I-TOO

Indicators and Tools for Restoration and Sustainable Management of Forests in East Africa

I-TOO working paper No. 3

State of Forests and Foresty Research in Tanzania

Compiled by

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ACRONYMS AND ABBREVIATIONS

I-TOO	Indicators and Tools for Restoration and Sustainable Management of Closed-Deciduous Forests in East Africa. A research project bringing together East African and European Researchers
BP	Before Present
CDF	Secondary Deciduous Forests
CDM	Clean Development Mechanism
CEC	Cation Exchange Capacity
EAM	Eastern Arc Mountains
FAO	Food and Agriculture Organization of the United Nations
FBD	Forest and Beekeeping Division (Tanzania)
GNP	Gross National Product
K	Potassium
KFL	Kilombero Forests Limited
N	Nitrogen
NGO	Non Governmental Organization
MNRT	Ministry of Natural Resources and Tourism
OM	Organic Matter
P	Phosphorus
TFAP	Tanzania Forest Action Plan
URT	United Republic of Tanzania

1. Introduction to the framework and index outline

1.1 Overview

The main objective of this review paper is to compile the existing information on prevailing CDF types, their management and uncontrolled utilisation history in Tanzania. This paper is considering available: standard literature, research publications, consultant reports and inventory results.

1.1 Countries profile

The I-TOO country profiles are presented in Table 1 below:

Table 1: Partner countries profile

Parameter		Ethiopia	Uganda	Tanzania
Land area	million ha	110	19	88
Population	million people	61	21	33
Population density	caput/km	61	110	37
Annual change	%	2.5	2.8	2.3
People living in rural areas	%	83	86	73
GNP	per capita	112	326	183

Source: FAO, 2001

2. Legal forest aspects in Tanzania

2.1 Forest law

The Forest Ordinance Cap. 389 (1957) which was the forest law of the United Republic of Tanzania (URT) has been replaced by the Forest Act No. 14 of 2002. The Forest Act of 2002 controls the State, and Local Authority owned forest reserves (URT, 2002). The forest laws are passed and accepted by the National Assembly and published by the Government Printer as Chapters, Supplements, Orders or Notice which, until revoked or amended, remain the primary legislative control of the forests in Tanzania (Holmes, 1995a).

2.1.1 Forest regulations in state and private owned forests

The Part V of Forest Act of 2002 of the laws of the URT is the major legal instrument of the Tanzania Forest Policy. It covers the creation and declaration of forest reserves and forest resources. The requirements necessary for declaring an area as a forest reserve are spelled out. This part also covers the establishment of institutions other than state forest reserves, such as village forest reserves, controlled areas, silvi-pastoral areas for pastoralists, etc. Minimum management standards for village and private forestlands have been included in the Forest Act, with a provision that the Forest and Beekeeping Division (FBD) supervises their enforcement. Consideration has been made for key areas that should be reserved for biological conservation as strict nature resources. Appropriate incentives in the form of subsidies, subsidised loans or tax reductions are considered desirable for fostering afforestation.

Royalties and penalties in the Forest Act Rules are established by the Government in such a way that fees are payable on non-plantation and plantation forest produce by types. These royalties are periodically adjusted. The fees neither reflect the value of forest products to the society nor the resource replacement cost. This contributes to deforestation and forest degradation. At the same time, artificially low wood prices are hampering farmers to make investment in tree growing, due to low expected earnings. The Government will in the future subsidize conservation and not consumption. Most of the private owned forests found in the country are plantations belonging to private companies and religious organization (Birger *et al.*, 1994). Land use act of 1973 regulates the land right ownership and forest act will apply only for reserved trees situated in the private owned lands.

2.1.2 Community forest regulations

The Forest Act of 2002 promotes the private and community based forest including the village forest reserves. Minimum management standards for village and private forestlands have been included in the Forest Act, with a provision that the Forest and Beekeeping Division supervises their enforcement. Key areas should be reserved for biological conservation as strict nature resources. In addition, the Tanzania Forest Policy (URT, 1998) provides the framework for the promotion of the private and community based ownership of forest including forest reserves and allows farmers to be entitled to have ownership rights of the indigenous species including the reserved species. The community owned forests such as sacred forests that were controlled through customary laws and sometimes by village By-laws have been turned to the status of declared forest reserve by virtue of the Forest Act of 2002. In addition, the Forest Law gives the Minister for Natural Resources and Tourism the power to alter the status of a National or Local Authority Forest Reserve "to become a Village or Community Forest Reserve" [Clause 36]. This provision gains direct support from new land law (Land Act, 1999), which sets out procedures through which land may be removed from the general or government class of land into Village Lands. Village Councils and community groups (among others) may also apply to lease a Government Reserve [Clause 27].

2.2 Forest resource and ownership

2.2.1 Forest area

Tanzania has an area of 886,000 km^2. About 33.5 million hectares, or 37.8% is covered by forests and woodlands. Out of the total 33.5 million hectares classified as forest land, almost two thirds consists of woodlands on general (public) lands. The main vegetation types include Afro alpine heath and moorland, forests, woodlands and grasslands, bushlands and thickets, swamps, mangroves and man made forests. About 13 million hectares of this total forest area have been gazetted as forest reserves. Over 80,000 hectares of the gazetted area is under plantation forestry and about 1.6 million hectares are under water catchment management. According to FAO (1992) and URT (1998) the total forested area in Tanzania is classified on the basis of forest type, use and legal status as shown in Tables 2a, 2b and 2c respectively.

Table 2a: Generalized distribution of forest types by area in Tanzania

Forest type	Area ('000 ha)
Forests (other than mangrove forests)	1,141
Mangrove forests	115
Woodlands	32,299
Total	**33,555**

Source: FAO (1992); Holmes (1995 b); URT (1998)

Table 2b: Distribution of forest use by area in Tanzania

Forest type	Area ('000 ha)
Production forest	23,810
Protection (including water catchment)	9,745
Total	**33,555**

Source: FAO (1992); Holmes (1995 b); URT (1998)

The forest estate has productive, protective and scientific functions. Productive benefits include: woodfuel, structural timber, roundwood etc. Protective functions include: soil conservation, environmental amelioration, habitats for fauna and flora and water catchment areas. The remnants of tropical high forests in the Usambaras, Ulugurus and Udzungwa (otherwise known as the eastern arc) provide good scientific research sites due to their unique flora and fauna and high levels of endemism (Mgeni, 1992; URT, 1998).

There are about 80,000 ha of plantation forests. These are designed to provide industrial wood. The plantation forests consist of 86% softwoods and the remaining hardwoods. The main softwood tree species are *Pinus patula, P. caribaea, P. elliottii* and *Cupressus lusitanica*. The main hardwood plantation tree species are *Tectona grandis, Melia excelsa, Acacia mearnsii, Eucalyptus saligna, E. maidenii* and *E. grandis* (Kowero, 1990).

2.2.2 Forest resource ownership

The central government owns most of the forest resource in Tanzania through the FBD. It owns the gazetted forests, the woodlands in national parks, the plantations and the general lands (or non-reserved forest land) (Table 2c). Local governments own some forest reserves, which are mainly protective in function (URT, 1998). The current exact area is not known due to encroachment in many of these forests. It is interesting to note that most of the central government's forests (both reserves and unreserved) situated in the provinces (Regions) particularly in remote areas such as Kigoma and Rukwa regions in the western parts of Tanzania are currently not managed due to limited financial resources and forestry staff deficit in the country (Ishengoma, 2003).

Table 2c: Distribution of forest legal status by area in Tanzania

Ownership[1]	**Forest area ('000 ha)**	**Remarks**
TT	10,637	Forest reserve
LA	1,730	
TT	2,000	Forest/woodland within national parks etc
TT	80	Plantations
Private	70	
Open access regime	19,038	Non-reserved forest land
Total forest area	**33,555**	

[1]TT – Territorial; LA- Local Authority. Source: FAO (1992); Holmes (1995 b); URT (1998)

Corporations own the small area of private forests, e.g. TANWAT Co. Ltd and Kilombero Valley Teak Company both largely owned by the Commonwealth Development Corporation in Njombe and Ifakara respectively, private individuals and NGOs. It has been estimated to be nearly 70,000 hectares only (MNRT, 1989). It consists of mainly plantations established for specific productive functions. TANWAT, for example, established black wattle plantations (*Acacia mearnsii* De Wild) to produce tannin from wattle barks mainly for export and power generation. Other private areas are established under the village afforestation programme and farm forestry for the market (Kihiyo, 1992).

3. Classification of Tanzania forests

3.1 Background

Existence of many rock groups and types, and altitude zonations has contributed to corresponding diversity in soils and to some extent vegetation. A number of different forest classification systems have been proposed for Tanzanian forests employing various terms that are somewhat confusing for non-professionals. Extensive quantitative work has shown that the composition of forest communities varies continuously with differences in altitude and rainfall. In this context, where there may be some discontinuities, they are often a result of differences in past disturbances. Thus the most sensible approach to classification of Tanzanian forests would be to use broad arbitrary definitions with approximate elevation and rainfall limits. An alternative approach could be to define forest types on the basis of dominant tree species. The major flaw of the latter approach is that various successional stages of forests under the same environmental conditions are then classified independently. Thus forest classification based on environmental conditions, such as altitude and rainfall is recommended.

3.2 Existing forest classification systems

Tanzanian forests are classified based on notably physiognomic and floristic criteria. Subdivision of Tanzania's vegetation into physiognomic types can shade some light on floristic diversity (Polhill, 1968). Floristically, Tanzanian forests have been classified into five broad categories or more specific, phytochoria (floristic units) as described by White (1983). Both criteria have some points in common. Table 3a summarizes the linkage between physiognomic vegetation classification and floristic classification with emphasis on localities and species composition while the area covered by each forest types and sub types is shown in Table 3b.

Table 3a: Relationship between floristic and physiognomic and their variants found in Tanzania

S/N	Unit (phytochorion)	Proportion (% of country)	Location and species composition
1.	Closed Forests (Afromontane archipelago-like regional centre of endemism)	2-3	
	• Moist Lowland/Lowland Rainforests		-Eastern Arc Mountains i.e. Pares, Usambaras, Nguru, Nguu, Uluguru, Ulanga, Udzungwa, Mahale, and parts of Bukoba District. Has affinity with Guinee-Congo forests but species frequently distinct. -Genera such as *Allanblackia, Cephalosphaera, Isoberlinia, Macaranga, Newtonia, Parinari* may be amongst numerous co-dominant trees.
	• Moist montane/upland Rainforests		-Found at altitudes exceeding 1200 m a.s.l in East Usambara, Nguru and Uluguru. Characteristic genera include, *Aningeria, Cassipourea, Chrysophyllum, Conopharyngia, Ocotea, Podocarpus, Macaranga* and *Neoboutania*.
	• Dry montane evergreen forest/upland evergreen forest		-Commonly found in rain shadow aspect of larger mountains such as West Usambara, Pare, Northern slopes of Mount Kilimanjaro, eastern parts of Mount Meru, Crater Highlands, Mount Hanang Poroto and Livingstone Mountains. -Commonly found genera are *Agauria, Cassipourea, Ekebergia, Ilex, Juniperus Olea*, *Dombeya, Afrocania* and *Noxia*.
	• Dry lowland evergreen forest/lowland evergreen forest		-Northern end of East Usambara Mountains, South West Tanga and East Handeni. Common genera being *Brachylaena, Cynometra* and *Manilkara*. -Tanga to Lindi plateau in the southeast dominated by *Albizia*, *Milicia*, *Lannea*, *Pteleopsis* and *Sclerocarya*.
2.	Mangrove Forests (Zanzibar-Inhambane regional mosaic)	0.1	-Tanga to Mtwara Coastline including estuaries of the Rufiji, Ruvuma and Wami Rivers. -*Avicenia* and *Rhizophora* are commonly found genera

Table 3a: Continued

S/N	Unit (phytochorion)	Proportion	Location and species composition

		(% of country)	
3. .	Forest-Grassland Mosaic (Somali-Masai regional centre of endemism)	12.1	
	• Grassland		-Patches near moist forest foothills of Uluguru, Iringa and Ufipa dominated by *Eragrostis*, *Exotheca*, *Hyparrhenia* and *Themeda*. -Ngorongoro Crater dominated by *Eleusine*. -Eastern part of Mount Meru dominated by *Cymbopogon* and *Sporobolus*.
	• Thickets		-Inselbergs around Lake Victoria, Central and Southern plateaus. Dominant genera include, *Dalbergia, Diospyrus, Dombeya, Markhamia, Lannea, Strychnos* and *Teclea* (fire climax vegetation) -Itigi thickets on the Central plateau, dominated by *Baphia, Bussea, Canthium, Commiphora, Corolyla, Croton* and *Hyppocratea*. *Lannea* and *Strychnos* found further east in Mpwapwa, Iringa and Kilosa Districts. Other thickets found in Handeni (dominated by *Mansonia* and *Burttdavya*) and near Pugu (dominated by *Erythrophleum* and *Entada*) -Steep or rocky northern slopes of the Usambara and Pare Mountains dominated by *Euphobia* thickets. -Bamboo thickets found in patches on Mount Meru, Oldeani, Poroto and Rungwe. *Arundinaria* dominates. *Oxytenanthera* common in the south-east and extends to Kilosa and across to the west.
	• Comiphora, Acacia bushland		-Most extensive in eastern Rift valley zone, the eastern river valleys, and coastal hinterland, also in the north-east as a continuation of a more extensive zone in Kenya, oftenly includes *Adansonia, Delonix, Combretum, Elaeodendron, Erythroxylum, Grewia, Manilkara, Mimusops* and *Sideroxylon*.

