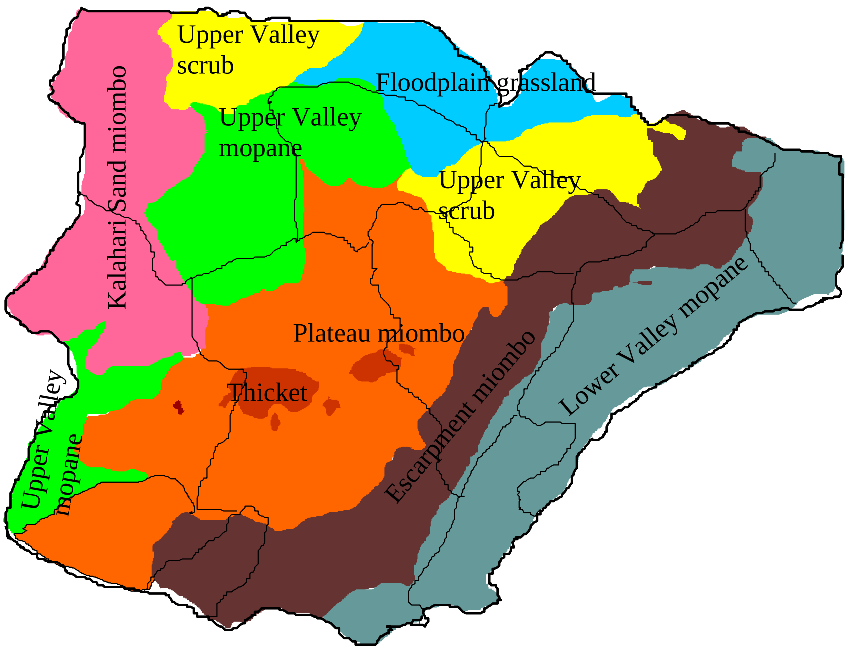

Figure 3.1 *The vegetation-soil map for Southern Province based on Trapnell and Clothier (1957). For a description of soils and floristic associations see Table 3.2.*

Table 3.2 *Description of vegetation and soils of Southern Province based on Trapnell and Clothier (1957).*

Landscape	Formation	Soil type	Association	Map reference (see Figure 3.1)
Plateau	Woodland	Sandy soils	*Julbernardia paniculata-Brachystegia*	Plateau miombo
		Sandy loams and Kalahari contact soils	*Julbernardia globiflora-Brachystegia*	Kalahari sand miombo
		Upland Kalahari sands	*Julbernardia paniculata-Brachystegia*	Kalahari sand miombo
	Thicket	Chestnut sands	*Commiphora* thicket	Thicket
Upper Valley	Woodland	Grey alluvial clays	*Colophospermum*	Upper Valley

Landscape	Formation	Soil type	Association	Map reference (see Figure 3.1)
			mopane	mopane
	Scrubland	Transitional and thorn soils	*Combretum* scrub and *Acacia* termitary	Scrub
Escarpment	Woodland	Escarpment soils	*Julbernardia globiflora-Brachystegia*	Escarpment miombo
Lower Valley		Brown soils	*Colophospermum mopane*	Lower Valley mopane
Floodplain	Grassland	Alluvial soils		Floodplain grassland

The vegetation classification for north-eastern Zambia (Luapula, Northern and Eastern Provinces and parts of Central and Lusaka Provinces) by Trapnell (1953) (Table 3.3) was similar to that adopted for central and western Zambia. A separate vegetation-soil map (1:1,000,000) for north-eastern Zambia was published in 1962.

Table 3.3 *Vegetation classification system for north-eastern Zambia used by Trapnell (1953).*

Main vegetation Class	Main land system unit	Land system unit	Miscellaneous groupings	Floristic association
Forest (11 – 25m tall:)			Evergreen fringing forest and allied vegetation (mushitu in Bemba)	Mist forest relicts (*Parinari-Podocarpus* forest)
				Upland streamside vegetation (*Syzygium-Gardenia-Apodytes* forest)
				Swamp (*Syzygium-Xylopia-Mitragyna* forest)
				Eastern and Lowland streamside (*Adina-Khaya-Trichilia-Diospyros* forest)
Woodland	Main plateau	Northern uplands	*Brachystegia-Isoberlinia*	*Brachystegia-Julbernardia globiflora*
		Central plateau		*Brachystegia-Julbernardia paniculata* of northern uplands & *Julbernardia paniculata-Brachystegia longifolia* of central uplands
		Transition to lake basin soils		*Brachystegia spiciformis*
	Eastern plateau, escarpment and lower	Poorer watershed areas		*Julbernardia paniculata-Brachystegia*
		Other parts		*Brachystegia manga- Julbernardia*

Main vegetation Class	**Main land system unit**	**Land system unit**	**Miscellaneous groupings**	**Floristic association**
	valley regions (area Eastwards from Muchinga escarpment)	of eastern plateau		
		Lower escarpments and lower valley region		*Julbernardia globiflora-Brachystegia*
		Transition to upper valley soils		*Brachystegia spiciformis*
		Chambeshi-Bangweulu basin	Chipya (high-grass woodland: non miombo woodland in very tall grass)	*Erythrophleum-Pterocarpus-Parinari*
		Lower Luapula valley		*Pterocarpus-Diplorhynchus*-bamboo
		Mweru-Tanganyika lowlands	Itigi thicket	*Bussea-Combretum-Pseudoprosopsis*
		Eastern upper-valley areas	*Combretum* and *Acacia*	*Pterocarpus-Combretum*
		Riversides in the lower valley		*Acacia* and associated *Combretum*
		Southern lower-valley areas	Mopane and associated thicket	*Combretum-Commiphora-Kirkia* and *Pterocarpus* thickets
		Main lower-valley floor		*Colophospermum mopane* (Mopane)
Grassland		Upland dambos on the main plateau		*Scleria-Rhynchospora-Cyperus*
		Main plateau and higher lake basin regions		*Loudetia simplex*
		Dambos in the lower lake basin		*Hyparrhenia*

Main vegetation Class	Main land system unit	Land system unit	Miscellaneous groupings	Floristic association
		regions		
		Permanently flooded areas of Bangweulu swamps, lower Luapula valley and Mweru-Wantipa		*Oryza-Sacciolepis-Cyperus*

3.2. Classification of forests by Lees

Lees (1962) prepared a working plan for the forests of the Copperbelt area using a classification system based on the 1958–1960 survey. The survey collected data on:

(i) Exploitable volume of trees with a 14cm girth and above

(ii) Frequency of canopy tree species that was used in woodland type classification

(iii) Average top height of canopy trees

(iv) Frequency or abundance of *Landolphia* creeper as an indicator species

(v) Occurrence by numbers present of tree species that might have indicator value (*Syzygium guineense*, *Erythrophleum africanum* and *Albizia adianthifolia*)

The analysis of survey data also attempted to correlate the composition of overwood, ground vegetation, soil features, tree height, basal area and volume with site quality. The study concluded that the relationship between site quality and other factors was complex. However, Lees (1962) recognized the following seven miombo woodland floristic types in the Copperbelt area:

(i) *Marquesia* woodland
(ii) *Bracystegia utilis* woodland
(iii) *Brachystegia longifolia-Brachystegia spiciformis* woodland
(iv) *Brachystegia floribunda* woodland
(v) Mixed *Julbernardia paniculata* woodland
(vi) *Brachystegia bussei* woodland
(vii) *Brachystegia* scrub

3.3. Classification of forests by Fanshawe

The vegetation description by Fanshawe (1969) was based on data collated from published sources, unpublished manuscripts, working plans, district management books, the results of research projects and from observations and studies he conducted while on reconnaissance with the Forest Department Forest Survey Units. Survey Units systematically surveyed the country's forest resources district by district, and at the end of the field work, their findings and recommendations were written up in a District Management Book.

Fanshawe, while accompanying Forest Survey Units, also collected and recorded the following ecological information:

(i) Broad outlines of the vegetation (similar to Trapnell's Vegetation-Soil Map of Northern Rhodesia) through a rapid reconnaissance of the district
(ii) Lists of the woody species in representative samples of each vegetation type
(iii) Detailed observations of any new or unusual vegetation types
(iv) Specimens of any new or interesting plant species for the herbarium

The classification of the vegetation by Fanshawe (1969) followed, as far as possible, the classification proposed for 'African Vegetation Types' agreed upon at the 1957 Yangambi Conference. The major sub-division is between closed and open forests. Closed forests are climatically or edaphically controlled. Climatic forests include the dry evergreen and dry deciduous forests of medium and low altitudes, and the montane forest of high altitudes. Edaphic forests include swamp and riparian forests.