Table 3a: Continued

S/N	Unit (phytochorion)	Proportion (% of country)	Location and species composition
4.	Woodland/deciduous woodland (Zambezian regional centre of endemism	36.9	
	• Miombo woodlands		-These dominate vast expanses of plateau in the western, central and southeastern parts. *Brachystegia* and *Julbernadia* are dominant genera. -In the southeast *Milletia, Dalbergia* and *Lanchocarpus* dominate.
	• Dry miombo		-Abundant in coastal, Southern Highlands, Eastern and Southern Tanzania, have additional genera including *Afzelia*, *Pterocarpus*, *Sclerocarya* and *Tamarindus*.
5.	? (Lake Victoria regional mosaic)	?	-Greatly modified by cultivation and settlement. *Bridelia, Maesopsis*, and *Markhamia* are common genera in the wet Western side of the Lake. Dry eastern side has *Acacia* and *Combretum* as main genera.

3.3 Description of forest types in Tanzania

Forest types refer to wide groups of vegetation within the broadest units i.e. formations, which possess certain characteristics in common. In most cases, however, types are not distinct and between one type and another there may be a number of transitional types. Distribution of forest types in Tanzania has been given in Table 3b. The following brief description of the various forest types and their variant subtypes is given in the proceeding subsections.

3.3.1 Closed Forests

Closed forests of Tanzania mainly occur in fragmented blocks in the chain of mountains known as Eastern Arc Mountains (EAM) (Fig 1). The forests extend down through eastern Tanzania to the gap between the Udzungwa Mountains and Mt. Rungwe (Makambako Gap) (Lovett and Wasser, 1993). From north to south, the main blocks are the North and South Pare, the East and West Usambara, the North and South Nguru, the Ukaguru, the Uluguru, the Rubeho, and the Udzungwas. There are also smaller isolated outliers such as Mahenge to the south of the Udzungwas, Malundwe Hill in Mikumi, and the Uvidundwa Mountains north of the Udzungwas.

Generally, the occurrence of closed forests is associated with altitude and climate. In addition, variations related to site factors such as soil type and drainage conditions may exist. Thus closed forests are divided into forests at high altitudes (montane) and low altitudes (lowland), which are then subdivided according to their degree of wetness into evergreen and dry forests (Dallu, 1989).

Figure 1: A map showing location of closed forests of Tanzania in the Eastern Arc Mountains

In Tanzania, nearly all the closed forests are confined to the uplands, with the most valuable parts occurring in two regions, the larger covering Mts. Meru and Kilimanjaro and the West Usambaras and the smaller part is found in East Usambaras (Nshubemuki, 1998). The majority of the upland forests are in the form of isolated blocks and are of similar nature as those found elsewhere on the East African uplands (Iddi and Sjöholm, 1997). The main species are *Podocarpus* spp (podo), *Ocotea usambarensis* (camphor), *Juniperus procera* (cedar), *Olea capensis* (loliondo), *Cephalosphaera usambarensis* (mtambara), and *Cassipourea malosana* (pillarwood) (Persson, 1974). The dominance of these species is correlated with the various closed forest sub types described in Table 3a.

Table 3b: Regional forest vegetation types distribution by area in mainland Tanzania

Region	Major vegetation types							
	Closed /evergreen forests		Woodland/deciduous woodland		Forest-Grassland mosaic		Mangrove	Lake Victoria regional mosaic
	1		2		3		4	5
	Vegetation sub-types							
	Montane forests	Lowland forests	Miombo woodlands	Dry miombo	Thickets	Grassland	-	-
Kilimanjaro	1,760	-	-	-	2,795	-	-	-
Dodoma	400	-	4,160	2,720	5,900	1,410	-	-
Dar es salaam	-	-	-	-	-	-	21.7	-
Arusha	1,600	960	1,280	1,920	1,6265	-	-	-
Mwanza	-	560	1,440	221	5,545	-	-	-
Kagera	-	320	3,600	2,080	12,985	-	-	**?**
Rukwa	-	-	28,800	2,620	9,290	-	-	-
Mtwara	-	-	-	720	4,195	-	89.4	-
Mbeya	320	-	13,600	3,840	9,707	-	-	-
Iringa	2,400	1,040	1,360	1,0240	16,350	-	-	-
Singida	-	-	11,840	11,840	4,910	1,900	-	-
Lindi	-	-	2,320	22,080	19,380	1,480	269.8	-
Tanga	1,840	720	4,160	720	5,065	-	111.6	-
Tabora	-		23,040	9,600	5,710	530	-	-
Mara	-	-	-	-	1,680	-	-	-
Kigoma	-	-	1,360	1,280	6,750	-	-	-
Morogoro	1240	4580	2,080	-	111,470	-	-	-
Shinyanga	-	-	11,041	2,160	4,142	-	-	-
Ruvuma	-	960	15,040	1,320	13,200	-	-	-
Pwani	-	-	1760	2600	4,190	290	662.3	-
Total km^2	**9,560**	**9,140**	**13,9121**	**7,5961**	**165,529**	**5,610**	**1154.8**	**-**
% Coverage	1.0	1.0	14.9	8.1	17.8	0.6	-	?

Adapted from Holmes (1995 a); Nshubemuki (1998);

3.3.1.1 Geology and climate

(a) Geology

A short account of geology and climate of the EAM has been given by Schulman *et al*. (1998). These mountains occur on three main geological formations: a) Precambrian crystalline rock, b) Cretaceous and Jurassic sedimentary rocks and c) Tertiary to recent volcanic rocks. The Precambrian rocks are metamorphosed granites, sandstones, shales and limestones formed more than 450,000,000 yrs before present (BP). The Cretaceous and Jurassic were formed 135 and 180 million years BP respectively while sedimentary rocks result from the onset marine conditions following the break-up of Gondwanaland and development of the Indian Ocean. The rocks of EAM were formed as a result of block-faulting of Precambrian crystalline rocks starting from 290 – 180 million years BP. The rocks have been modified by continuous cycles of erosion and uplift and activation of the faults. Metamorphosed limestone rocks occur along the eastern edge of EAM where the coastal sediments meet the crystalline rocks of the EAM.

The Eastern Arc is comprised of heavily metamorphosed Pre-Cambrian basement rocks, which have been periodically uplifted by faulting and weathering over millions of years. The soils derived from these sediments are typically less rich than those of the volcanic mountains of East Africa, but the consistent rainfall in the area increases the agricultural potential. These block-faulted mountains have been geographically isolated for millions of years. The main blocks are uplifted along ancient faults, with uplift events occurring periodically, probably at least since the Miocene (about 30 million years ago). However, the faults, and therefore perhaps also the mountains, appear to be considerably older than this (Griffiths, 1993).

(b) Climate

In Tanzania, closed forests are found in areas where annual rainfall exceeds 1200 – 1500 mm and where the dry season is not too marked or enhanced by high temperatures. The EAM in which moist forests occur act as condensers of moisture originating in the Indian ocean and are important catchment areas. Proximity to the Indian Ocean affects rainfall, which is higher on those mountains near to the coast. Closed forests in areas closer to the coast such as the East Usambara, or where there is no high ground level between them and the coast, such as the Ulugurus, receive the highest rainfall exceeding 2000 mm/yr and some times exceeding 3000 mm/yr (Schulman *et al*., 1998).

Annual variation in climate is determined by the Indian Ocean monsoon. The hottest time of the year is from December to March when winds are from the north. The rainy season peaks in April. Southerly winds are from May to October with the coolest and driest time of the year in June and July. The southern monsoon slackens in September with lesser rains in November. The north-east trade winds bring rain to northern part of EAM which have a bimodal rainfall distribution with peaks in November and April. On the other hand, the south-east trade winds bring rain to the southern part with a single rainfall peak.

3.3.1.2 Closed forest sub types

(a) Moist montane forests

Geographically moist montane forests occur along the West Usambara Mountains and in a zone on Mt. Kilimanjaro (not on north slopes). They are found at an altitude ranging from 1200 to 1800 m with a well-distributed rainfall ranging from 1200 mm to more than 2000 mm annually. The rainfall distribution varies form clearly bimodal to distinct monomodal. These forests are usually richest in species and have distinct stratification.

Three distinct strata with an understorey of shrubs (mainly Rubiaceae) can be identified i.e. i) the upper stratum comprised of emergent trees at about 15-30 m height; ii) below the upper stratum is a stratum of sub-emergent trees at about 5-10 m height; the herbaceous stratum on the forest floor that consists of ferns, seed plants and broad-leaved grasses. Emergent trees may reach the height of 45 m and all diameter classes are found in the area, which belongs to different tree species. Dominance of herbaceous vegetation in the undertorey is influenced by the quantity of light penetrating through the tree canopy.

Tall trees found in the forest are *Ocotea usambarensis*, *Podocarpus usambarensis*, *Entandrophragma excelsum* and *Prunus africana* and trees found in the strutum of 9 –21 m include *Albizia gumifera, Croton macrostachys, Syzygium guineense* and others. Most of the trees are evergreen and lianes and epiphytes are present especially in the wetter areas (Lind and Morrison, 1974). In addition, closed canopies have very little herbaceous understorey while open canopies have luxuriant herbaceous understorey. It is interesting to note that forests of similar composition, but without *Ocotea*, occur on Mt. Meru, on the Mbulu highlands, on the Ufiome-Mikiulu uplands and on the Ifiome and Hanang Mountains. Furthermore, a similar forest composed almost entirely of *Ficalhoa laurifolia* and *Afrocrania volkensii* covers large areas of the Mporoto and Rungwe Mountains (Iddi and Sjöholm, 1997).

(b) Dry montane evergreen forest

This type of forest occurs from about 1200 m altitude up to 3200 with rainfall not well distributed usually 850-1300 mm or less per annum, with a prominent long dry period of up to 5 months. In Tanzania, this forest type is common in rain shadow aspects of large mountains. Good examples are found in West Usambara, Pare, Northern slopes of Mount Kilimanjaro, eastern part of Mount Meru, Crater Highlands, Mount Hanang, Poroto and Livingstone Mountains.

Canopy trees have mean height ranging from 10 to 20 m sometimes reaching 45 m. the Canopy trees of small diameters such as *Juniperus* are confined to higher elevations while trees of larger diameters such as *Olea capensis* are found on the lower elevations. In general, most trees have dbh less than 40 cm with a few large trees of diameter exceeding 100 cm and the mean basal area in this forest type ranges from 10-20 m^2/ha (Iddi and Sjöholm, 1997). The *Juniperus* species can reach the height of 45 m and diameter of 3 m in the natural forests and prefer rainfall of about 875 –1375 mm per year. Tree species found in the cedar forests *are Olea africana, Olea capensi, Dombeya species, Afrocania volkensii* and others (Lind and Morrison, 1974; Schulman *et al*., 1998).

Zonation of species with respect to elevation is a common feature in this forest type. In this context, *Juniperus* species are confined to higher elevation followed by *Olea* species. Between 1 200 and 2 750 m *Cassipourea* species occur accompanied by *Albizia* species. Heights are up to 21 m. The most important area is found on Mt. Kilimanjaro. Other blocks of this forest have been reported in Mufindi, Ukwene, Myumbaniku, Udzungwa, Dabaga, and the West Side of Rungwe and Umalita (Iddi and Sjöholm, 1997).

In addition, formations of mountain bamboo (*Arundinaria alpina*) are found on Mts. Meru and Rungwe, on the Ulugurus and the Livingstone Mountains, and in the Iringa Highlands and the Porotos while small patches are noted in forest areas of southern Tanzania (Iddi and Sjöholm, 1997).

(c) Moist lowland forest

This type of forest occurs below 800 m altitude with rainfall exceeding 1500 mm per annum (Schulman *et al*., 1998). Good examples are found in EAM and parts of Bukoba district (Table 3a).

Canopy trees have mean height ranging from 25 to 40 m with emergents reaching up to 50 m. There are many large trees with diameters exceeding 50 cm together with quite many trees of diameter greater than 100 cm. Stem densities of trees with diameter greater than 20 cm is about 140 stems/ha while mean basal area in this forest type ranges from 20-50 m^2/ha (Schulman *et al*., 1998). Dominant tree species include *Allanblackia* spp, *Cephalosphaera* spp, *Isoberilinia* spp and *Newtonia* spp (Nshubemuki, 1998).

(d) Dry lowland evergreen forest

Similar to moist lowland forests good examples of this forest sub type are found in EAM occupying only modest areas in the Usambara, Nguru, and Uluguru Mountains and parts of Zanzibar (Iddi and Sjöholm, 1997; Nshubemuki, 1998). They consist of secondary semi-deciduous and low growing stands below 800 m altitude with rainfall ranging from 1000 - 1500 mm per annum (Schulman *et al*., 1998). Associated with dry lowland evergreen forests are lowland bamboo (*Oxytenanthera abyssinica*) occuring from the south of Iringa to the Lindi district up to 615 m altitude, and also in the form of widely spaced clumps in the miombo woodland. In addition, there is the ground-water formation consisting of gallery forest, often representing the only remnants of once extensive forests in the lower zones (Iddi and Sjöholm, 1997).

In this forest sub type canopy trees have mean height ranging from 15 to 20 m with emergents reaching up to 35 m (Schulman *et al*., 1998). Dominant tree species include *Brachylaena* spp, *Cynometra* spp and *Manilkara* spp in the north; and *Albizia* spp, *Milicia* spp, *Lannea* spp, *Pteleopsis* spp and *Sclerocarya* spp in the South (Nshubemuki, 1998).

3.3.2 Mangrove Forests

3.3.2.1 Overview

Mangrove vegetation is characteristic of sheltered coastlines in the tropics. Mangrove communities are extensive in protected shallow bays and estuaries, around lagoons, and on the leeward side of peninsulas and islands. In Tanzania mangrove forests occur on the sheltered shores of deltas, alongside river estuaries, and in creeks where there is an abundance of fine-grained sediment (silt and clay) in the upper part of the inter-tidal zone.