Open forest is all woodland including miombo, Kalahari, mopane and munga woodland. The term 'munga' (meaning thorn), refers to the composition of a particular type of woodland in which A*cacia* trees are dominant. The vegetation of termite mounds (termitaria) and grasslands were dealt with separately.

Fanshawe used a number of local descriptive terms for want of better words, and also because they were familiar to foresters, agriculturists and others working with the vegetation of the country.

chipya —woodland with high grass in which fierce fires occur annually.
dambo —a shallow depression or drainage channel.
miombo —woodland dominated by *Brachystegia* and *Julbernardia* species.
mopane —woodland dominated by *Colophospermum mopane*.
mutemwa—dry deciduous *Baikiaea* forest, or specifically the thicket understorey of such forest.

Valleys were separated into the Upper Valley (elevation 920–1075m) that extends in a belt surrounding the Kafue Flats (Mumbwa, Kabwe, Chisamba, Kafue, Mazabuka, Monze and Pemba), and the Lower Valley at elevations of 370–920m in Luangwa, Lunsemfwa and Zambezi valleys (see Figure 2.1 for example), with rainfall of 500–750mm per annum.

Thus, the description of Zambia's vegetation by Fanshawe (Table 3.4) was based both on the global vegetation classification system and the work of Trapnell and Clothier in the 1930s and 1940s.

Table 3.4 *Vegetation classification system for Zambia used by Fanshawe (1969).*

Broad subdivision	Vegetation category	Topographic/ Edaphic unit	Miscellaneous groupings	Floristic association
I: Closed forest	A:Climate	1. Low- and medium- altitude	(a) Dry Evergreen	i. *Parinari*
				ii. *Marquesia* (A: Lake basin Chipya)
				iii. *Cryptosepalum* (A: Kalahari Sand chipya)
			(b) Dry Deciduous	i. *Baikiaea*
				ii. Itigi
		2. High-altitude	(a) Montane	*Aningeria-Cola-Myrica-Nixia-Olinia-Parinari-Podocarpus*
	B:Edaphic	1. Swamp		*Ilex-Mitragyna-Syzygium*
		2. Riparian		*Diospyros-Khaya-Parinari-Syzygium*
II: Open forest with grass	A: Woodland	1. Miombo		*Brachystegia-Julbernardia-Isoberlinia*
		2. Kalahari		*Brachystegia-Julbernardia-Isoberlinia-Guibourtia-Burkea-Erythrophleum*
		3. Mopane		*Colophospermum mopane*
		4. Munga		*Acacia-Combretum-Terminalia*
III: Termitaria		1. Miombo		*Brachystegia-Julbernardia-Isoberlinia*
		2. Kalahari		*Brachystegia-Julbernardia-Isoberlinia-Guibourtia-Burkea-*

Broad subdivision	Vegetation category	Topographic/ Edaphic unit	Miscellaneous groupings	Floristic association
				Erythrophleum
		3. Mopane		*Colophospermum mopane*
		4. Munga		*Acacia-Combretum-Terminalia*
		5. Riparian		*Diospyros-Khaya-Parinari-Syzygium*
IV: Grasslands		1. Headwater valley		
		2. Riverine		
		3. Flood plain		
		4. Swamp	(a) Alkaline	
			(b) Other	
		5. Lake		

3.4. Land use and cover classification by Schultz

Schultz (1974) prepared the land use map of Zambia from 1970 to 1972 using information from topographic maps (1:250,000 and 1:50,000), air photography, publications, field observations, unpublished reports and discussions with informants on various subjects. As a planning document, Schultz used a single vegetation class of woodland but mapped a number of land use categories as shown in Table 3.5 on the following page.

Table 3.5 *Land use categories in Zambia by Schultz (1974)*

Land use/ Population	Province							
	Copperbelt	Northern	Luapula	North-Western	Eastern	Central	Southern	Western
Area km^2	31330	147810	50560	125830	69100	116290	85280	126400
Stateland	5477	0	0	0	2400	8844	7337	0
Forest estate	9061	5305	1428	24298	8849	5117	6763	6600
National Parks	0	17655	1389	6933	4102	10818	9520	8936
Hilly area	595	17442	5612	3523	16860	23724	10745	0
Wetland (area liable to flood and swamp)	3416	25423	9202	12708	484	10884	10168	32106
Cropland	3635	52916	11629	12331	14848	17792	14263	14536

Land use/ Population	Province							
	Copperbelt	Northern	Luapula	North-Western	Eastern	Central	Southern	Western
and fallow								
Unused woodland	12340	26396	17210	66037	22250	39111	24008	64222
Total population (1969)	816000	545000	336000	232000	510000	713000	496000	410000
Rural population (1969)	72000	531000	320000	232000	474000	305000	356000	395000

3.5. Classification of forests by Lawton

During the reconnaissance assessment of the land resources of Northern and Luapula Provinces conducted from 1968 to 1970 (Mansfield et al., 1976), Lawton carried out an extensive vegetation survey with the following objectives:

(i) To determine the vegetative pattern by means of quantitative sampling and to investigate the dynamic relationships within the vegetation
(ii) To investigate the effect of fire and other human activities on the vegetation
(iii) To determine the significance of the vegetation pattern (including particularly soil-vegetation correlation) in site quality assessments for land-use purposes
(iv) To determine appropriate methods for forest production and conservation, and
(v) To recommend the cultivation of certain minor crops.

The vegetation was sampled at 398 sites, all of which, apart from 13, were located at a soil pit or soil auger boring to facilitate soil-vegetation correlation (Figure 3.2). These sites were chosen by studying the vegetation patterns on the air photographs at the soil sampling sites, and then selecting those sites with the least disturbed vegetation.

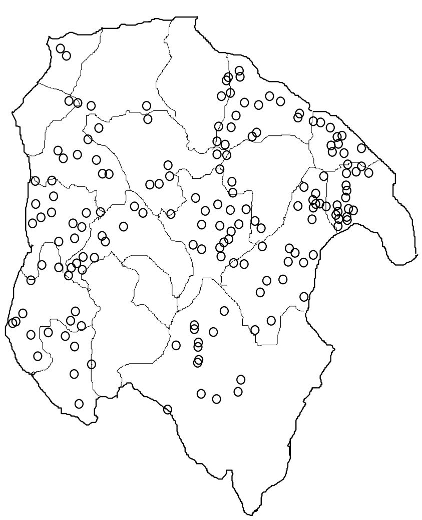

Figure 3.2 *Vegetation sample quadrants surveyed by Lawton (1968–1970) in Northern (including Muchinga, except Chama District) and Luapula Provinces in Zambia.*

The samples were 20m x 20m quadrants in which all the woody growth was recorded. Tree height and diameter at breast height (dbh, 1.3m above ground) were measured with a Suunto hypsometer and a diameter tape respectively. Plants <2m high or <5cm dbh were recorded and counted, but not measured. Coppice regrowth was counted in clumps or colonies; the individual shoots were not counted. Tree canopy cover, an ecologically important variable, was recorded at a scale with five classes to assess percentage canopy cover for each sample quadrant as follows:

Class 1: 0-20%
Class 2: 21-40%
Class 3: 41-60%
Class 4: 61-80%
Class 5: 81-100%

Observations were made on the vigour of the vegetation and on any sign of damage by fire or frost, etc. Evidence of previous cultivation was noted, and the age of the regrowth was estimated, sometimes by ring-counts. Colour and black-and-white photographs were taken at many of the sampling sites, to illustrate both the vegetation and soil profile.

The integration of the vegetation sampling with the soil survey imposed some restrictions on sampling, and towards the end of the survey, it was necessary to select 13 samples to cover the types of vegetation which had not been adequately covered on the random soil traverses.

A principal component analysis, using Orloci's formulae for similarity, was used by the Statistical Branch of the Commonwealth Forestry Institute, Oxford, to analyze 206 samples. The plotting divided the samples into a number of groups, but there was no clustering, and knowledge of the ecology of the vegetation was necessary to interpret the graphical plots.