The establishment of mangrove vegetation is governed to some extent by the degree of exposure to strong winds. The largest continuous mangrove areas are to be found on the coasts of Tanga district in the north, the delta of the Rufiji River in Kilwa and Lindi districts, and in Mtwara, where the Ruvuma River forms an estuary close to the Mozambique border (Figure 1). Thus, the mangrove forests stretch along coastal districts from Tanga to Mtwara and cover an area of 79,937 ha. Mangroves are also well represented on the coasts of the main islands, Zanzibar, Pemba, and Mafia. On Pemba, mangroves cover an area of 12,146 ha, while on Zanzibar there are 6,073 ha under mangroves (Mainoya *et al*., 1986; FBD, 1991)

Mangroves occur along the continental coast and on Zanzibar Island. The mangrove forest varies from scrub of about 2 m high to a forest 30 m high or more. The succession of mangroves starts from a bare ground, which arises on deposited mud. The first colonists, modifying the condition of the areas, which is then, invaded by the Sonnerretia and Avicennia species as pioneers. After time, the areas are occupied by Rhizophora spp and overtop the pioneer species (Mainoya *et al*., 1986; FBD, 1991).

3.3.2.2 Vegetation structure and composition

The mangrove forest varies from scrub of about 2 m high to a forest 30 m high or more (Mugasha, 1996). Six principal species of mangroves are found in Tanzania: *Sonneratia alba* Sm. (Sonneratiaceae), *Rhizophora mucronata* Lam. (Rhizophoraceae), *Ceriops tagal* (Perr.) C. B. Robinson (Rhizophoraceae), *Bruguiera gymnorrhiza* (L.) Lam. (Rhizophoraceae), *Avicennia marina* (Forsk.) Vierh. (Avicenniaceae), *Xylocarpus granatum* Koen. (Meliaceae) (McCusker, 1971). In addition, *Heritiera littoralis* Dryand (Sterculiaceae), an "associated species," has been reported from estuarine mangrove swamps in East Africa (MacNae, 1968). Other "associated species" frequently encountered in Tanzania are *Lumnitizera racemosa* Willd. (Combretaceae), *Arthrocnemum indicum* Moq., *Salicornia pachystachya* (Bunge ex Ungernsternb), *Sesuvium portulacastrum* Linn., and *Sueeda monoica* (Forsk. ex J. F. Gmel).

The composition of mangrove vegetation is influenced by a number of factors. According to MacNae (1963) the presence of sand could restrict the growth of certain species, notably *Bruguiera*, *Rhizophora*, and *Ceriops* while *Bruguiera gymnorrhiza* predominates under conditions of fresh-water influence. MacNae and Kalk (1962) also noted that *Ceriops* and *Bruguiera* seedlings develop only in the shade of other trees. Though *Rhizophora* can germinate and grow anywhere in the upper intertidal zone, it will grow to maturity only in waterlogged areas. Moreover, *Sonneratia alba* is most commonly found in loose muddy sand, and *Xylocarpus granatum* is virtually confined to sandy soils with a low humus content (McCusker, 1971).

3.3.2.3 Zonation of mangrove species

Zonation of vegetation involves grouping of plant species apparently typical of each zone or belt. Where there is mixed vegetation, usually one species dominates. Zonation in mangroves is intimately related to the duration of tidal flooding through its influence on salt levels (Mugasha, 1996). Thus basically the composition of the mangrove community in a given zone is largely a function of tolerance to salinity of the water and waterlogging characteristics of the substrate (Chapman, 1970). Due to constant deposition of mud that raises land to cause environmental changes responsible for distribution of mangroves it follows that zoning of mangrove is a dynamic or developmental phenomenon (Mugasha, 1996). However, such factors as clearing through its indirect influence on soil aeration (Lyimo *et al*., 2002), changes in amount and regime of rainfall, and changes in the pattern of sand bars at the mouth of a creek which limit the rise and fall of the tide in the mangroves can all lead to changes in the species composition of the vegetation (McCusker, 1971). FBD (1991) distinguished between nine zones of mangrove vegetation starting from the seaward side as follows:

(1) *Rhizophora* dominant, with *Avicennia*, *Ceriops*, *Sonneratia*, *Bruguiera*, *Heritiera* and/or *Xylocarpus*

Rhizophora occurs on muddy soils, the most favourable substrate for this species, and often forms extensive pure stands. On the other hand, *Bruguiera* is found as a narrow zone between *Rhizophora* and *Ceriops* zones or mixed with them.

(2) *Sonneratia*-almost pure stands

Pure stands of *Sonneratia alba* are found in areas, which are flooded daily by tides. These areas are on the seaward side of the coast and the substrate is soft, fine silt and mud. In addition, the species is a pioneer colonizer of depositional areas. Softness of the substrate and large peg roots of this species make walking across extremely difficult and so large trees characterize the zone since little or no harvesting takes place.

(3) *Sonneratia* dominant, with *Avicennia*, *Bruguiera* and/or *Rhizophora*

Sonneratia occurs together with the species shown above as you go further inland on some tidal channels that do not receive substantial fresh water inputs. It grows on depressions that are flooded daily by tides contrary to the other species that are found on slightly raised portions.

(4) *Heritiera*-almost pure stands

Herritiera littoralis is a riverine mangrove species. It grows only in habitats with low salinity hence restricted to areas in the vicinity of river mouth. These areas are only flooded by spring high tides.

(5) *Heritiera* dominant, with *Avicennia*, *Bruguiera* and/or *Rhizophora*

This forest is found upriver with freshwater influence in mangrove formations. There is heterogeneity and more than one species is present.

(6) *Avicennia* dominant, with *Rhizophora*, *Bruguiera*, *Heritiera*, *Ceriops* and/or *Xylocarpus*

Due to its ability to tolerate high ranges of salinity and varied flooding regimes *Avicennia* is the most widely distributed species occurring on the landward margin, on the seaward side and in the mid-points of the forest. It grows on compacted substrate, sand flats and/or on newly deposited sediments. Nonetheless, *Avicennia* does poorly on muddy soils that tend to be dominated by *Rhizophora* and Ceriops. When mixed with other species, it is commonly associated with *Ceriops* and *Xylocarpus*. *Xylocarpus* is most often found mixed with *Avicennia*, and it grows on raised portions where flooding takes place only for a few days, a month and where there is fresh water influence. As in the case of *Heritiera*, *Xylocarpus* is an important element of the riverine mangroves but does not form pure stands in Tanzania.

(7) *Avicennia*-almost pure stands

Avicennia occurs in pure stands on depositional sites on the seaside where the species is a pioneer colonizer and on sandy flats to the landward side where salinity fluctuations are too high to support the growth of other mangrove species. It is interesting to note that on the seaward side the species attain large sizes but on the landward margin is present only as bushes.

(8) Mixture of *Avicennia* and *Ceriops*

A mixture of *Ceriops* with *Avicennia* is found on slightly raised ground where flooding occurs only during spring tides. The substrate is usually firm during low tides. Conditions are less favourable for fast mangrove growth and hence the trees are short with yellow leaves and the stand density is often low.

(9) *Ceriops* dominant, with *Rhizophora, Avicennia* and/or *Bruguiera*

*Ceriop*s is largely found on the landward side of the *Rhizophora* zone. It becomes frequently more dominant in areas where mud is thin and on relatively higher ground than the *Rhizophor*a zone.

3.3.2.4 Climate and hydrology

The climate in mangroves areas is influenced by a hot and humid coastal climate with temperatures ranging between 25ºC and 30ºC sometimes reaching 35^{0}C (FBD, 1991). Humidity is high throughout the year, up to 90% during rainy season. It is influenced by two monsoon winds, one of which, the northeast monsoon, “kaskazi”, blows from October to March and the other, the southeast monsoon, “kusi”, from April to October. The main rainy season is from March to May, with short intermittent rains between October/November and December. Annual rainfall ranges from less than 800 mm for Lindi and Mtwara regions to 1981 mm for Mafia. The coast is washed by a northward flowing current known as the East African Coastal Current. The surface waters are warm, 25^{0}C to 27^{0}C, with only small annual variation. The water is poor in nutrients, especially nitrates and phosphates, and has a salinity of 34.5 ppt (FBD, 1991; Lyimo *et al*., 2002).

The mangrove areas of Tanzania are situated in the three most important deltas in the country, namely Wami River Delta and Ruvu River Delta in Bagamoyo District, and Rufiji River Delta in Rufiji District. These deltas extend from the central to southern Tanzania coastal area (Fig 2). The Ruvu Delta’s main catchment area is the Uluguru Mountains in Morogoro Region. The Wami has its sources in the Ukaguru Mountains and flows to the southeast across the Mkata Plains to the Indian Ocean.

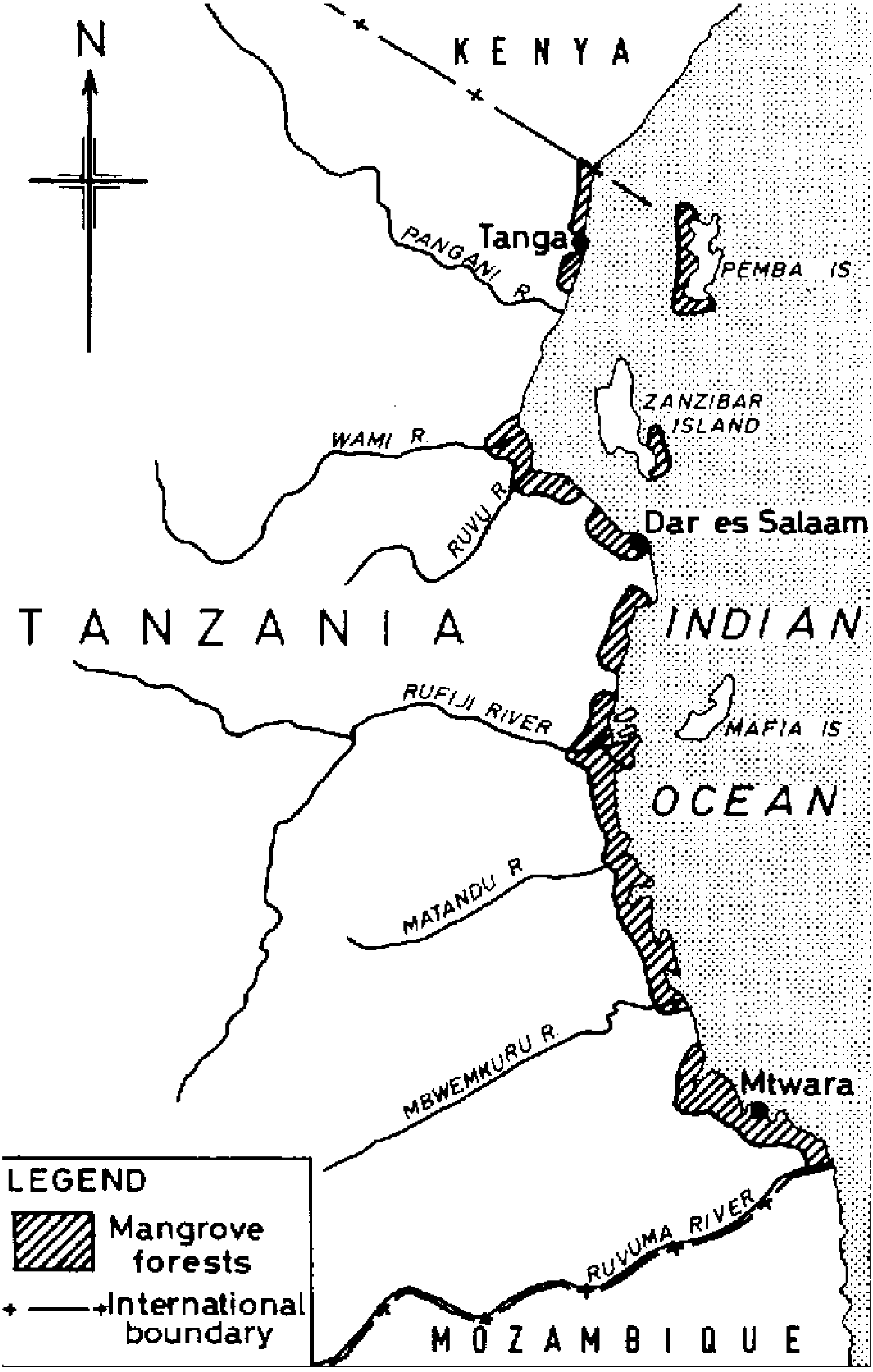

Figure 2: Mangrove forests along the coast of Tanzania

The Rufiji Delta with its nine major tributaries form the Rufiji River basin, which extends for about 177,000 km^2 and covers roughly 20% of Tanzania's area (Semesi, 1991; RUBADA, 1981). There are some 43 islands in the Delta. The entire delta area is generally flat.

3.3.2.5 Soils and nutrient cycling

The soils of the coastal areas and of the islands are predominantly sandy and caralline with poor moisture-holding capacity, extremely saline soil with a hard subsoil which results in poor drainage (FBD, 1991; Mwalyosi and Kayera, 1995). The soils have strongly reducing conditions (Thom, 1984) and higher content of sulphides and high solubility of many metals that could result in toxicity if in excess. In addition, recycling of key nutrients is low due to reduction of nutrients availability as a result of denitrification or volatilization losses of inorganic nitrogen, enhanced phosphate mobility and slow decomposition rate favoured under anaerobic conditions (Lyimo *et al*., 2002). Consequently, mangrove trees have a well developed mechanism that enables them to frequently evolve gases at the root hair region creating an oxidized rhizosphere in which sulphide and solubility of metals to toxic levels are virtually absent within the anaerobic soil environment (Lyimo *et al*., 2002). This creates a microenvironment whose biogeochemistry differs from the surrounding sediment. The mechanisms involved include, introduction of oxygen by pneumatophores as in *Sonneratia* spp and *A. marina,* use of root aerenchyma to actively bring air to roots growing in anaerobic substrate (Nickerson & Thibodeau, 1985; Scholander *et al*., 1955). This implies that cutting of mangrove trees leaves the area without roots and so could lead to less aeration of the sediment, and toxic sulphide may start to accumulate to very high concentrations, making the area inhospitable to both fauna and flora.