The analysis produced six vegetation groups, as described below.

Group I consisting of chipya samples that represent quadrants where dry-season fires are intensive.

Group II is a mixture of *Marquesia macroura* evergreen forest and forest/chipya mixtures, indicating the close relationship between forest and chipya.

Group III is made up of *Bridelia duvigneaudii* subgroup and *Protea petiolaris* subgroup representing quadrants on deep, freely drained soils.

Group IV is a blend of *Marquesia macroura* forest and *Brachystegia-Julbernardia* mixtures.

Group V is made up of *Brachystegia floribunda*, *B. glaberrima*, *B. spiciformis*, *B. utilis* and *B. wangermeeana* mixtures on deep soils.

Group VI consisting of *Bridelia cathartica* with *Brachystegia allenii*, *B. boehmii* and *B. manga* on shallow compact soils.

The continuous spread of the samples on the graphical plots indicated that the vegetation is a continuum with overlaps of species and groups of species, suggesting that the relationship between dry evergreen forest, chipya and woodland is complex, thereby making the separation of ecological groups difficult.

3.6. Classification of forests by Edmonds

Edmonds (1976) followed the vegetation classification scheme of Fanshawe (1969) to prepare the Vegetation map (1:500,000) of Zambia, but he combined *Parinari* forest and Copperbelt Chipya into one mapping unit, and separated Lake Basin Chipya from *Marquesia* forest and Kalahari Sand Chipya from *Cryptosepalum* forest, as shown below (Table 3.6). Edmonds also subdivided miombo woodland into two subtypes: (a) on plateau, escarpment and valley soils and (b) on hills and rocky outcrops. All termitary vegetation was aggregated into one mapping unit, which he did for all grasslands as well.

***Table 3.6** Classification of vegetation of Zambia by Edmonds (1976).*

Broad subdivision	Vegetation category	Topographic/ Edaphic unit	Miscellaneous groupings	Floristic association
I: Closed forest	A:Climate	1. Low- and medium- altitude	(a) Dry Evergreen	i. *Parinari* and Copperbelt chipya
				ii. *Marquesia*
				iii. Lake basin chipya
				iv. *Cryptosepalum*
				v. Kalahari sand chipya
			(b) Dry deciduous	i. *Baikiaea*
				ii. Itigi
		2. High-altitude	(a) Montane	*Aningeria-Cola-Myrica-Nixia-Olinia-Parinari-Podocarpus*
	B:Edaphic	1. Swamp		*Ilex-Mitragyna-Syzygium*
		2. Riparian		*Diospyros-Khaya-Parinari-Syzygium*
II: Open forest with grass	A: Woodland	1. Miombo	(a) on plateau, escarpment and valley soils	*Brachystegia-Julbernardia-Isoberlinia*
			(b) on hills and rocky outcrops	*Brachystegia-Julbernardia-Isoberlinia*

Broad subdivision	**Vegetation category**	**Topographic/ Edaphic unit**	**Miscellaneous groupings**	**Floristic association**
		2. Kalahari		*Brachystegia-Julbernardia-Isoberlinia-Guibourtia-Burkea-Erythrophleum*
		3. Mopane		*Colophospermum mopane*
		4. Munga		*Acacia-Combretum-Terminalia*
III: Termitaria	Termitary associated vegetation and bush groups within grassy drainage zones.			
IV: Grasslands	All naturally treeless and grassy areas, comprising mountain and watershed grasslands, Kalahari-sand plain, dambo, floodplain, swamp and papyrus sudd.			

3.7. Classification of forests by SADCC Fuelwood Project

The Southern African Development Coordination Conference (SADCC) Fuelwood study was based on 1978 to 1984 data acquired by the AVHRR sensors on board the NOAA satellites (Millington et al., 1986). The results of the study included theoretical, subjective and empirical estimates extracted from a few detailed, localized projects and/or general country-wide studies. In cases where numerous studies provided multiple estimates for a single biomass class, average figures were used. All these figures were extended to provide estimates for the specific biomass classes identified within each SADCC country. These data were in turn adopted to estimate total biomass when studied in association with the calculated area of each biomass class.

The study divided the country into nine biomass classes (Table 3.7) as follows:

i. Wet Miombo Woodland
ii. Seasonal Miombo Woodland
iii. Dry Miombo and Munga Woodland
iv. Degraded Miombo Woodland
v. Dry Evergreen Forest
vi. Kalahari Woodland
vii. Mopane Woodland
viii. Scrub Woodland
ix. Swamp and Lake Vegetation

***Table 3.7** Aboveground woody biomass stock and MAI data for Zambia based on the SADCC Fuelwood Project.*

Biomass class	Area		Growing Stock		Mean Annual Increment (MAI)	
	Km²	%	Million tonnes	%	Million tonnes	%
Wet miombo woodland	223942	30.9	1809.5	61.2	57.2	3.2
Dry miombo and munga woodland	53085	7.3	50.1	1.7	1.2	1.3
Seasonal miombo woodland	125716	17.3	247.8	8.4	6.1	2.5
Dry evergreen woodland	9798	1.3	69.8	2.4	2.2	2.4
Degraded miombo woodland	110160	15.2	369.6	12.5	11.1	3.0
Mopane woodland	69000	9.5	252.1	8.5	7.4	8.2
Scrub woodland	9801	1.3	22.9	0.8	0.8	0.9
Swamp and Lake vegetation	46140	6.3	0	0	0	0
Kalahari woodland	79211	10.9	133.0	4.5	3.9	4.3
Total	726853		2954.8		89.9	

The **Wet Miombo Woodland biomass class** is widely distributed throughout Zambia, being found in all provinces, but it is especially important in Central, Eastern, Luapula, Northern and North-Western Provinces, accounting for over 30% of vegetation in each case. Wet Miombo Woodland has high levels of productivity throughout the year, ranging from Normalized Difference Vegetation Index (NDVI) values of 175-285 between November and April and lower NDVI values in the dry season, reaching a low of about 160 in September.

Two main variants of Wet Miombo Woodland were recognized in Zambia: one on the deeper soils of the plateau in which the main canopy dominants are *Brachystegia boehmii*, *B. floribunda*, *B. spiciformis*, *B. utilis*, *Isoberlinia angolensis* and *Julbernardia paniculata*; and another on shallower soils on hills, escarpments and on extensive pockets of sand (isengas) in which the canopy dominants change to *B. glaucescens* in the south, or *B. microphylla* in the north, and to *B. taxifolia* and *Cryptoseplum exfoliatum* elsewhere. This change is even more marked in the shrub and grass components. The hill miombo is found on the Muchinga Escarpment and the Bwinjifumu Hills. The woody biomass reserves of the Wet Miombo Woodland are very high, both in terms of growing stock and productivity.

The **Seasonal Miombo Woodland biomass class** is closely related to the Wet Miombo Woodland, with the main differentiation based on the marked seasonality in phenology. This woodland occurs on the plateau, the Zambezi Escarpment and extensively along the Mozambique and Malawi borders.

The **Dry Miombo and Munga Woodland biomass class** is found in all districts except in the Copperbelt, Luapula and North-Western Provinces. The greatest extent is to the south-west of Lusaka and to the north of Lake Kariba in Lusaka and Southern Provinces.

Extensive areas of **Degraded Miombo Woodland**, and related woodland and wooded grassland vegetation types, are found to the north of the Kafue Flats, in the Copperbelt and in northern Zambia adjacent to the Tanzanian border. It is most extensive in Central, Copperbelt, Luapula and Northern Provinces, in areas where the woodland has been destroyed by chitemene shifting agriculture.

Dry Evergreen Forests are now mostly restricted to western Zambia with the largest areas being found in North-Western and Western Provinces.

Kalahari Woodland is restricted to western Zambia and is mainly found in North-Western, Western and Western Provinces.

Mopane Woodland is widespread in the Luangwa Valley and in southern Zambia to the west of Lake Kariba, although small patches occur in other areas.

Scrub Woodland is restricted to the tributaries of the Zambezi on the Angolan border, with the largest areas found in Western Province. Elsewhere, it probably represents small isolated areas of scrubby thickets.