3.3.2.6 Phenology

Phenology describes the recurring biological events such as budding, flowering and fruiting of plants in relation to seasonal climatic changes. The importance of phenology lies in the relation of seed or propagule production to nutrient enrichment, seed selection, treatment and nursery operation. Phenology makes one understand the effects of environment on plant development. Information on phenology helps growers analyze periodicity of plant development and biological organization of communities and ecosystems, composed of animal and plant interactions. These interactions affect pollination, seed dispersal and seed predation. This kind of information serves as a tool for local and global environmental monitoring. This type of data also benefits activities involving breeding program development and genetic centers.

Despite the importance of phenology in forest conservation and rehabilitation, phenology of mangrove tree species has not been studied. Some studies on phenology have been done in European countries (e.g. Sinohin *et al*., 1996; Palis, 1998) and India (McGuinness, 1997) but these are most likely not applicable to neither Tanzania nor East Africa conditions. Thus this area requires further investigation.

3.3.3 Closed deciduous forests

These are forests found from sea level onward in areas of high water table, in riverine or in riverbanks. In Tanzania information on these forests is not well documented probably due to the small proportion in relation to other forest types. A short account of these forests has been given by Holmes (1995a) and they include ground water forest and riverine forest (Holmes, 1995a).

3.3.3.1 Ground water forests

These are forests on ground with a high water table, on which the land surface is permanently, seasonally or diurnally flooded. They occur from sea level upwards and often maintained in unfavourable climatic areas. Common species in ground water forests include *Faidherbia albida, Acacia campylacantha* and *A. robusta*

3.3.3.2 Riverine forests

Riverine forests sometimes designated as “gallery forests”, “fringing forests” or “riparian forests” are found in patches surrounding springs at their sources or along the banks of rivers, streams or lakes. In most cases they grade into swamp forest or permanent swamp if the ground becomes flooded permanently to a shallow depth. Species composition can vary greatly from place to place. Common species found in riverine include *Khaya anthotheca*, *Milicia excelsa, Tamarindus indica, Trichilia emetica, Newtonia buchananii, Rauvolfia caffra* and *Olea capensis*. Other species are *Diospyros* spp, *Parkia filicoides* and *Adina microcephala* (Holmes, 1995a).

3.3.4 Open deciduous forests

3.3.4.1 Overview

Open deciduous forests occur in the foothills, along the coast as ground-water woodlands and in the widely distributed so called Miombo woodland. Miombo forests are situated in southern Africa. They reach from little south of the equator to the Tropic of Capricorn, and extend over the continent from east to west. The total area of miombo forests is about 2.7 million km², which belongs to seven countries: Angola, Democratic Republic of the Congo (former Zaire), Malawi, Mozambique, Tanzania, Zambia and Zimbabwe (Campbell *et al*., 1996; Desanker *et al*., 1997).

In Tanzania, miombo woodlands occur extensively except in Zanzibar and are estimated to occupy 90% of total forest cover (URT, 1998). They extend from sea level up to 1 600 m, with an annual rainfall of 500 to 1200 mm and one rainy season. They occupy the central plateau in the north and the southeast, separated by a "miombo-free" corridor about 500 km long and 60 to 120 km wide. In areas with more than 1200 mm of mean annual precipitation, miombo forests grade into seasonal dry forest (Frost, 1996b). The upper altitudinal limit of miombo forests is determined by the mean minimum temperature of about -4 °C (Ernst, 1971; Desanker *et al*., 1997).

3.3.4.2 Structure and composition

Miombo forests make up a mosaic with other vegetation types correlated with drainage characteristics (Niemelä, 1988; Desanker *et al*., 1997). Cusory examination of the horizontal structure can reveal a consistent zonation with respect to drainage pattern. The well-drained ridges bear miombo woodland on their upper and middle slopes; the valley bottoms are occupied by grasslands and, in between, bushland or wooded grassland with *Combretum* and other species. Stands of borassus palm occur where there is shallow ground water (Mugasha, 1996). Green shallow valleys break the monotony of the miombo, part of extensive drainage systems locally known as "mbugas" or “dambo”. The mbugas have scattered termite mounds and characteristic tree vegetation, including muninga *(Pterocarpus angolensis*) and African blackwood (mpingo or poyi) (*Dalbergia melanoxylon*). Other trees common in the grasslands and sometimes in farming woodlands belong to the genus Acacia: *A. xanthophloea* (fever tree), *A. tortilis, A. abyssinica, A. robusta* and others. In the flood plains of the Igombe and Ugala rivers, and in other riverine communities, palm grassland occurs with borassus and, sometimes, crooked palm trees of *Hyphaene spp*. (doum palm). In the northern and central provinces of Tanzania and the central highlands, where upland forest has given way to grassland, a community is found called *Protea-Dombeya* highland grassland, with the tree species *Brachystegia microphylla, Uapaca kirkiana, Aeschynomene burtii, Erythrina abyssinica, Dombeya quinquisete* and *Cussonia arborea* (Iddi and Sjöholm, 1997). In Africa miombo forests and dambos cover together about 5 million km^2 (Anon., 1998b). On more fertile soils and/or where rainfall is lower, arid-eutrophic savannas occur (Campbell *et al*., 1996).

Miombo forests are floristically distinct: The canopy is dominated by trees belonging to the subfamily Caesalpinioideae, particularly to three closely related genera *Brachystegia*, *Julbernardia* and *Isoberlinia* (White, 1983). Other important genera include *Afzelia, Albizia, Burkea, Combretum, Dalbergia, Erythrophleum, Monotes, Ostryoderris, Pericopsis, Pterocarpus, Swartzia, Strychnos, Sterculia* and *Uapaca* (Holmes, 1995 a). Mature miombo forests typically have a 10 – 20 m tall, single-stored canopy. Most of the trees are single stemmed and are scattered and often about 12 – 15 m high sometimes reaching 20 cm but rarely form a closed canopy. Three distinct layers can be distinguished, first layer consist of canopy trees up to 14 – 20 m in height, the second layer consist of trees with height ranging from 8 – 12 m at a stocking of about 80 stems per ha (Mugasha, 1996); the third layer varies from a dense and tall (1 – 2 m) grass stand to a sparse but continuous cover of herbaceous plants. Most of the grass species are C_4-plants and perennial, and many are tussock-forming (Niemelä, 1988; Campbell *et al*., 1996).

3.3.4.3 Climate and hydrology

The miombo region lies within the subhumid tropical zone, generally within the uni-modal rainfall zone. Dry season (in winter) lasts for at least 4 months. Rainy season (in summer) brings more than 95 % of annual rainfall during 5 – 7 months time. Mean annual precipitation ranges from 700 to 1400 mm (Frost, 1996a; Desanker *et al*., 1997). Five main phenological seasons for miombo woodland can be distinguished: warm dry pre-rains season; early, mid and late rainy season; and cool dry season (Figure 3) (Chidumayo and Frost, 1996).

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
				fires occur							

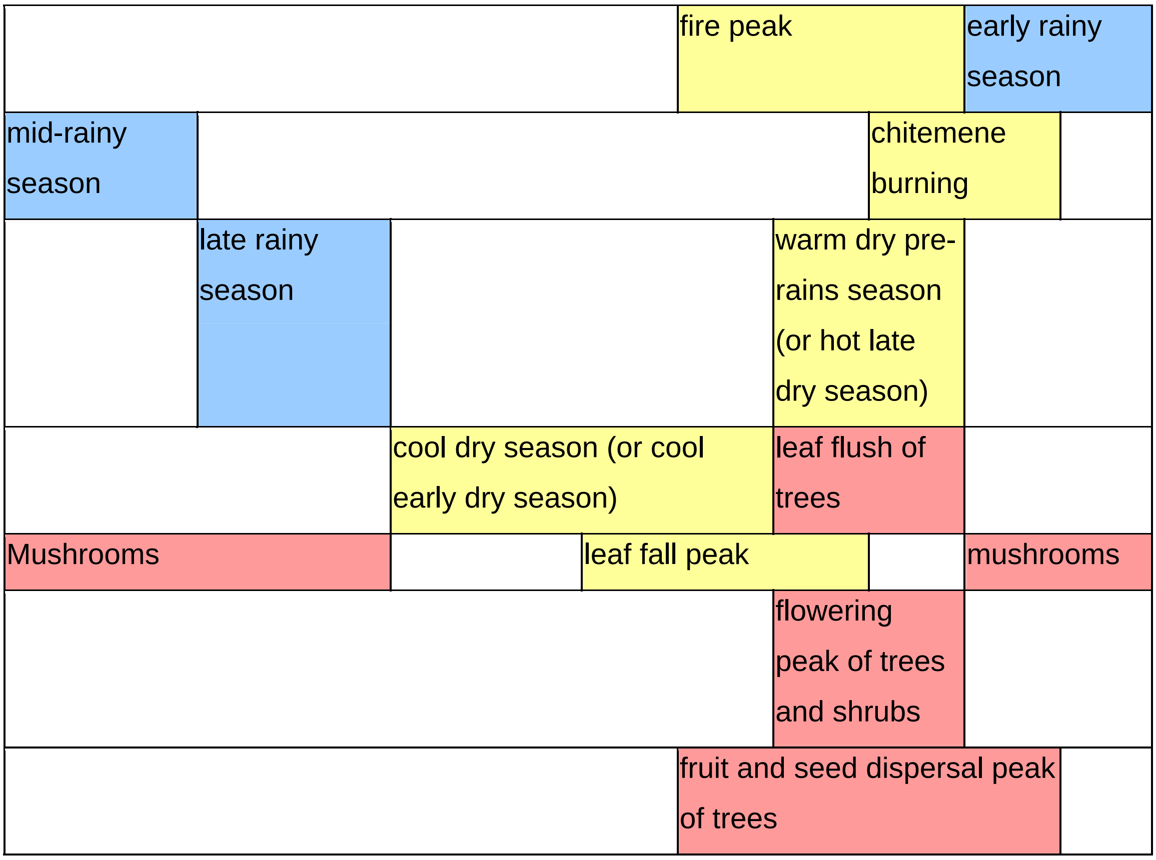

Figure 3: Generalized miombo seasons (Modified from Boaler, 1966; Astle, 1969; Malaisse, 1974; Malaisse *et al*., 1975; Guy *et al*., 1979, Chidumayo 1993, 1995, 1996; Chidumayo and Frost 1996, Clarke *et al*. 1996)

The headwaters of several major river systems lie in the miombo region (e. g. the Zambezi and the Congo/Zaire). Changes in land cover in their watersheds (or catchment areas) may affect the regional hydrology (Desanker *et al*., 1997).

3.3.4.4 Soils and nutrient cycling

Miombo soils are typically acid, have low cation exchange capacities (CEC), and are low in nitrogen, exchangeable cations and extractable phosphorus (Frost, 1996a). Organic matter levels in miombo woodland soils are generally low. This is a consequence of the abundant occurrence of termites and the frequent incidence of fire (Trapnell *et al*., 1976; Jones, 1989). Organic matter contributes substantially to cation exchange capacity in these soils (Frost, 1996a). Most miombo soils have good permeability due to microaggregation of the clays. The soils are generally freely draining (Young, 1976).

During a fire, nutrients are abruptly mineralised. Nitrogen and sulphur (and to a lesser extent phosphorus) are volatilised (Frost and Robertson, 1987). Calcium, potassium and magnesium are dispersed in very fine atmospheric particles. Some nutrients remain in the ashes on the ground. Part of the nutrients lost to the atmosphere return to the soil by gravity, or in solution as rain water (Gillon, 1983). A small fraction of the carbon burned (<1%) is converted to charcoal and soot (Andreae, 1993), which are chemically inert and contribute little, if at all, to soil properties (Frost, 1996a).

The ashes contain cations which increase the soil pH. The increased pH and heating of soil during slash fires can affect phosphorus compounds, making more phosphorus available to plants (Desanker et al., 1997). The change in soil pH usually increases populations of soil bacteria, but reduces fungi (Barbour et al. 1980). The decrease in food sources affects soil invertebrates. However, termites which are capable of storing food in their nests remain remarkably unaffected (Athias et al., 1975).

Termites are abundant in miombo forests. The biomass of termites is larger than that of other soil fauna groups (Goffinet, 1976; Malaisse, 1978). Almost all miombo areas are widely affected by termites (Jones, 1989). In some respects termites and fire have a complementary effect on carbon and nutrient cycling. If fire occurs regularly, much of the grass and litter is burned before it can be removed by termites. Regular burning releases nutrients in a single pulse, and results in more rapid cycling of nutrients. In the absence of fire, more material is available for termites to transport to their mounds. This material is protected from fires, and its nutrient contents are only slowly released (Menaut, 1983; Frost and Robertson, 1987; Frost, 1996a). Nutrients accumulate in termite mounds also when minerals concentrate from the water that evaporates within the mounds (Weir, 1973), and when termites transfer soil material from low in the profile to the surface (Montgomery and Askew, 1983).

3.3.4.5 Phenology

Miombo trees are typically deciduous and the length of leafless period varies from year to year according to site. Normally the trees become leafless during dry season and flushing of new shoot growth occurs just before the rains in September and October (Lind and Morrison, 1974). Figure 3 summarizes typical phenology of miombo tree species and the relationship between climate and/or weather conditions and phenology. However, wide variations among sites can be expected.

3.3.4.6 Fire ecology and frequency

Man-made fires are much more frequent than natural fires. Natural fires are most frequently caused by lightning (Gillon, 1983). Lightning and human activity may develop some periodicity and thus act as a directional evolutionary force (Komarek, 1967). In African savannas, intentional burning has been practised for at least 50 000 years (Clark, 1959; Rose-Innes, 1972).

The effects of fire depend on its intensity. Fire intensity depends on the amount of fuel, physical and chemical properties of the fuel, meteorological conditions, soil moisture and topography. Soil acts as an effective insulator. During a fire, soil temperatures decrease very rapidly with increasing depth. Due to this, soil organisms and subterranean parts of plants (including perennating buds of many grasses) can survive surface fires (Barbour *et al*., 1980; Gillon, 1983).

In miombo forests, dry-season fires in the understorey occur regularly and frequently (Trapnell, 1959; Kikula, 1986). At a given site, there is variation in the seasonal timing of fires and in the interval between them. The complete absence of fire is rare and probably limited to dense miombo forests with an evergreen understorey and little grass (Frost and Robertson, 1987). Chidumayo (1995) has observed a mean fire-return interval of 1.6 years. According to another source of information (R. J. Scholes, pers. comm. cited in Frost 1996a), 37% of the studied area is burnt in any one year, which equals to a regional fire-return interval of about 3 years. Fire-return intervals at any one location are likely to be more variable, depending on fuel accumulation and potential sources of ignition (Frost, 1996a).

Miombo fires are fuelled largely by grass. Fire intensity therefore depends much on the recent grass production. Fires tend to be more frequent and intense in areas where canopy cover is lower, mean annual rainfall is higher and grazing intensity is lower. Woody material contributes little to the main fire front, but may continue burning long afterwards, creating localised, deep, sterile ash beds (Frost, 1996a). Late dry-season fires are more intense and destructive than early season fires. Early season fires (and late wet season fires) are less intense, because the fuel material is still moist (Frost, 1996a). The difference in fire intensity (W m^{-1}) may be 50-fold (Robertson, 1993). If fires are prevented, litter accumulation increases the risk of accidental intensive fires. Such fires even become statistically unavoidable (Gillon, 1983).

In general, fire is more destructive to woody plants than to grasses (Barbour *et al*., 1980). The degree of damage depends also on the intensity of the fire, the size and phenological state of the plant, and the plant species (Gillon, 1983). Physiologically active plants are generally less tolerant than dormant ones (Frost and Robertson, 1987).

According to Trapnell (1959), four levels of fire tolerance can be defined: **Fire-tolerant** species are able to survive regular late dry season fires as adults, saplings and regrowth. They include some canopy trees and understorey trees and shrubs. **Semi-tolerant** species are relatively unaffected by early dry season fires but are reduced somewhat under late dry season fires. **Fire-tender** species decline under regular burning and increase under complete protection. Most of the dominant canopy species belong to this group. Mortality rates of mature trees and saplings are higher under late dry-season burning than under early dry-season burning, and the lowest mortality rates occur under complete protection. **Fire-intolerant** species can't survive fire and therefore occur only where completely protected from it. Most of these species are evergreen trees or lianes.

In Zambia, Lawton (1978) has proposed five species groups based on fire tolerance and other ecological characters: **Group 1** (the "chipya species") comprises species which can survive intense late dry-season fires but which are intolerant of shade and therefore depend on regular fires to maintain an open woody canopy. **Group 2** is made up entirely of the moderately fire-resistant *Uapaca* species which can establish in lightly wooded habitats, such as mature chipya, but cannot establish or persist in tall grassland which is subject to intense dry-season fires. When mature, these species form a low dense canopy beneath which grass production is reduced. These conditions are presumed to favour the establishment and growth to maturity of fire-tender species. **Group 3** includes most of the dominant *Brachystegia*, *Julbernardia* and *Isoberlinia* species characteristic of mature miombo woodland. Although these trees can invade the *Uapaca*-dominated communities, they cannot invade or persist under chipya. **Group 4** comprises species which are intolerant of fire. Many of these are species characteristic of the evergreen and semi-decidious forest patches found alongside wet miombo woodland. **Group 5** is made up of a suite of ubiquitous species which persist throughout. Within any one stand, however, there is considerable overlap in the occurrence of these species groups (Lawton, 1978; Robertson, 1984; Kikula, 1986; Stromgaard, 1986), so the discreteness of this group may be questionable (Frost, 1996a).

4. Regeneration ecology by forest type

4.1 Overview

In Tanzania, detailed information on the regeneration ecology by forest type is lacking because very little research has been conducted on most natural forest tree species. The major reason given for this is occurrence of numerous different tree species, different age classes, long rotation age and species heterogeneity each with different ecological requirements. This is aggravated by insufficient financial and human resources (Mugasha *et al*., 2002). Mugasha (1996) summarised information on regeneration (both natural and artificial regneration) of some few closed forests and miombo tree species. Species covered include *Ocotea usambarensins*, *Podocarpus species*, *Allanblackia stuhlmannii*, *Cephalosphaera usambarensis*, *Milicia excelsa*, *Olea capensis*, *Maesopsis eminii* and *Juniperus procera* are for closed forests; and *Pterocarpus angolensis*, *Dalbergia melanoxylon*, *Acacia nilotica*, *A. Seyal* and *A. Tortilis* for miombo tree species. However, the work on regeneration of indigenous tree species was limited to trial plots and it has never been applied on large scale. Information on regeneration ecology by forest types based mainly on literature review of similar research done elsewhere is given in the following subsections.

4.2 Closed forest and miombo woodland regeneration

4.2.1 Natural regeneration

4.2.1.1 Overview

Miombo tree species can regenerate naturally from seeds, coppices and root suckers. However, although most miombo trees can produce abundant seeds almost every year generation from seeds appears to be problematic particularly for dominant canopy trees (Mugasha, 1996). One of the typical features of dominant canopy trees in miombo woodland is limited seed-dispersal distance, often only 10-20 m (Malaisse, 1978). In addition, there is no extended seed dormancy (Chidumayo and Frost, 1996) and mortality of seedlings is high during the establishment phase (Robertson, 1984). Furthermore, most of the seedlings originating from natural seed germination do not attain maturity mainly due to destruction by fire and drought (Mugasha, 1978a) and if they do a period of 8 - 10 years has to elapse for the seedlings to reach sapling phase (Lees, 1962).

Most of natural regenerants found in miombo originate through coppice regrowth and root suckers than through seeds (Trapnell, 1959; Boaler and Sciwale, 1966; Strang, 1974; Robertson, 1984; Banda, 1988; Campbell *et al*., 1988), a phenomenon that has been accepted to be an adaptation to risks such as drought and fire and regarded as a major factor leading to a greater flexibility of the vegetation (Nyerges, 1989). Natural regeneration from root suckers may be facilitated by disturbances to the forest floor like clear felling, burning of charcoal, woodland fires, shifting cultivation, logging using heavy machinery, etc. However, successful establishment and growth of seedlings, root suckers and coppice will depend on several environmental factors including drought, moisture stress, and fires, harvesting and browsing.

Miombo tree stumps and roots produce coppice in abundance, but during the establishment period the number of shoots decreases due to inter-shoot competition. Only dominant shoots contribute to the next generation. Depending on species, four to five years are required for the emergence of one or two dominant shoots (Chidumayo, 1988; Chidumayo and Frost, 1996). Miombo forests are remarkably resilient to cutting, due to the effective vegetative reproduction and large numbers of existing suppressed seedlings. Miombo forests have capacity to sustain regrowth, even when regrowth is regularly consumed (Chidumayo and Frost, 1996).

It is worth noting that both fire and browsing have beneficial and adverse influences on enhancement of natural regeneration. For example, fire is essential for germination of some seeds such as *Pterocarpus angolensis* but this depends very much on intensity of fire as related to the period of burning. Early burning done in the beginning of the dry season is less detrimental as opposed to late fires burned during the late dry season that may kill many young seedlings (Chidumayo and Frost, 1996). Similarly, browsing is an important agent of seed dispersal and considered to increase the germination rate of several seeds, but also removes seedlings (Kessler and Breman, 1993). Thus these factors must be taken into consideration when fire and browse animals are to be used as management tools for enhancement of natural regeneration in miombo woodlands.

With the case of suckers and coppice, fire can either slow or accelerate growth. If a destructive fire occurs before dominant shoots attain a safe height to escape mortality, the process of sucker shoot domination reverts to the initial stage and stumps respond by producing an equal or large number of replacement shoots (Chidumayo, 1988). However, resistance to these environmental factors varies with species.

4.2.1.2 Development and growth of regenerants in miombo woodlands

This has been documented for miombo tree species while information is scarce for closed forests species. In addition, the little information available is based on experiences from Zambia since studies of that kind have not been done in Tanzania. The naturally regenerated seedlings of most miombo woodland tree species such as *Pterocarpus angolensis* experience a prolonged period (7-20 years) of successive shoots dieback during their development phase in order to cater for moisture and heat stress. Shoot dieback is caused by water stress and/or fire during the dry season. When the shoot die back occurs during the dry season, seedlings continue to develop a strong deep root system during rainy seasons, which enable them to produce fast growing stems capable of surviving drought later. Even in the absence of stem dieback, seedlings continue to develop strong deep root systems at the expense of stem development leading to slow stem growth (Chidumayo and Frost, 1996).

In Tanzania *P. angolensis* is reported to have mean annual diameter increment ranging from 0.6 to 1.0 cm in poor sites and 1.4 cm at 10.7 years in good sites respectively. In good site the height increment of 0.8 m at 10.7 years has been reported (Brayant, 1969). Elsewhere a mean stem height growth in regrowth dry miombo woodland of 4 – 5 m at the ages between 15 and 18 years has been reported (Robertson, 1984; Chidumayo, 1993b; Grundy, 1995).

4.2.2 State of knowledge

In Tanzania, natural regeneration requirements for some miombo tree species including *Pterocarpus angolensis*, *Dalbergia melanoxylon*, *Acacia nilotica*, *A. seya*l and *A. tortilis* has been documented. Similarly, information on some closed forest species such as *Podocarpus latifolius*, *Allanblackia stuhlmannii*, *Cephalosphaera usambarensis*, *Milicia excelsa*, *Olea capensis*, *Maesopsis eminii* and *Juniperous procera* is documented (Mugasha, 1996).

However, some of the information compiled is based on experiences from elsewhere necessitating testing of the techniques under specific site conditions.

4.2.3 Status of implementation

Enhancement of natural regeneration has not received much attention in Tanzania. In central Tanzania overgrazing was found to depress natural regeneration of miombo woodland as to culminate in severe woodland degradation and desertification coupled with soil erosion. Complete de-stocking of livestock and complete protection of overgrazed woodland resulted in rapid regeneration of miombo woodland tree species (Mugasha and Nshubemuki, 1989). However, this technique has not been applied in any other areas with similar situation. It s worth noting that efforts to regenerate closed forests species have not received much attention (Mugasha, 1978a; Nsolomo and Venn, 1998).

4.2.4 Artificial regeneration

4.2.4.1 Background

Like many other developing countries, forests and woodlands of Tanzania have been subjected to selective overexploitation of most valuable tree species such *Dalbergia melanoxylon*, *P. angolensis* and *Pericopsis angolensis* (Malimbwi and Mugasha, 2001), and *Podocarpus* species and *Ocotea usambarensis* (Nsolomo and Venn, 1998) resulting in scarcity of these species and so forest degradation (WRI *et al*., 1994). This has resulted in decreased value of the forests and woodlands to the society. Thus there is an urgent need to restore these forests and woodlands in order to increase their utility to the society. As noted earlier artificial regeneration appears to be appropriate for restoration of selectively harvested (degraded) forests and woodlands.

Proponents of natural regeneration assert that artificial regeneration is more expensive than natural regeneration (Piearce, 1993). However, there is enough evidence to demonstrate the fact that artificial regeneration is more effective in regenerating selectively overexploited tree species than natural method (Adegbehin *et al*., 1991), a situation that exists in Tanzanian forests and woodlands. In addition, experience from East Usambara and Kilimanjaro (areas with closed forests) in Tanzania for natural regeneration of *Ocotea Usambarensis* (Mugasha, 1978a; Nsolomo and Venn, 1998), again tend to favour artificial regeneration over natural regeneration for restocking of the selectively overexploited species.

4.2.4.2 Status of implementation

In Tanzania, artificial regeneration is only applied for establishment of forest plantations of exotics (FBD, 1982) while for indigenous tree species it has been applied for only few species in trial plots and is yet to be applied for large scale planting of indigenous tree plantations (Mugasha, 1996). On the other hand, natural regeneration has been applied in trial plots in natural closed forests and miombo woodland stands.

5. Forest dynamics and succession

5.1 Background

Vegetation succession refers to ecosystem development and may start from bare ground or very simple system: succession is manifested through a series of communities that succeed one another until the final or climax community is attained. The various stages in succession are known as sere stages. Thus succession can be prisere if it commences on a bare ground such as sand dunes. On the other hand, succession that commences on a disturbed area such as a forest destroyed by burning or cultivation is known as subsere. During the normal course of succession, the early stages can be regarded as far removed from equilibrium with the environment or habitat, successive communities becoming more and more in harmony with it, so that when the climax state is attained the final community is in equilibrium with the habitat. In the course of succession, each successive community adds to what may be called the habitat potential, or the degree to which the habitat is increasingly capable of accepting a new and perhaps wider range of plant species (Chapman, 1976).

At present prisere is rare to find while subsere is common. Subsere emanates from ecosystems disturbances caused by various anthropogenic and ecological factors including climate, topography, soil fertility, fires, grazing/browsing by wildlife and livestock, shifting cultivation and burning. The most common disturbance agents in Tanzania are wild fires and clearing for cultivation including shifting cultivation and wood harvesting. From a disturbed ecosystem or subsere a series of community is observed to succeed one another until the final or climax community is attained.