Swamp and Lake Vegetation is found along the shores of main lakes — Bangweulu, Kariba, Mweru and Tanganyika — and in the large swamps typical of the Zambian plateau, the Bangweulu, Lukanga and Mweru swamps being the most important. It is found in all districts but is particularly important in the Northern, North-Western, Southern and Western Provinces. All swamp forests are controlled by high groundwater levels and are also small in extent, varying from 1 to 120ha.

3.8. Classification of miombo forests by dominant woody species

Chidumayo (1987a) carried out a survey of the woody flora on 94 old-growth and 58 coppiced miombo woodland stands in Copperbelt, Central, Lusaka, Northern, Luapula, Eastern, North-Western and Western Provinces during 1982-1985. Study sites were systematically selected following a literature review and a preliminary field survey of miombo distribution in each study area. However, a special effort was made to ensure representation of different miombo associations found in each study area in the samples. Only stands with little or no obvious human disturbance and, in the case of coppiced stands, of known age were included in the study. Each coppiced sample plot was 20m x 50m (0.1ha) while each old-growth sample plot consisted of four contiguous 20m x 50m subplots. The term 'stem' was preferred to that of 'tree' because tree branches at or below a 0.3m height were enumerated as separate stems.

Miombo woodland in Zambia has been divided into wetter and drier types (White 1983) which are separated by the 1,000mm mean annual rainfall isohyet. However, in Chidumayo's study, the 1,100mm mean annual rainfall isohyet was used because it approximates the 1.1 aridity ratio (mean annual precipitation/annual potential evapotranspiration) line (Chidumayo 1987b). Using topographic and soil criteria, Trapnell (1953) and Trapnell and Clothier (1957) recognized 16 miombo classes. Chidumayo (1987a) used a combination of these variables and rainfall to divide miombo into five subtypes: Northern wetter miombo, North-western wetter miombo, Central drier miombo, Eastern drier miombo and Western drier miombo (Figure 3.3). On the basis of numerically dominant and frequent canopy and understorey species, these miombo subtypes were described as follows:

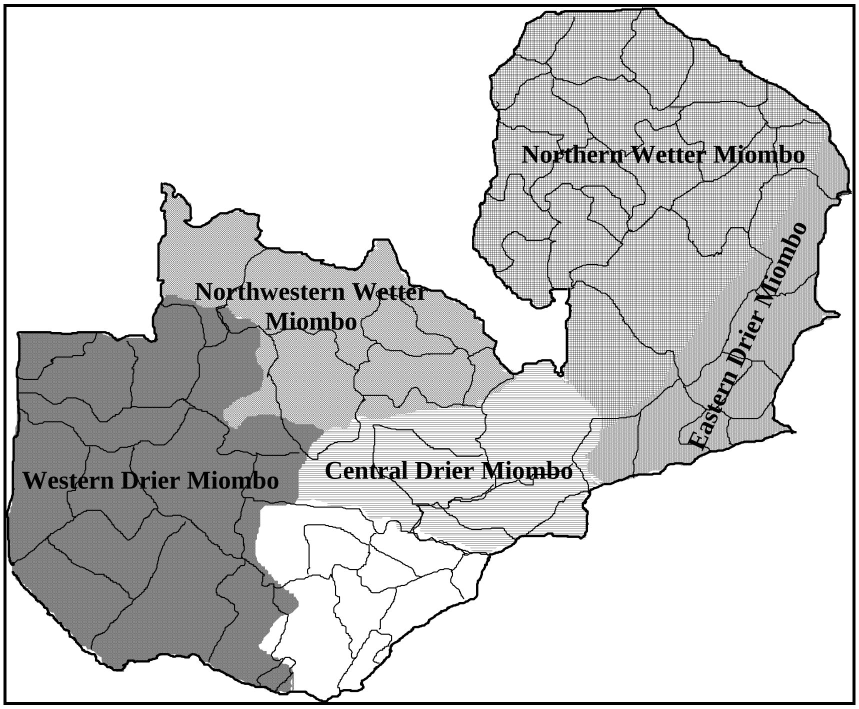

Figure 3.3 *Ecological classification of miombo woodlands (including Kalahari sand miombo) in Zambia. Based on Chidumayo (1987a).*

Northern wetter miombo: *Brachystegia* (*B. spiciformis* - *B. utilis*) woodlands with *Julbernardia paniculata* and *Parinari curatellifolia* as common canopy co-dominants and *Monotes africanus*, *Syzygium guineense macrocarpum* and *Uapaca* spp. as common understorey taxa.

North-Western wetter miombo: *Brachystegia* (*B. spiciformis* - *B. longifolia*) woodlands with *Isoberlinia angolensis* and *Julbernardia paniculata* as common canopy co-dominants and *Anisophyllea boehmii*, *Diplorhynchus condylocarpon*, *S.guineense macrocarpum* and *Uapaca* spp. as common understorey taxa.

Central drier miombo: *Brachystegia* (*B. boehmii* - *B. spiciformis* - *B. utilis*) woodlands with *Julbernardia globiflora* as a common canopy co-dominant and *Diplorhynchus condylocarpon*, *Lannea* spp., *Ochna* spp. and *Pseudolachnostylis maprouneifolia* as common understorey taxa.

Eastern drier miombo: *Brachystegia manga* - *Julbernardia* spp. woodlands with *Diospyros* spp., *Diplorhynchus condylocarpon*, *Ochna* spp. and *Pseudolachnostylis maprouneifolia* as common understorey taxa.

Western drier miombo: *Brachystegia spiciformis* - *Julbernardia paniculata* woodlands with *Burkea africana* as a common canopy co-dominant and *Diplorhynchus condylocarpon* as a common understorey taxon.

Using the results from Chidumayo's study, old-growth wetter miombo can be distinguished from dry miombo on the basis of the average number of canopy and understorey species per 0.4ha plot. The density of canopy species (# per plot) is higher in wetter (6–7) than in drier (4–5) miombo and similarly, the density of understorey species is higher in wetter miombo (22–23) than in drier (11–20) miombo. Together, woody species richness is higher in wetter than in drier miombo.

3.9. Classification of forests by cover types

The Provincial Forestry Action Programme (PFAP) in the Forestry Department developed a land-cover classification system based on LandSat MSS images of 1993, as summarized in Table 3.8. The classification did not involve floristic associations.

***Table 3.8** The land-cover classes developed by PFAP using LandSat MSS images of 1993*

Major Class	Class	Subclass
Forest	Dense forest	
	Medium dense forest	
	Low dense	Traditional farm land
		Settlement
		Degraded forest area
	Mushitu (evergreen forest along rivers)	
	Forest plantation	
Grassland	Plain/Plateau grassland	
	Marsh/Swamp	
	Dambo and Valley	
Non-vegetated (Bare)	Bare rock	
Agricultural land	Commercial (≥10ha well aligned fields)	
Water bodies	Dams/Lakes	

3.10. Classification of forests by ILUA I

The Integrated Land Use Assessment (ILUA) I, despite recognizing the major ecosystems in Zambia, used the FAO-based land use/forest type classification for the purpose of relating the national classification system to the global system (Table 3.9).

Table 3.9 *FAO-based land use/forest type classification used in ILUA I for Zambia*

Broad subdivision	**Subdivision**	**Phenology and growth form groupings**	**Edaphic/ Topographic types**	**Floristic association**
Forest (Area ≥0.5ha, tree crown cover ≥10%; tree H ≥5m)	Forest with natural or natural assisted regeneration	Evergreen		*Cryptosepalum* (Mavunda)
				Syzygium guineense afromontanum (Mufinsa)
				Entandrophragma delevoyi
				Parinari-Syzygium
			Riverine/Riparian	
		Semi-evergreen		*Brachystegia-Isoberlinia-Julbernardia-Marquesia*
		Deciduous		*Baikiaea plurijuga* (Mkusi)
				Baikiaea-Brachystegia-Isoberlinia-Guibourtia-Julbernardia-Schizophyton (Kalahari)
				Colophospermum mopane (Mopane)
				Acacia-Combretum-Terminalia (Munga)
		Other		Palm/bamboo
	Plantation	Broadleaved		
		Coniferous (Needle-leaved)		
Other wooded lands (Area ≥ 0.5ha; tree canopy cover 5-10% or shrubs/bushes canopy cover ≥ 10%		Wooded grassland (Tree canopy cover 5-10%)	Dambo/plains (with sparse trees canopy cover 5-10%)	
		Shrubs/Thicket (shrub/bush canopy cover ≥10%)		*Acacia-Commiphora* bushland and thicket (Munga woodland)
				Macchia-type scrub
			Termite mound vegetation (Termitaria), sometimes treeless	
Other land (Tree canopy	Natural and semi-natural		Barren land	
		Grassland		