5.2 Succession in miombo woodland

Disturbances in miombo woodlands can have marked effects on the composition and structure of the woodland, but from which the woodland may recover over a few to many years afterwards (Walker, 1981). Very few systematic observations have been made on natural vegetation succession in miombo woodland (Trapnell, 1959; Boaler and Sciwale, 1966; Lawton, 1978; Stromgaard, 1986) and none in Tanzania. Thus our knowledge on vegetation succession in miombo woodland is mainly based on experiences from Zambia (Mugasha, 1996). For example, if typical undisturbed Miombo woodland is subjected to severe annual late fires or shifting cultivation, the area will develop into grass vegetation. If fires will be abandoned, the woodland species will invade the areas and develop into woodland or wooded savannah. *Uapaca* species will invade the areas and inhibit fire penetration. Then the areas will be invaded by the *Brachystegia* and *Julbernardia* species, which will develop into typical Miombo woodland. If no more fire and cultivation, the areas will be developed into dry evergreen forest (Mugasha, 1996)

As noted earlier dynamics of miombo woodlands are of subsere nature. The major driving force being fire coupled with clearing for agriculture. Succession phenomenon in miombo woodland has been viewed differently by different authors and the concept has been refined over time. In the past the dynamics of miombo forests were based largely on a single-state equilibrium model of a regional climax vegetation. Thus miombo forests were considered sub-climax to evergreen or semi-evergreen forest, maintained as such by frequent fires and other disturbance (Freson *et al*., 1974; Strang, 1974; Lawton, 1978). Of recent are multi-state models, which asserts multiple quasi-stable states in miombo vegetation structure and composition. It is generally agreed that repeated disturbances can degrade closed-canopy miombo forests to open woodland and secondary grasslands, but the process is reversible if fire is excluded and other disturbances are minimised (Freson *et al*., 1974; Lawton, 1978; Stromgaard, 1988). Based on these three directions with regard to miombo dynamics and succession have been proposed: a) changes that lead to development of mature miombo forests, b) changes occuring in cleared or severely burnt miombo forest, and c) changes occuring in abandoned miombo-derived field.

5.2.1 Changes leading to mature miombo forest

Protection against fire greatly modifies the structure of the forest. The herbaceous stratum disappears gradually as the canopy closes and a woody understorey develops, resulting in a dense dry forest. The canopy may remain unaltered for twenty years, and it may take almost thirty years for the miombo dominants to die and their saplings to be suppressed by the evergreen thicket (Schmitz, 1950; Trapnell, 1959; White, 1968).

Woody plants are favoured by early burning and long intervals between fires (Trapnell, 1959; Frost, 1996a). Late fires are much more harmful. Stem mortality under late burning may be remarkably higher than under early burning (Chidumayo, 1989). Late fires may reduce the canopy into coppice. Decline in woody plant cover results in increases in grass production which, in the absence of compensating herbivory, provides more potential fuel for fire. Higher fuel loads in turn mean more intense fires. The process leads eventually to chipya secondary woodland. In this stage, only fire-resistant woody species survive (Menaut, 1983; Frost, 1996a). Chipya may revert to miombo, if the fire regime changes in favour of miombo trees (Niemelä, 1988).

Frequent late dry-season fires eventually transform woodland into open, tall grass savanna with only isolated, fire-tolerant canopy trees and scattered understorey trees and shrubs (Trapnell, 1959).

5.2.2 Changes occuring in cleared or severely burnt miombo forest

Miombo forests regrow virtually unchanged following clearing, if the growth remains uninterrupted (Fanshawe, 1971). This is because regeneration consists of stump/root sucker shoots and recruitment from old stunted seedlings already present in the field layer at the time of cutting (Grundy, 1990). Species which are dominant at the time of felling miombo woodland are likely to dominate regrowth (Trapnell, 1959). Fire tolerance determine the species that first colonize the area after the grass period. Thus in wooded savana or open woodlands known as **Chipaya** in Zambia created by clearing, and/or severe burning primary species are fire torelant species such as *Pterocarpus angolensis*, *Syzygium guineense*, *Pericorpsis angolensis*, *Hymenocardia acida*, *Diplorhynchus condylocarpon* and *Vitex doniana* (Mugasha, 1996). Gradual canopy closure suppresses grass production and allows fire-sensitive species to establish as the fire fails to penetrate (Frost, 1996a). This in turn gives room for the shade torelant and more fire-sensitive species such as *Brachystegia* species, *Julbernadia* species and *Marquesia macroura* to establish and become dominant in a few years (Celander, 1982).

5.2.3 Changes occuring in abandoned miombo-derived field

The vegetation on a field after abandonment is relatively open, with much grass. Grasses are most dominant in areas cultivated intensively or cleared mechanically. The dominant trend in regenerating miombo woodland in absence of frequent late fires or other intense disturbance is towards the recovery of miombo forest. Unless the plants have been thoroughly uprooted (e. g. ploughing may affect stump survival), most of the subsequent development of woodland derives from regrowth of coppice from the remaining stems and rootstocks (Strang, 1974; Chidumayo *et al*., 1996; Frost 1996a).

Four phases can be identified in regenerating woodland: 1) initial regrowth, 2) dense coppice, 3) tall sapling phase, and 4) mature woodland. Most woody plants in the initial regrowth phase are less than 1 m tall. Regular late dry-season fires can suppress recovery, restricting the vegetation to this phase. Protection from fire or early dry-season fires enable a dense coppice phase to emerge. The coppice tends to suppress grass growth, though not to the point where a fire cannot be supported. A change in fire regime at this stage to one of predominantly late dry-season fires may return the vegetation to the open initial phase (Trapnell, 1959; Robertson, 1984).

If the originally dominating caesalpinioid trees have been eradicated, recovery to the original species composition is unlikely, or at least very slow. It is not easy to eradicate the trees, however (Frost, 1996a). The slow reinvasion by miombo trees may promote establishment of woody weeds. *Lantana camara* is already a widespread invasive weed in Zambia (Lawton, 1982) and in the wetter parts of Zimbabwe (Chidumayo and Frost, 1996).

Farms which are near savanna will almost certainly be invaded by savanna grasses, for these have efficient means of dispersal. Once cultivation ceases these may become established. Savanna grasses are tolerant of burning, whereas forest plants are not. Thus, the area will change into a grassland (Hopkins, 1983).

5.3 Succession in mangrove forests

In mangrove both prisere succession, starting on the bare ground following mud deposition, and subsere succession following clearing of mangrove due to various forms of disturbances such as uncontrolled harvesting of trees and clearing for agriculture can occur.

Bare land that is created through the action of erosion and deposition is first invaded by colonialists, normally shade intolerant. Typical shade intorelant mangroves and so first colonists capable of colonizing bare lands include *Sonneratia* species and *Avicennia* species. *Rhizophora* species also need full sunlight to develop, but its propagules can survive shade as domant seedlings ready to grow as canopy opens up. Thus *Sonneratia* species and *Avicennia* species are the first colonists of the bare land whereas *Rhizophora* species is the first species to appear in the cleared mangrove (Mugasha, 1996).

Prisere stage in mangrove ecosystems is controlled by a number of factors including proximity of potential seed parents and method of seed dispersal (wind, water, animals, etc.). In addition, survival of the first colonists is a function of ability of the seed to germinate that is dependent on suitable substrate conditions such as temperature, moisture and absence of predators. On the other hand, successful growth of new germinants is determined and controlled by factors of the environment or habitat. For example, *Rhizophora* can germinate and grow anywhere in the upper intertidal zone but it will grow to maturity only in waterlogged areas. Moreover, *Sonneratia alba* is most commonly found in loose muddy sand, and *Xylocarpus granatum* is virtually confined to sandy soils with a low humus content (McCusker, 1971). Rhizophora species and *Sonneratia* species have modified root systems known as stilt roots and pneumatophore. The modified root systems enable the two species to survive in anaerobic conditions due to their ability to introduce oxygen from outside (Lyimo *et al*., 2002). Likewise *A. germinans* is capable of bringing air to roots growing in anaerobic substrate through its root aerenchyma (Nickerson and Thibodeau, 1985; Scholander *et al*., 1955). Thus it has been observed that the usual pioneer species in sandy habitats is *Avicennia marina*, and in muddy areas *Sonneratia alba* (McCusker, 1971).

Once a bare land is colonized by the first colonists changes in habitat conditions occur thereby favouring invasion by other species notably shade torelant, until when the climax community is reached and ultimately dominance of the principal life-form (Mugasha, 1996). It is interesting to note that in mangrove ecosystems often there is deposition in some parts while at the same time erosion occurs in other parts. The same thing occurs inside the forest due to action of meandering channels that deposit sediments on one bank and simultaneously erode the opposite side. In such cases successsion may go in circles with pionners following “later” stages (FAO, 1982b).

6. Forest wood production and wood products

6.1 Forest biomass and standing volume

Combined biomass and volumes for all types of forests and woodlands is given in Table 4.

Table 4: Current biomass and standing volume for all types of forests in Tanzania

Item	Quantity
Volume by area (m^3/ha)	43
Volume total (Million m^3)	1,676
Biomass by area (ton/ha)	60
Biomass total (Million ton)	**2,333**

FAO, 2001

6.2 Wood-based industries

6.2.1 Overview

In Tanzania, the target of wood-based industry and products is to increase employment and foreign exchange earnings through sustainable forest-based industrial development and trade (MNRT, 1998). The growth of the wood-based industry in Tanzania is influenced by many factors, which include the type and distribution of indigenous forest resources, small domestic demands of some forest products concentrated in some cities and transportation systems. These factors have led to the presence of many small industrial units concentrated in few regions. Nevertheless, forest based industries in Tanzania notwithstanding smallness of unit sizes, form an important part of the industrial sector in Tanzania (Ngaga, 1998).

According to MNRT (2001b) key problems faced by the mechanical and chemical wood industry is lack of information on the raw material availability. The existing plants are also far from the forest resources and there are serious problems with transportation. In addition, plantations are in most cases under-utilized in relation to allowable cuts, while there is diminishing supply of raw material from indigenous forests. There are also increasing concerns on how logging is affecting the environment in terms of biodiversity, water and soil conservation, among others. Processing is hampered by poor performance and inefficiency of the plants and poor quality of raw materials. The timber processing industries fall under two ownerships i.e. a) The parastatal owned industries and b) private owned industries. The parasitatal owned industries are now being privatised.

6.2.1.1 Parastatal owned wood-based industries

In Tanzania, the target of forest-based industry and products is to increase employment and foreign exchange earnings through sustainable forest-based industrial development and trade (MNRT 1998). According to MNRT (2001b) key problems faced by the mechanical and chemical wood industry is lack of information on the raw material availability. The existing plants are also far from the forest resources and there are serious problems with transportation. In addition, plantations are in most cases under-utilized in relation to allowable cut, while there is diminishing supply of raw material from indigenous forests. There are also increasing concerns on how logging is affecting the environment in terms of biodiversity, water and soil conservation, among others. Processing is hampered by poor performance and inefficiency of the plants and poor quality of raw materials.

6.2.1.1 Private owned wood-based industries

The private forestry industries sector in Tanzania is relatively small and is limited to small scale saw milling, secondary wood processing mills such as furniture and joinery, doors and windows manufacturing (MNRT, 2001b). The production capacities of these factories vary according to the types of equipment employed. MNRT (2001b) estimated their production capacities are in the range of about 800 m^3 per annum to 10,000 m^3 per annum of round wood. The majority of the mills operated by the private companies features very old and simple machines and equipment, which although are in operative condition, have problems of maintenance and spare parts (Mbonde, 1993).

Some private companies and individuals have recently introduced and acquired modern technology i.e. mobile sawmills and wood working machines, which have been imported or locally fabricated. However, their rate of utilization is relatively low due to; improper lay out plans, limited skills of operators, limited managerial skills and personnel to run the enterprises effectively, lack of logging equipment and machinery, lack of seasoning systems or drying kilns including proper timber storage facilities, insufficient saw doctoring and maintenance facilities, and limited access to financial institutions for acquisition of financial support for local investments and foreign currency for increased investments and procurements of essential spares, equipment, and production inputs (Mbonde, 1993). However, the new Forest Policy (MNRT, 1998) and new Forest Law (Forest Act, 2002) give more opportunities to the private sector to play key roles in the national economy, not only in the development of this sector but also to buy shares in the public industries including the public forestry industries.

6.2.2 Status of wood-based industries

6.2.2.1 Sawmilling

Sawmilling is the earliest wood-based mechanical industry to be introduced in Tanzania and dominates the industry and accounts for between 50 and 90% of the wood production in most countries of the Southern Africa (Mwaura and Kamau, 1991). In Tanzania, Jaako Poyry (1992) reported about 130 sawmills in the country, in 1992. In addition to saw milling, pit sawing which is often organized on private basis by individuals or joint groups, is significant in Tanzania, particularly in areas having natural forests, and account for about 40% of the country’s sawn wood production. Also, because of the low capital costs the employment and profitability of pit sawing are higher compared to ordinary mills (Skage and Naess, 1994) although productivity is generally low due to low lumber recovery rate and huge wood wastes.

Initially, all of the sawmills were based on logs from natural forests and, because of the local nature of their markets and the lack of investment capital, most were small and often fitted with reconditioned machinery and equipment (Mwaura and Kamau, 1991). In Southern Africa, the type of equipment used in sawmilling today varies widely from simple roller benches, producing a few hundred cubic metres per annum, to very large, integrated mills with annual capacities in the order of 30 000 m^3.

In Tanzania, based on the installed capacity, the total wood processing capacity in 1992 was estimated at 900,000 m^3 of round wood per year, compared to 710,000 m^3 per year in 1988. Indigenous hardwood from natural forests accounts for about 300,000 m^3 of round wood per year, whereas plantation forests contribute about 600,00m^3 of roundwood per year (Sharma 1992 in Ngaga 1998). Mwaura and Kamau (1991) estimated the total number of sawmills at 130 mills while Ishengoma (2003) reported 242 small-scale mills operating in plantations alone indicating the growing nature of this sector. Regardless of size, most of the sawmills in operation produce sawn timber of low quality. Reasons for this include: lack of management skills; shortages of skilled labour; poor maintenance of equipment; shortages of hard currency for procuring spares parts; and the inaccessibility of markets for high-quality products. In addition, small-scale mills tend to offer sawnwood at low prices, therefore decreasing incentives for the larger, more modern mills to produce higher-quality products as these would require higher pricing.

6.2.2.2 Wood-based panel industries

Wood based panel products consumed in Tanzania are veneer and plywood, hardboards, chipboards and to a very small extent blackboards (MNRT, 2001b).

(i) Veneer and plywood

There are two veneer and plywood industries in Tanzania, one is in Tanga region and the other in Kilimanjaro region. The present annual production rate is below 300 m^3 per year (MLNRT, 1989 in Ngaga, 1998).

(ii) Hardboards

Hardboards in the country are produced by Fiberboard Africa Ltd, located in Arusha region. The estimated annual capacity is 9,000 m^3 but production has been 52% of the annual mill capacity, and has continued to decline.

(iii) Chipboard

Chipboards are produced by Tembo Chipboards Ltd., located in Tanga region, formerly owned by Tanzania Wood Industry Corporation (TWICO), a government parastatal but recently sold to a private entrepreneur. The mill performance has been declining and the utilization capacity in 1992, 1993, 1994, and 1995 were 34%, 39%, 24% and 10%, respectively.

6.2.2.3 Pulp and paper industry

There are three major mills producing pulp and paper in the country namely; Kibo Paper Industry Ltd., Kibo Pulp and Paper Mills and Southern Paper Mills Co Ltd. (SPM). The total production capacity is 75,000 t/year, and the manufacturing capacity is 78,000 t/year (MLNRT, 1989b cited in Ngaga, 1998).

The Kibo Paper Industry Ltd is located in Dar es Salaam and the annual capacity is 7,500 m^3 per year at operating capacity of 30% (MLNRT, 1989b cited in Ngaga, 1998).

The Kibo Pulp and Paper Mills, a private enterprise, is located in Moshi. The capacity utilization was by 1994 below 70%, due to inadequate raw material availability (MLNRT, 1989b in Ngaga, 1998).

The Southern Paper Mill Ltd. (SPM), located in Iringa region, is owned by a parastatal organization, the National Development Corporation (NDC), and has also been put for share sales. The mill is the biggest wood industry in the country, if it could reach its full capacity utilization, it was supposed to produce 60,000 tons per year of various paper grades, using 298,000 m^3 of pulpwood per year.

6.3 Wood consumption

The consumption of sawlogs based on the data presented by the Minister for Natural Resources and Tourism in her Budget Speech of 1999 are presented as Annex 1a while that of wood fuel consumption is based on the data from MNRT (2001a) and presented as Annex 1b.

6.4 Wood consumption by species

Data is not available for wood consumption by species. In plantations, mostly pines and cypress species are planted and therefore most consumed by individual and industrial sectors. In natural forests, very few well-known species are presently being harvested, processed and utilized. Preferred species include *Dalbergia melanoxylon, Sawartzia madagascariensis* and *Pterocarpus angolensis*. Selective utilization of these species is threatening their continued availability. Currently there is a research project in the Department of Wood Utilization of the Faculty of Forestry and Nature Conservation at Sokoine University of Agriculture to investigate wood properties of lesser-known tree species in order to widen potential tree species for various wood end uses.

6.5 Charcoal as woodfuel

The most important use of wood in Tanzania is for fuel and about 95% of the country's energy supply is met by fuelwood (Iddi & Hakan, 1997). Miombo woodlands which constitute about 90% of the total area of forests in Tanzania are the chief source for firewood and charcoal in Tanzania. Woodland trees produce a heavier and more concentrated fuel than most fast growing softwood species and trees from tropical rain forests (Gauslaa, 1988).

There is high fuelwood consumption in Tanzania attributed by low per capita income and limited investment in alternative energy supplies. Households consume about 97% of wood energy in SADC region mostly for cooking, heating and cottage industries while industrial sector is the second to household sector (SADC Energy Sector, 1993). Most of the industrial wood energy is consumed by small-scale industries which include food processing industries and service sectors such as brewing, fish smoking, salt production, baking, restaurants, schools, hospitals and food vending; agro-processing industries such as tobacco curing, tea drying and beeswax processing; and production of building materials such as burnt bricks, lime, smiths, foundries, pottery and ceramics. These industries and domestic activities which rely upon wood energy provide employment and income for rural people particularly during off-season in agricultural production (Monela and Kihiyo, 1999).

The Tanzania energy policy of 1997 still stress development and use of indigenous energy sources such as bio-energy, coal, natural gas and hydropower (URT, 1997). However, less than 2% of energy development budget is allocated to wood energy programs, and fuelwood is still regarded as minor forest product with little market value (TFAP, 1989). Yet, the vast majority of woodfuel consumers cannot afford the high investment costs associated with alternative commercial energy sources (Moyo *et al.,* 1993). Availability, reliability of supply and cheaper prices renders fuelwood more preferable than alternative sources of energy.

Luoga *at al.,* (2000) reported that the initial cost for charcoal production is US $ 20.5 which is equivalent to Tshs 20,500. These costs are mainly for purchasing tools and equipment for the beginners who want to engage in charcoal production. Labour and raw materials are free since the household members are engaged themselves in the production. The average charcoal production per household per month has been reported to be 43 bags (Luoga *at al.,* 2000; Zahabu, 2001). The royalty fees per bag is 800 and 400 Tanzania shillings for central government and local government respectively. Men mostly do charcoal production because it is a muscular work (Zahabu, 2001). However, women can be involved in storage and delivery to customers.

Looking at the present economic forces, the majority of urban population in Tanzania will continue to depend on fuelwood for long time to come (URT 1998; Moyo *et al* 1993). Annexes 1b and 1c show household wood fuel consumption for rural and urban areas respectively. Overall firewood and charcoal household consumption have been estimated at 400 and 100 tons respectively. The corresponding values for urban areas range from 0.12 to 0.5 and 0.08 to 0.12 tons. This shows clearly that wood fuel consumption in urban areas is much lower compared to rural areas. This can be attributed to availability of alternative fuels such as kerosene and electricity and the fact that most people can afford to use it in the urban areas. Due to the anticipated steady increase in population (at an annual rate of increase of 2.8%) it is expected that actual consumption of firewood and charcoal will continue to rise to a greater extent. This will put strains on natural forests from where the wood fuel is obtained, possibly resulting in deforestation of the forest ecosystems.

Commercial fuelwood extraction such as charcoal production requires large volume of wood, which in turn depletes tree stocks causing deforestation. According to the 1990 FAO Forest Resources Assessment, deforestation is defined as a change of land use with the depletion of tree crown cover to less than 10 percent (Adger and Brown, 1994). Little is known about the actual extent of deforestation due to urban charcoal use.

6.6 Sawn wood from natural forest

Normally, FBD sell raw materials as logs or poles to the customers and the royalty of the timber tree species are charged according to species classification as listed in Table 5a. Due to conservation and development aspects the Government charges taxes and royalties to harvested logs per m^3 between US$ 5-90 depending on the types of wood. Hardwood is normally charged highly. Confiscated timber is sold at Government price as set per species class.

Table 5a: Species classification in relation to royalty charges in Tanzania

Species class	I A	I B	I I A	I I B	III	IV	V
Royalty (TShs)	60,000	25,000	20,000	15,000	10,000	5,000	3,000

Source: Government Notice no. 462 (1996)

6.7 Sawn wood from plantations

Plantation species are sold in diameter classes as classified in species group, either softwood or hardwood. In plantation softwood, *Juniperus procera* is grouped in I, all pines and cypress species are grouped in group II, *Araucaria* species are grouped in group III and the rest softwoods are group in group IV. Royalty for these species is set according to diameter classes as shown in Table 5b.

Table 5b: Prices for plantation softwoods in class IV in relation to diameter classes in Tanzania

Dbh	11 - 20	21 - 25	26 - 30	31 – 35	36 and above
Royalty (TShs)	1,500	2,000	2,600	3,200	4,000

Source: Government Notice no. 462 (1996)

Plantation hardwoods are group in three groups and are sold in diameter classes (Table 5c). *Tectona grandis* and *Cimommum camphora* are grouped in group I, *Terminalia, Grevillea* and *Cedrela* species are grouped in group II and all *Eucalyptus and Senna siamea* are grouped in group III. Diameter less than 10 cm for all groups is sold as poles.

Table 5c: Royalty for plantation hardwoods in relation to class group and diameter classes in Tanzania

Diameter class	Royalty (TShs)		
	Group I	Group II	Group III
10 - 20	5,000	3,000	2,000
21 - 30	10,000	5,000	2,500
31 - 35	15,000	8,000	3,500
36 and above	25,000	10,000	4,000

Source: Government Notice no. 462 (1996)

6.8 Wood quality aspect

In Tanzania, timber grading in the domestic market has not been taken seriously due to scarcity of timber (Holmes, 1995b). However, in the export market timber grading is a compulsory practice that has to be exercised on each parcel of timber going out of the country (Forest Act, 2002). Grading and standardization of timber is done for the following reasons (Holmes, 1995b; Forest Act, 2002):

- (i) To establish prices in accordance with the quality group
- (ii) To facilitate sale of timber in external markets without difficulty
- (iii) To group timber of similar quality together
- (iv) To establish better use of timber and wood products

In Tanzania, both hardwood and softwood timber to be exported with the exception of *Dalbegia melanoxylon* is graded according to the rules stipulated in the Forest Act (2002). Grading of hardwood timber species is stipulated under Part IV clause 60 and 61 of the Forest Act (2002). The hardwood timber is graded and classified as boards, planks, strips, shorts or scantling and the grading is done on the worse face. The softwood timbers is graded according to either strength or appearance. There are six strength grades and five appearance grades, which are used in grading softwood timber.

6.9 Other forest services

6.9.1 Water protection

About 1.6 million ha of the forests in Tanzania have been gazetted as catcment forests. These forests play a key role in maintaining the stable supply of clean water to human beings both in rural and urban areas. The large biomass of plant materials present in varied strata of forest acts as a reservoir in intercepting the rainfall and reduce surface runoff.

6.9.2 Carbon mitigation

Forests play a key role in mitigating Carbon dioxide. Rural forests sequester about twice as much Co_2 as urban forests per unit land area. In the rural forest ecosystem, approximately 63% of stored carbon is in the soil, 27% is tree biomass (Gregory and James, 1999}. Tanzania has vast areas of closed forests and woodlands, which cover about 50% of the total land area, since most of them are situated in rural areas, Co_2 mitigation is expected to be higher.

6.9.3 Erosion control

About 13 million ha of forests in Tanzania are gazetted as forest reserves. These forests are managed in sustainable basis for productive and protective functions. The protective functions of these forests are, soil and water conservation, soil erosion control and conservation. However due to deforestation and degradation, the capacity of the forests to provide these services is threatened.

7. Natural forest management in CDF types

7.1 Forest inventories

Most of the forest inventory done in Tanzania are ground based inventory, sometimes supplemented by aerial photographs in case the area is required to be stratified and mapped. Remote sensing and Geographic Information System technology are rarely (if ever) applied in Tanzania due to inadequate financial and human resources.

Ground based inventories use systematic random sampling with or without stratification. Stratification is mostly applied in natural forests due to heterogeneity and less common in plantations due homogeneity. Stratification is done based on topography, vegetation types, management regimes, etc. In either case, transects are laid out and plots allocated along transects at a constant interval depending on the sampling intensity desired with the starting point selected at random. Common ground based inventory methods applied in East Africa are summarized as Annex 3.

7.2 Forest management planning

All forest plantations in Tanzania are managed according to the directives stipulated in the management plan. The management plan stipulates the management objectives of such forest, silvicultural operations and the marketing of the forest products. The purpose of the management plan is to manage the forest assets in sustainable basis. In order to achieve the sustainable management of the forest, management planning must be done. Normally management planning is done every five years. The new national forest policy also encourages the sustainable management of natural forests by preparing management plans of each natural forest.

7.2.1 Annual allowable cut

The allowable cut in plantation is stipulated in each plantation's management plans, but the total allowable cut is estimated to be 3.2 million m^3 and in natural forest is estimated to be 35.2 million m^3 (TFAP, 1993).

7.2.2 Rotation length of major timber species

Information on the rotation length of the majority of indigenous timber tree species is lacking, as research in this aspect has not been done. In plantation forests, the rotation period for most timber species ranged between 25 – 35 years. Since the rotational length for most natural forest timber species are not known, the FBD recommends the harvestable diameter for most of the indigenous timber tree species. The recommended harvestable diameter is then published in the Government gazette as Notice. The last recommended harvestable diameter was published on 12//12/1996, Government Notice No.462 (Table 6).

Table 6: Recommended harvestable tree diameter for some indigenous tree species of Tanzania

Species	Rotation age (years)[1]	Harvestable diameter (cm)[2]
Khaya anthotheca		55
Milicia excelsa		55
Antiaris usambarensis		55
Morus hactea		55
Bombax rhodognaphalon		55
Afzelia quanzensis		55
Ocotea usambarensis	70 – 75	55
Beilschimediakweo		55
Podocarpus all spp		60
Olea capensis		50
Pterocarpus angolensis		45
Pterocarpus stolzii		45
Vitex all spp		45
Erythrophloem guinence		45
Terminalia all spp		45
Ilese mitis		45
Fagaropsis angolensis		45
Albizia all spp		45
Syzygium all spp		45
Diospyros mespiliformis		55
Brachystegia speciformis		40
Jubernardia globiflora		40
Brachylaena hutchinsii		24
Hagenia abbysinica		24
Swartizia madagascarensis		24
Dalbegia melanoxylon		20
Adina macronata		55
Combretum Stuhlmannii		54
Entandrophragma all spp		55
Juniperus all spp		24
Markamia all spp		50
Newtonia pacijuga		50
Newtonia all spp		50
Parinaria exelsa		50
Osyris santallum		24
Baphia kirkii		45
Casipourea malosana		55
Maesopsis all spp		55
Codyla africana		50
Burkea africana		50
Fagara amaniensis		50
Spirostachys africana		50

Source: [2]Government Notice No 462 (1996) [1]Mugasha (1996)

7.3 Species classification systems according to utilisation value in Tanzania

Both natural forests and plantation timber tree species are classified according to the quality and type. The FBD classify species and the classification is published in the Government Gazzete according to the Forest Act (2002). The last classification was published on 12//12/1996, Government Notice No. 462

7.4 Management intervention intervals

Different management practices and approaches exist between the plantation forest and natural forest. In the plantation forest, the management intervals (silvicultural operations are stipulated in the management plans. The management plans indicate the silvicultural and cultural operations required to be conducted during the rotation period. In the natural forests, available information on the silvicultural and cultural operations required by most indigenous trees species is lacking, this is because in the past more research efforts were directed to exotics than indigenous tree species.