Broad subdivision	Subdivision	Phenology and growth form groupings	Edaphic/ Topographic types	Floristic association
<5% or shrubs/bushes <10%)	land	(including dambos)		
			Marshland	
	Cultivated and managed land	Annual crop		
		Perennial crop		
		Pastures		
		Fallow		
	Built-up area		Urban	
			Rural	
	Extraction sites/mining areas		Open pit ore mining	
			Quarry	
Inland water			Lakes	
			Rivers	
			Dams	

The major differences in the ILUA I classification (Table 3.9) from previous classifications is the inclusion of new floristic subclasses. Firstly, under evergreen forest, only *Cryptosepalum* forest and riverine/riparian forests are recognized in previous classifications; *Syzygium*, *Entandrophragma* and *Parinari* forests are not generally recognized as distinct vegetation types in Zambia because these taxonomic groups are components of other vegetation formations. Secondly, miombo forest is not a semi-evergreen forest, although a few less dominant species, such as *Marquesia macrora* and *Parinari* (these also occur in other forest types), are semi-evergreen. The only *Brachystegia* species that has a leaf-exchanging habit is *B. spiciformis* while the rest of the miombo species are deciduous. Miombo, therefore, is not a semi-evergreen forest but belongs to the deciduous forest group. Kalahari woodland is to a very large extent miombo woodland with all the typical *Brachystegia*, *Julbernardia* and *Isoberlinia* species, but in addition *Guibourtia*, *Schinzophyton* (*Ricinodendron*) and *Baikiaea* species may be present. Raffia palms, although placed under a separate forest type in Table 3.9, are a component of riverine/riparian or swamp forest. Bamboos in Zambia do not occur as distinct forests but as components of other forest types. Munga woodland is characterized by the dominance of *Acacia* species and is in reality a narrow-leaved woodland as opposed to other undifferentiated broad-leaved woodlands dominated by *Combretum*, *Piliostigma* and *Terminalia* species in which *Acacia* may be a minor component or may be absent altogether (see White, 1983). *Baikiaea* has traditionally been classed as a closed deciduous forest in Zambia. Therefore, in relation to the global classification system, these forest types can be classified as follows (see Table 4.3):

i. Closed forest that includes evergreen forest and *Baikiaea* deciduous forest.
ii. Open deciduous forest that includes miombo, kalahari, mopane, munga and other broad-leaved woodlands.

4. ECOLOGICAL INDICATORS FOR FOREST CLASSIFICATION

4.1. Ecological indicators and forest classification in Zambia

There have been no comprehensive studies of indicator species in Zambian forests. The only long-term experiment on the responses of miombo woodland to burning was at the Ndola Indigenous Sample Plots that were established in 1933 and 1934 in the Ndola Forest Reserve, and that have now been completely encroached upon by urban development. The results of the burning experiment were first published by Trapnell (1959) after 11 years of treatments and later by Lawton (1978) after 36 years, and then by Chidumayo (1988) after nearly 50 years since the experiment started. Trapnell's classification of miombo trees and shrubs based on their response to fire is summarized in Table 4.1. It is important to note that the fire tolerance classification of miombo trees by Trapnell did not involve statistical comparisons of abundances before and after the experiment, which probably might have yielded different results (Chidumayo, 1997).

Table 4.1 *Trapnell's fire tolerance classification of trees and shrubs after 11 continuous years of fire treatments in wetter miombo at Ndola in Copperbelt Province.*

Fire-intolerant and semi-tolerant species	Fire-tolerant species
Brachystegia longifolia	*Anisophyllea boehmii*
Brachystegia spiciformis	*Dialiopsis africana*
Bridelia carthatica	*Diplorhynchus condylocarpon*
Bridelia duvigneaudii	*Erythrophleum africanum*
Byrsocarpus orientalis	*Dombeya rotundifolia*
Chrysophyllum bangweolense	*Hymenocardia acida*
Garcinia huillensis	*Maprounea africana*
Hexalobus monopetalus	*Parinari curatellifolia*
Isoberlinia angolensis	*Pterocarpus angolensis*
Julbernardia paniculata	*Strychnos cocculoides*
Lannea discolour	*Strychnos spinosa*
Ochna schweinfurthiana	*Swartzia madagascariensis*
Parinari polyandra	*Syzygium guineense macrocarpum*
Pseudolachnostylis maprounefolia	*Uapaca nitida*
Uapaca kirkiana	*Vitex madiensis*
Uapaca pilosa	
Xylopia odoratissina	

In 1969, 36 years after the establishment of the Ndola plots, Lawton enumerated some 10m x 10m random quadrats in the experimental plots. His observations and those made by Trapnell (1959) were used to develop ecological groups (Mansfield et al., 1976). Lawton (1978) identified three main fire-related ecological species-groups that characterize distinct stages in the succession or development of miombo woodland after damage by fire. These ecological species-groups are chipya, *Uapaca* and *Brachystegia-Julbernardia* or miombo. The chipya species-group consists of fire tolerant species (see Table 3.2) that survive as scattered groups of trees in chipya vegetation that is characterized by tall grasses and other herbs, and is maintained by frequent intense late dry-season fires. Chipya, therefore, is some kind of a "fire-trapped" vegetation type that represents a regressive stage of semi-closed miombo woodland after damage by frequent intense fires as observed by Trapnell (1959). According to Lawton's (1978) hypothesis, a reduction in fire frequency allows the *Uapaca* species-group (made up of fire semi-tolerant species) to invade chipya and form scattered tree canopies that suppress grass production, thereby reducing fire to a creeping surface litter fire or to its complete suppression. This process facilitates the invasion and development of *Brachystegia* and *Julbernardia* saplings and the emergence of a tree canopy that in turn suppresses the *Uapaca* canopy, which then dies back to coppice. However, this hypothesis has not been tested experimentally and Chidumayo (2004), after 11 years of observations at permanent dry miombo sites in central Zambia, contested the validity of this hypothesis.

Indeed, Fanshawe (1969) considered miombo to regenerate virtually unchanged after damage by fire, cultivation or exploitation and suggested that all miombo woodland in Zambia is secondary vegetation recovering from previous clearing for cultivation, including those areas which today look as if they have not been touched (Figure 4.1). He also observed that large areas of miombo woodland on plateau soils that are dominated by *Uapaca* species (*Uapaca kirkiana U. nitida* and *U. sansibarica*) actually represent secondary invasive species that persist in the woodland for a very long time and should be classified as secondary miombo woodland. These observations also cast doubt on the validity of Lawton's hypothesis.

Figure 4.1 *Even a miombo open forest consisting of large spaced trees with a moderately dense carpet of grass and no understorey or shrub layer (Fanshawe 1969), like this stand in central Zambia, has been disturbed in the past.*

Savory (1962), from his study of the soils and rooting habits of the major miombo species at Chati Forest Reserve near Kitwe, observed that *Julbernardia paniculata* is very adaptable and occurs on all sites, while its close relative *Isoberlinia angolensis* exhibits similar adaptability and can live within a moving permanent water table. In fact, a recent study in Mpika provided evidence that *J. paniculata* tends to over-dominate in areas regenerating after disturbance or degradation (Chidumayo and Mbata, 2002; Figure 4.2). Savory also noted that some miombo species exhibit site preferences as follows:

i. *Brachystegia spiciformis* prefers really deep soils and cannot stand waterlogging.

ii. *Brachystegia longifolia* prefers deep sandy soils and cannot penetrate murram but can live in a permanent (moving) water table.
iii. *Brachystegia utilis* prefers deep loams and cannot penetrate hard murram.
iv. *Brachystegia floribunda* prefers heavy-textured soils and can penetrate murram
v. *Brachystegia boehmii* prefers clay loams and can penetrate murram.

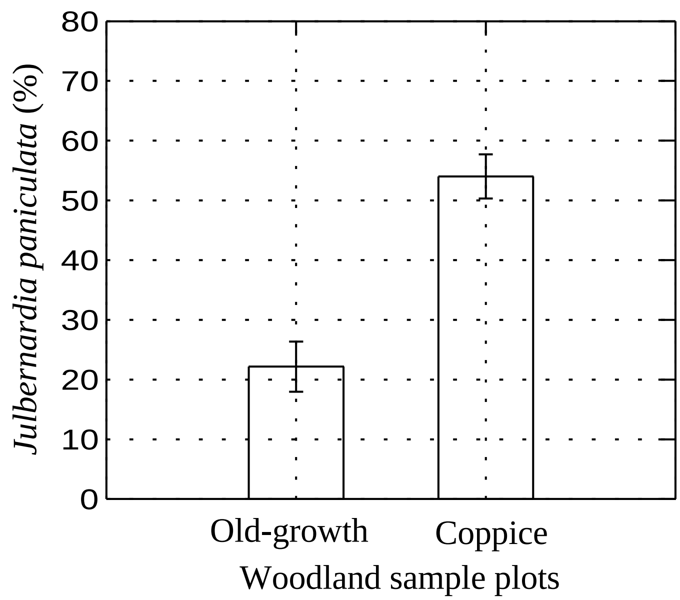

Figure 4.2 *Changes in relative abundance of Julbernardia paniculata in old-growth and coppiced miombo woodland samples in Kopa Chiefdom in Mpika District in Muchinga Province, Zambia. Vertical line on each bar shows 1 standard error of mean.*

In *Baikiaea* dry deciduous forest, crown fires can create gaps in the canopy that are often colonized by *Acacia ataxacantha* that forms mutemwa thickets. Mutemwa thickets can also develop after the abandonment of cultivated land. Such thickets consist of *Acacia fleckii, A. schweinfurthii*, *A. ataxacantha* with *Markhamia obtusifolia*, *Terminalia sericea* and *Combretum* spp. The presence of mutemwa thickets therefore indicates a regression from *Baikiaea* forest following a disturbance.

The indicators described above are useful in the interpretation of ecological dynamics in Zambian forests and can sometimes be applied in the ecological classification of forests, especially those that have been subjected to disturbances. Table 4.2 gives examples of some of these indicators and how their presence might be interpreted. Therefore, rather than use ecological indicators to classify forests, these should be used in interpreting the inventory data and developing scenarios for future trends in vegetation composition or dynamics.

Table 4.2 *Some ecological indicators and their interpretation in forest dynamics.*

Indicator	Indicator measure	Impacted ecosystem	Type of disturbance	Comparison
Julbernardia paniculata	Over-abundance	Miombo woodland	Clearing and/or cultivation	Relative abundance in old-growth versus coppiced regrowth (see Figure 3.2)
Dichrostachys cinerea	Over-abundance	Woodlands and scrub	Overgrazing, invasion and low intensity fires	Relative abundance in un-impacted versus impacted areas
Lantana camara	Presence	All ecosystems, including man-transformed ecosystems	Invasion	Not applicable
Diplorhynchus condylocarpon	Over-abundance	Miombo woodland and chipya	Frequent intense bush fires	Relative abundance before and after disturbance
Deformed stems	Over-abundance of deformed stems	Miombo and Kalahari woodlands	Lopping and frost damage	Not applicable
Acacia polyacantha	Over-abundance of deformed stems	Woodlands and scrub	Land clearing, including roadsides	Relative abundance in affected versus unaffected sites
Fire-scarred and dead charred stems	Presence	All forest/woodland ecosystems	Frequent intense bush fires	Not applicable
Mimosa pigra	Presence	Wetlands and riverine	Invasion	Not applicable
Acacia ataxacantha, A. fleckii, A. schweinfurthii (Mutemwa)	Over abundance	*Baikiaea* forest	Invasion	Relative abundance before and after disturbance
Aframomum biauriculatum, Pteridium aquilinum and	Over abundance	Chipya and wetter miombo	Frequent intense bush fires	Relative abundance before and after disturbance

Indicator	Indicator measure	Impacted ecosystem	Type of disturbance	Comparison
Smilax kraussiana				
Tree stumps and felled stems	Presence	Forest and woodlands	Timber/pole and caterpillar harvesting	Not applicable
Residual cultivation ridges	Presence	All ecosystems	Clearing and cultivation	Not applicable
Charcoal kiln mounds	Presence	Forest and woodlands	Clearing and charcoal making	Not applicable
Exotic fruit trees	Presence	All ecosystems	Settlement	Not applicable

4.2. Preliminary classification of Zambian forests for ILUA II

The proposed preliminary classification of Zambia forests is based on the integration of previous approaches to classify the vegetation of Zambia, as described in Section 3 above. This preliminary classification is presented in Table 4.3 below.

Table 4.3 *A preliminary classification of Zambian forests and land cover types for ILUA II. Definitions of forest types are as in Table 3.9.*

	Broad group	Phenology class	Stature class	Edaphic-topographic group	Floristic association	Above ground wood biomass Class
(A) Natural	(I) Closed Forest	(a) Evergreen	High (>10m)	Montane	*Aningeria-Cola-Myrica-Nixia-Olinia-Parinari-Podocarpus*	High (100–150t/ha)
				Plateau	*Parinari*	
					Marquesia	
					Cryptosepalum	
				Riverine	*Diospyros-Khaya-Parinari-Syzygium*	
				Swamp	*Ilex-Mitragyna-Syzygium*	
		(b) Deciduous	High	Plateau	*Baikiaea*	
			Low (<10m) (thicket)	Plateau	*Baphia-Boscia-Burttia-Bussea-Diospyros* (Itigi)	Low (10-30t/ha)
				Valley (Upper	*Commiphora-*	

				and Lower)	*Euphorbia-Markhamia-Schrebera* (Munga thicket)	
	(II) Open Forest	(b)Deciduous	High (5-5m)	Plateau	*Brachystegia-Julbernardia-Isoberlinia* (miombo)	Medium (40 – 100 t/ha)
				Hill	*Brachystegia-Julbernardia-Isoberlinia* (miombo)	
				Plateau	*Brachystegia-Julbernardia-Isoberlinia-Guibourtia-Burkea-Erythrophleum* (Kalahari Sand)	
				Valley (Upper and Lower)	*Acacia-Combretum-Terminalia* (Munga)	
					Colophospermum mopane (Cathedral Mopane)	
			Low	Valley (Upper and Lower)	*Colophospermum mopane* (Scrub Mopane)	Low (10-30t/ha)
	(III) Grassland with bush	(b) Deciduous		Termite mound	Mixed species	
	(IV)Grassland			Montane		Very low (<10t/ha)
				Dambo		
				Floodplain		
				Swamp		

(B) Man-Derived	**Broad group**	**Phenology Class**	**Type**	**Subtype**	**Floristic association**	**Biomass density class**
	(I) Forest	(a) Evergreen	Plantation		*Pinus*	Very high (>150t/ha)
					Eucalyptus	
	(II) Modified forest	(a) Evergreen	Degraded	Plateau (Chipya)	*Pericopsis-Albizia-Burkea-Erythrophleum-Parinari*	Medium (40–100t/ha)
		(b) Deciduous			*Brachystegia-Julbernardia-Isoberlinia* (miombo)	
					Brachystegia-Julbernardia-Isoberlinia-Guibourtia-Burkea-Erythrophleoum (Kalahari Sand)	
					Acacia-Combretum-Terminalia (Munga)	
	(II) Transformed vegetation		Cropland	Annual crops		Very low (<10t/ha)
				Perennial crops		Low (10-30t/ha)
				Mixed annual and perennial crops		
				Parkland (cropland with scattered trees)		
				Settlement		Medium/Low (10– 50t/ha)
		Extraction sites/mining areas		Open pit ore mining		
				Quarry		

For remote sensing mapping during ILUA I, all the forests were grouped into one category, although results were presented separately for evergreen forests, deciduous forests, semi-evergreen forests, shrub thickets and other natural forests. Although inventoried tracts and observed land-use units were used as the main source of ground information to validate the land-use and cover maps, it is not clear how the different forest types were delineated to derive their areal extent in the country. During ILUA I, 221 tracts were inventoried out of a total of 248 tracts that were initially selected. The distribution of the 198 fully sampled (4 plots per track) tracks by forest type is summarized in Table 4.4. It is not clear how the extent of the different forest types was derived from inventory data in ILUA I, especially for forest types that were represented by very few tracks, such as evergreen and *Baikiaea* forests.

Table 4.4 *Distribution of fully sampled tracks during ILUA I. Based on ILUA I database.*

Forest type	**ILUA I classification**	**Number of fully sampled tracks**
Cryptosepalum evergreen forest	Evergreen forest	1
Baikiaea forest	Deciduous forest	1
Miombo woodland	Semi-evergreen forest	135
Kalahari woodland	Deciduous forest	20
Mopane woodland	Deciduous forest	12
Munga	Deciduous forest	2
Other broad-leaved woodland	Deciduous forest	27
All forests		198

The detailed classification proposed in Table 4.3 may not be practical in the implementation of ILUA II because some vegetation types occur in small patches that are unlikely to be included in a sampling design that was used in ILUA I — unless ILUA II applies a stratified systematic sampling design that can ensure that such forest patches are included in the inventory. However, ILUA I and II may not be the appropriate approaches for sampling rare vegetation types due to cost considerations. Nevertheless, closed forests require more adequately sampling during ILUA II than was the case during ILUA I (see Table 4.4). There is also need to link forest classifications used in remote sensing mapping to those used in the field inventory during the design phase of ILUA II. This could be done by first stratifying the country into land cover types (see Table 3.8) and determining proportional sampling representation for each land cover class. A detailed post-classification of the vegetation types, as presented in Table 4.3, can be done using other variables for which data will be collected during the field inventory. Rare forest types may still not be represented using such a stratification approach, but these could be inventoried during targeted forest management surveys for local-level forest management planning.

4.3. Field data required for forest classification and analysis of relationships with other environmental variables

The data collection Forms (F1-F6) used in ILUA I are very comprehensive for collecting field data for forest classification but cost considerations may require reductions in the data to be collected during ILUA II. Table 4.5 gives a list of the most essential data to be collected in the field for meeting forest classification and related biodiversity, and REDD+ requirements, as well as the justification for the listing. The data collected during ILUA I that is not included in Table 4.5 is considered not essential for the ILUA II field inventory but could be collected if resources permit.

Table 4.5 *Essential data required for ILUA II and justification for categorizing as essential. Columns on Form, Section, Question and Data follow ILUA I. The data will be collected using ILUA I Forms but adjusted to include the proposed changes.*

Form	Section	Question	Data	Comment	Reason(s)
F1a	A. Track location	7-14	Geographical description of track location	Essential	Important for relocation in future
	B. Crew/Owner/Information list	18-19	Crew leader and owner	Essential	Important for data queries and land ownership
	C. Population	25	Settlement history	Essential	For relating data to population history
	D. Proximity to infrastructure	26-28	Distance of track to road/settlement	Essential	For relating data to infrastructure
F2	A. Plot access	34	Detailed description of plot	Essential only for permanent plots	Important for plot relocation and access in the future
	B. Work record	48-51			
	D. Plot plan				
	C. Plot starting point	39-47			
		53	Notes	Essential	Important for descriptive data
	2. Track #			Essential	Relating data to track
	3. Plot #			Essential	Relating data to plot
		55	Tree #	Essential	For identity of sample trees and stumps and determining the conservation status of tree species for the Convention on Biological Diversity requirements
		55b.	Stump	Essential	
		56	Species	Essential	
		56b.	Scientific name	Essential	

		57	Tree/stump location		For future relocation of trees and stumps
		57a.	Along plot axis	Essential for marker trees/stumps	
		57b.	Left and right axis		
		58	Diameter		For calculating volume and biomass for forest management and REDD+ requirements
		58a.	Diameter at 0.3 m AG	Essential (New)	
		58b.	Diameter at 1.3 m AG	Essential	
		60 (new)	Re-sprouts/Coppices	Essential	For estimating regeneration potential for forest management and REDD+ requirements
		61	Total height	Essential	For calculating volume for forest management and REDD+ requirements
		62	Bole height	Essential	
		66(new)	Reproduction		For assessing regeneration potential and bee foraging potential
		66a.	Flowers (False or True)	Essential	
		66b.	Fruits (False or True)	Essential	
		67 (new)	Fire damage (False or True)	Essential	For assessing fire impact on trees for forest management and REDD+ requirements
F4a (Subplots)	A. Soil	75aa (new)	Bulk density	Essential	For calculating carbon content for REDD+ requirements
		75ab	Organic matter	Essential	
		75ac (new)	Soil carbon	Essential	
	C. Tree measurement (H ≥ 1.3m and dbh ≤ 7cm)	77b	Scientific name	Essential	For plant identity and assessing advanced regeneration
		78a	Counts	Essential	
		78b	Total	Essential	

F5 (Land Use)	A. General	82	Protection status	Essential	For relating forest condition to status to protection and/or ownership
		83	Ownership	Essential	
	B. Land management	91	Stand structure (Expand): 91a. Closed forest 91b. Open forest 91c. Wooded grassland 91d. Grassland 91e. Plantation forest 91f. Cropland & fallow	Essential	For linking track/plot to forest/land use classification
		92b	Shrub coverage	Essential	For identification of thickets
		94	Disturbances (Expand): 94a. Tree cutting for poles 94b. Tree cutting for firewood 94c. Tree cutting for caterpillar collection 94d. Tree cutting for charcoal making 94e. Digging for roots or tubers 94f. Pollarding 94g. Tree hollowing for honey 94h. Grazing 94i. Invasion by alien species 94j. Debarking for	Essential	For assessing causes of forest degradation for forest management and REDD+ requirements

			medicine		
		95	Timber exploitation	Essential	For assessing causes of forest degradation for forest management REDD+ requirements

For ILUA II, it will also be necessary to provide some guidance on indicator species to assist in the ecological interpretation of field data (see Table 4.2). It is also proposed that the field manual should have photographs of both aerial and lateral views of the different land cover and forest types to facilitate the assigning of sample plots to the correct land cover and forest types by field crews. An example of this is shown in Figure 4.3.

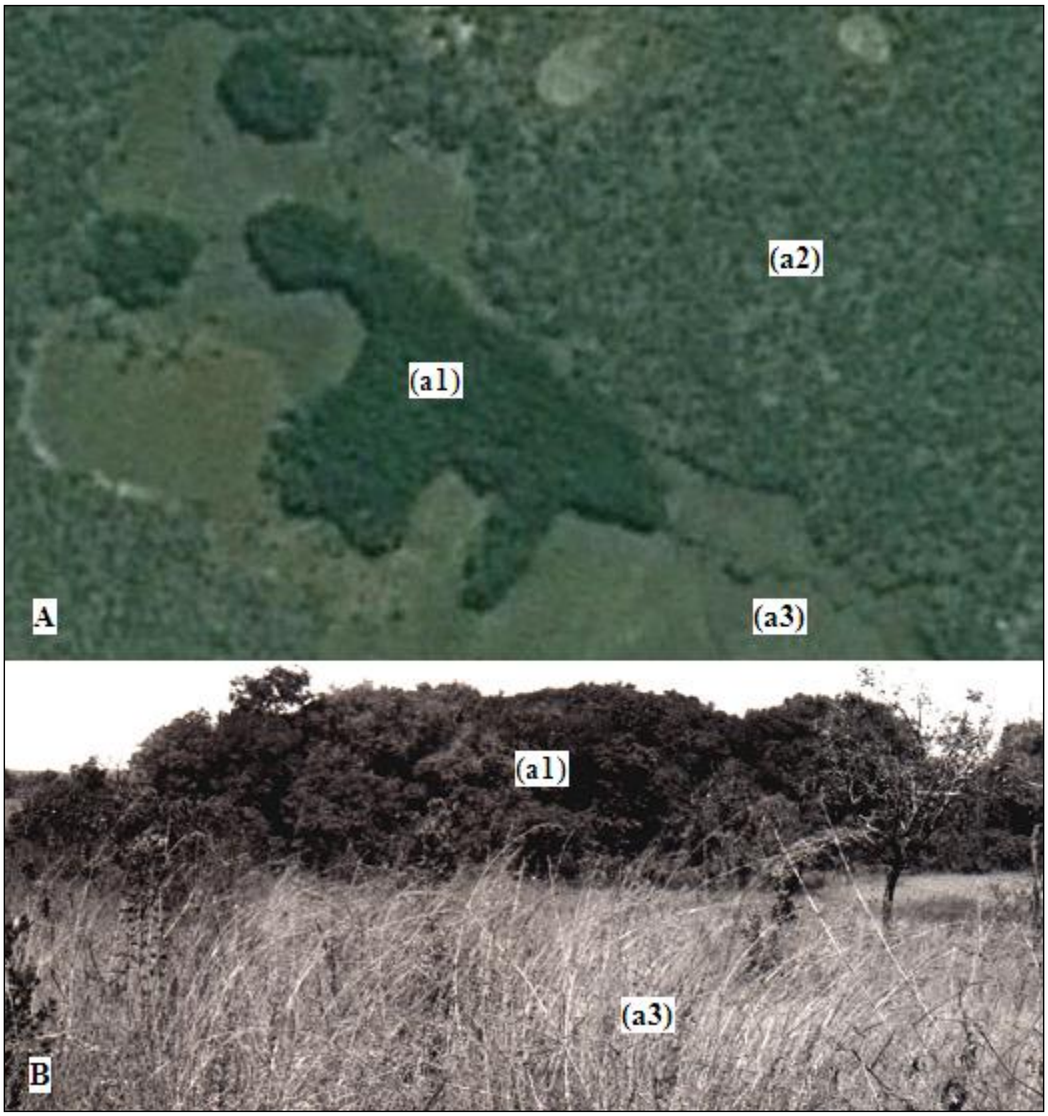

Figure 4.3 *Aerial (A) and lateral (B) views of vegetation types: closed forest (a1), open forest (a2) and grassland (a3). For a lateral view open forest see Figure 4.1.*

Collection and analysis of soil samples can be costly. Although previous studies have shown little or no correlation between soil and vegetation types, soils data, especially soil organic matter and carbon, are required for REDD+ implementation in the country. It is proposed that only limited soil samples be collected per land cover type for the determination of organic matter and carbon to meet REDD+ requirements. These data can also be used to develop models that relate soil carbon to organic matter. The models can be used to determine soil carbon from existing data on soil organic available at the Soil Survey Unit in the Department of Agriculture. For this purpose, it is proposed that during ILUA II, the location of sample plots be superimposed on existing soil maps produced by the Soil Survey Unit in the Department of Agriculture from which soil carbon can be determined for larger areas of the country. Similarly, the superimposition of sample plots on a map of the main Agro-Ecological zones should facilitate the analysis of data on the basis of these zones. Since these zones are large, the proposed sampling design based on land cover classes should be able to include a sufficient number of sample sites from each main Agro-Ecological zone.

The growing concern about impacts of climate change on forests and forest resources may require that ILUA II data is also analyzed with respect to the IPCC climate reference period (1960 to 1990) and scenarios for climate change for 2025 and 2050. This, together with a literature review, should enable an analysis of potential responses of forests to climate change in the country.

5. KEY ISSUES AND RECOMMENDATIONS

Given the issues raised in this report and the need to improve data analysis, the following recommendations are proposed for the implementation of ILUA II.

5.1 The sampling design for ILUA II should include stratification to ensure the adequate inclusion of all major land cover types.

5.2 The interpretation of the inventory data should include the use of ecological indicators so that trends in forest dynamics can be described and scenarios for the future made from the current distribution of key indicators of forest dynamics.

5.3 The collection and analysis of soil samples is often costly. It is therefore recommended that ILUA II only collects a limited number of soil samples for the purpose of determining soil organic matter and carbon. The relationship between soil organic matter and carbon can then be used to derive soil carbon from organic matter data available at the Soil Survey Unit in the Department of Agriculture.

5.4 Given the long-term impact of human activities on the Zambian vegetation structure, it might not be necessary to use climate zones for determining the sampling design for ILUA II. However, the growing concern about impacts of climate change on forests and forest resources necessitates the need to analyze ILUA II data in respect of the climate reference period (1960 to 1990) and scenarios for climate change for 2025 and 2050. This, together with a literature review, should enable an analysis of potential responses of forests to climate change.

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About Integrated Land Use Assessment (ILUA) Phase II

In 2005, the Government of the Republic of Zambia, through the former Ministry of Tourism, Environment and Natural Resources (now Ministry of Lands, Natural Resources and Environmental Protection; MLNRP) and in an effort to reduce poverty, promote economic growth, fill existing human capacity gaps and fulfil its international commitments, requested technical and financial assistance from the Food and Agricultural Organization of the United Nations (FAO) to design and implement an Integrated Land Use Assessment (ILUA). The aim of the project was to establish a permanent forest and tree monitoring system and to obtain baseline national-level data on forest and other related land use resources. This was in order to address the urgent need for knowledge on the state and trends of Zambian forestry resources, given the lack of existing national level surveys and the need to strengthen institutional and financial capacity. In this way, the ILUA served as a pilot to provide data on the national status of land cover, management and use. The ILUA results were seen as vital to supporting national policy processes and planning, but because ILUA was intended as a national-level inventory, the results had limited utility for informing provincial and district level land use planning and decision making due to limited available funds and therefore applied low sampling intensity.

Therefore, based on discussions held with project stakeholders, the continuation of ILUA through an extension was proposed, in March 2009, to the Government of Finland for financing. Since the Environment and Natural Resources Management and Mainstreaming Programme (ENRMMP) has been launched to bring improved coordination and implementation capacity to the environment and natural resource management sector in Zambia, the project is designed to be implemented during 2011-2014 under this programme, with technical assistance from the FAO.

While ILUA I generated baseline data, ILUA II, to be carried out from 2011 to 2016, aimed to enhance the use and development of data and information systems for forest resource monitoring and Sustainable Forest Management, particularly for provincial level land use planning as well as for selected districts. ILUA II aims to provide information on trends in forest change through refined methodologies, re-assessed field plots and a four-fold intensification of sampling density in order to report at the sub-national level. It also aims to cover socio-economic related information needs via the Forest Livelihoods and Economic Survey in order to better understand the drivers of deforestation and to inform policy interventions which support Sustainable Forest Management. Establishing a monitoring system that captures livelihood needs beyond the forests is critical to designing well-targeted and innovative policy solutions that can support and promote sustainable natural resource management. The principal objectives of the ILUA II project are to strengthen forest and land use inventories at the national and sub-national level, and to support the implementation of Sustainable Forest Management and initiatives to Reduce Emissions from Deforestation and forest Degradation (REDD) through better information, capacity building, dissemination of information, and improved multi-sectoral dialogue.

The main stakeholders of the project are: MLNREP and different departments and institutions with which it collaborates, Ministry of Finance and National Planning, Ministry of Agriculture and Livestock, Central Statistical Office, National Remote Sensing Centre (Ministry of Science and Industrial Research), University of Zambia, Copperbelt University, Centre for International Forestry Research, National Institute for Scientific Research, Zambian Agricultural Research Institute, other national and international education and research institutes, smallholder farmers, NGOs and civil society, UN-REDD and other projects, the FAO and other cooperation partners.

The intended beneficiaries of the project can be summarized as follows: policy and decision makers at all levels, forest industries with an interest in timber and non-timber forest products from forest areas, the international community and international organizations requiring reliable information on the natural environment, NGOs, academia and grassroots organizations with interests in forest resource management, environmental protection, timber trade and extension.

In line with the overall policy of the Government of the Republic of Zambia, the impacts of this project are that benefits of Sustainable Forest Management are increased and mainstreamed in the national economy and policies, thereby supporting sustainable development of environment and rural livelihoods and meeting the Millennium Development Goals in a changing climate.

The project's main outcome is ***"strengthened capacity in planning and implementation of Sustainable Forest Management and REDD through better information capacity building, dissemination of information and improved multi-sectoral dialogue"***. The three main outputs of the project are:

Output 1: Effective means of dissemination and utilization of the information for multi-sector dialogue

Output 2: Improved methodological and human capacity in collecting and analyzing forest resource information for Sustainable Forest Management, REDD monitoring and carbon inventory.

Output 3: Implementation of ILUA II Mapping and Field Survey

ILUA II
Integrated Land Use Assessment Project

Ministry of Lands Natural Resources and Environmental Protection
Forestry Department
P.O. Box 50042
Lusaka, Zambia
Tel. +260 211 221087

Food and Agriculture Organization of the United Nations
P.O. Box 30563
Lusaka, ZAMBIA
Tel: +260 211 252277
or +260 211 252558

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