7.4.1 Species-specific growth rates

Specific information on the growth of most indigenous tree species is lacking since little research on their regeneration and ecology has been done. Mugasha (1996) has reported information on few indigenous tree species as indicated in Table 7.

Table 7: Growth rates of some indigenous tree species of Tanzania

Name of species	Annual increment	
	Dbh (cm)	Height (m)
Ocotea usambarensis	0.9	0.92
Podocarpus usambarensis	0.8	0.7
Cephalosphaera usambarensis	0.98	0.89
Milicia excelsa	1.5	0.9
Olea capensis	1.2	0.8
Maesopsis eminii	2.0	1
Juniperus procera	0.88	0.86
Pterocarpus angolensis	1.4	0.8
Dalbegia melanoxylon	0.98 – 14.6	1.6 - 4.7
Faidherbia albida	3.2 –5.9	1.8 – 3.5
Acacia seyal	8.4 - 10.2	-
Acacia tortilis	3 – 5.8	0.6 – 2

Source: Mugasha (1996)

7.4.2 Forest growth information on stand/forest type level

No detailed research has been done on the ecology and growth of most indigenous forest stands or forest type in Tanzania. The ecology of the forest types or stands of Tanzania is complicated since the natural forest stand or forest types are heterogeneous in terms of species and age structures. However, attempts have been made to give some general overview of the growth characteristics of these forest types and stands. Mugasha (1996) reports some information on Miombo woodland while Lovett (1993) reports information on moist forests. Information on the growth and yields of mangroves in Tanzania are lacking. The available information is summarized in Table 8 below:

Table 8: Forest stands characteristics by forest type in Tanzania

<table>
<tr><th rowspan="3">Forest type/sub type</th><th colspan="5">Stand characteristics</th><th rowspan="3">References</th></tr>
<tr><th colspan="2">Height (m)</th><th rowspan="2">Dbh (cm)</th><th rowspan="2">Basal area (m^2/ha)</th><th rowspan="2">Stand density (stems/ha)</th></tr>
<tr><th>Canopy</th><th>Emergent</th></tr>
<tr><td>Miombo woodland</td><td></td><td></td><td></td><td></td><td></td><td>Data available but not summarised in Mugasha (1996)</td></tr>
<tr><td>Mangroves</td><td>NA</td><td>NA</td><td>NA</td><td>NA</td><td>NA</td><td>NA</td></tr>
<tr><td>Moist montane forests</td><td>10-20</td><td>25</td><td>20-40</td><td>330</td><td></td><td rowspan="3">Hamilton et al. (1989); Lovett (1992, 1993)</td></tr>
<tr><td>Dry montane forests</td><td>10-20</td><td>30</td><td>20-40</td><td>240</td><td></td></tr>
<tr><td>Moist lowland forests</td><td>25-40</td><td>50</td><td>50-100</td><td>140</td><td></td></tr>
</table>

Dry lowland evergreen forests	15-20	35	NA	NA	NA	

7.5 Silvicultural systems

In Tanzania both high forest and coppice silvicultural systems are documented but not much practised on a large scale. Detailed account of these systems is given by Mugasha (1996).

7.5.1 Mono cyclic systems

These systems result into even aged stand when clear cutting is applied followed by regeneration the by means of seeds. On the other hand, this can lead to uneven aged stand when trees are felled selectively at a given interval of time.

In Tanzania, high forest silvicultural system are used for establishment of even aged and uneven aged stands mainly regenerated from the seeds. Clear cutting with planting is used in afforestation or regeneration of existing plantations in the tropics. The area is clear felled in a single felling and the debris is burnt. Then the area is regenerated by planting or sowing. With this method, it is possible to control the species, but planting cost is high and the method leads to lowering of biodiversity (Mugasha, 1996).

Two-storey high forest system has been used to raise indigenous tree species, which require shade in their early stage. The light demanding species are planted with shade demanding species. In Kwamkoro, Amani Tanga, the *Cephalosphaera usambarensis* is planted under *Maesopsis eminii* and in Usa River Arusha, *Olea capensis* is planted under *Grevillea robusta*

7.5. 2 Poly-cyclic systems

This is the simplest method of regenerating the forest. Regeneration is from vegetative or adventitious buds on stump coppices or root suckers. It is suitable for light demanding species since it involves clear felling of all tree crops leaving behind stumps and root suckers which give rise to new even aged stand (Mugasha, 1996).

In its simplest form, poly-cyclic silvicultural systems involve clear felling of mature trees leaving behind stumps and root suckers. The stumps, and/or suckers sprout giving rise to new crop. It has some potential for regenerating artificial stands of *Eucalyptus, Tectona grandis* and *Senna siamea*, and natural stands of *Ocotea usambarensis.* This method has low investment and rapid volume production over short rotation.

7.5.3 Status of implementation

In Tanzania, silvicultural systems have only been used in experimental plots. Currently, Tanzania natural forests and woodlands are yet to be managed under any defined silvicultural system.

7.6 Thinning, liberation and re-fining operations

Thinning is done in both plantation and natural forests. In plantation of exotic timber species, thinning is done according to the technical orders issued by the FBD. Thinning in most softwood coniferous tree species are done at the age of 10,14,18, and 22 for the 1st 2nd 3rd and 4th thinning respectively. Clear felling is done at the age of 25 – 30 years. In indigenous tree species, the thinning of the *Ocotea usambarenis* and *Olea capensis* which is intercropped with the *Grevillea robusta* has been reported by Mugasha (1996). Thinning by removing *G. robusta* and some *O. capensis* is done up to the age of 30 years and then *O. capensis* is left to rotation age. In *O. usambarensis*, the thinning is done at the age of 15, 22, 30, and 40 years for the 1st 2nd 3rd and 4th respectively and felling is done at the age of 50 – 75 years in the West Usambara and Kilimanjaro.

7.6.1 Enrichment plantings

Enrichment planting is the natural regeneration supplemented by planting and is usually done in areas where the number of trees of desirable species regenerated is not sufficient, therefore the area is restocked by planting seedlings of the desirable species. Enrichment planting can be achieved through line planting or group planting (Mugasha, 1996)

7.6.1.1 Line enrichment planting

This involves clearing parallel lines at a constant distance of (10 – 25 m) apart. On both sides of the axis of each line a strip of 1 m wide is cleared completely. Climbers and brushwood layer and young trees are cleared up to the distance of 5 m. Plants for enrichment are planted on the line axis at a distance of 5 - 10 m apart. Sapling or stumps of at least 1 m high is suitable for this purpose (Mugasha, 1996).

7.6.1.2 Group enrichment planting

Group enrichment planting is done in order to reduce interspecies competition. This involves complete cleaning of patches by clearing of groups of all vegetation at specified interval (e.g. every after 10 m) to open up gaps of specified dimensions (e.g. 3.5 x 3.5 m). Thereafter groups of desirable tree species are planted in lines within each cleared patch. This method has been used in Usa River in raising *Olea capensis*. *O. capensis* is intercropped with *Grevillea robusta* in order to reduce interspecies competition (Mugasha, 1996).

7.6.2 Status of implementation

In Tanzania, similar to silvicultural systems, enrichment planting has only been applied in trial plots. Currently, Tanzania natural forests and woodlands are yet to be improved by enrichment planting.

8. Forest degradation and loss of forest cover

8.1 Definitions and investigation methods

Forest degradation is the depletion on forest cover caused by deforestation. Forests degrade because they are removed and the land changed to another kind of land use. In addition, forests degrade when they are cut at a frequency that is shorter than these trees sustainable-yield (i.e., the natural replacement of old trees but new ones).

8.2 Causes of deforestation and forest degradation in Tanzania

Turner (1995) divides the causes of deforestation into two categories: - proximate and underlying causes. Proximate causes are the immediate causes which change a forest to other uses which lead to the loss of forest cover, such as clearing forest for agriculture (both commercial and subsistence), clearing for pasture, logging activities, fuelwood gathering, clearing for infrastructure and mining activity. Underlying causes are indirect causes or secondary situation that makes people to clear forest for such purpose. The most important of these factors is demography i.e. population (density, size and rate of increase). Others are market and policy failures. Population growth has a fundamental bearing on food and agriculture. Each area of land has a maximum population capacity and if the capacity is exceed then the land is overexploited and the forest degradation results. Tables 9a and 9b show current forest cover and changes in forest cover respectively.

Table 9a: Current forest cover of Tanzania

Category	Sub-category	Forest cover in million ha
Forests	Closed forest	8.3
	Open forest	30.8
Woodland	Shrub/tree	13
	Forest fallow	9.2
Total		**61.3**

Source: FAO (2001)

Table 9b: Forest cover changes between 1980 and 2000 in Tanzania

Year	Forest cover in million ha
1980	37.9
1990	39.7
1995	36.8
2000	38.8

FAO (1990, 2001b)

From Table 9b it is evident that forest cover decreased in 1995 and it has been increasing since then despite the fact that deforestation continues to persist in Tanzania. This could be due to partially unreliable inventory methods used and afforestation in forest plantations and farmlands through the current tree planting campaigns by the Government of Tanzania.

8.3 Species specific over-utilisation

Most of natural forest valuable timber tree species have been over utilized. The most over utilized species include *Pterocarpus angolensis, Milicia excelsa, Juniperus procera, Olea capensis* and *Dalbergia melanoxylon* (MNRT, 2001b).

8.4 Causes of forest deforestation and forest degradation

In Tanzania, deforestation and forest degradation is attributed to a number of factors. More specific driving forces behind deforestation in Tanzania includes: clearing land for agriculture (both shifting cultivation and permanent agriculture land uses), overgrazing, charcoal burning, harvesting for pole and firewood, pitsawing. Other factor are:-uncontrolled and frequent bush fires, harvesting for industrial wood, illegal logging, settlements, and infrastructure construction (TFAP, 1989) and outbreak of forest diseases (Abeli and Maliondo, 1992; Nsolomo and Chamshama, 1990). The causes and extent of deforestation in various places in Tanzania has been reported by (Abeli and Nsolomo, 1998; Lulandala *et al.,* 1995; MNRT, 1991; Kowero and O'Kting'ati, 1990; Kalaghe *et. al.,* 1988)

9. Invasive species

9.1 Species specific information

9.1.1 *Broussonetia papyrifera*

Although *Broussonetia papyrifera* is a well-known invasive species this species is not common in Tanzania

9.2 Forest management concepts

Forests in Tanzania are managed according to the objectives stipulated in the management plans. The National Forest Policy (1998) stresses the need for sustainable management of Tanzania forests. The policy area states that in order to ensure sustainable supply of products and services and environmental conservation, all forest reserves will be managed for production and/or protection based on sustainable management objectives defined for each forest reserve. The management of all forest reserve will be based on forest management plans (URT, 1998).

10. State of forest certification

No forest in Tanzania is certified according to the FSC standard.

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ANNEXES

Annex 1a: Average monthly solid wood consumption in Tanzania

Product	Amount consumed	
	Formal	Informal
Sawlogs from natural forests in tons(m^3)	40,000	NA
Poles (tons)	NA	
Sawlogs from Plantation forests in tons (m^3)	453,000	
Roundwood (m^3)	564,000 m^3	
Sawn wood (m^3)	24,000 m^3	

Source: FAO (1999); URT (1999)

Annex 1b: Average overall monthly wood fuel consumption in Tanzania

Product	Amount consumed	
	Formal	Informal
Domestic firewood household consumption (tons)	0.358	NA
Commercial firewood consumption in tons	NA	
Charcoal consumption (tons)	0.096	

Source: URT (1999)

Annex 1c: Estimates of wood fuel consumption per month in five Municipalities in Tanzania

Region	Household wood fuel consumption per month (kg)	
	Fuelwood	Charcoal
Mbeya	486.2	76.6
Mwanza	519.0	102
Arusha	123.3	123.3
Dodoma	374.0	89.3
Dar es Salaam	286.6	86.9
Average	**357.8**	**95.6**

Source: MNRT (2001a)

Annex 2: Charcoal production and marketing in Tanzania

Item	Costs (TShs)
Production costs (m^3)	NA
Retail price (regional differences)	1,500
Royalty fees (Central Government)	800
Royalty fees (Local Government)	400
Gender aspects (proportion of woman involved in charcoal production)	NA
Proportion of legal production	NA

Source: Luoga *at al*. (2000); Zahabu (2001)

Annex 3: Some common inventory methods applied in East Africa

Location	**Area** in ha	Year	Method
Budongo Forest, Uganda	42,800	1990	Stratified random with nested sub-plots, 467 sampling plots, covering 0.5 % of the forest area **Sampling strata:** Trees < 10cm DBH, two 5x5 m plot Trees >10 cm DBH, 50-10 m plot Trees >20 cm DBH, 100-10 m plot Trees >50 cm DBH, 100-50 m plot
Data availability:		Data are available at the Forest Department and Makerere University, in Uganda	

Source: Babweteera and Reynolds (2000).

Location	**Area** in ha	Year	Method	
Mgori Forest Reserve, Singida, Tanzania	44,000	1994	Systematic, 48 sampling concentric circular plots of 0.07 ha, laid at 6.4 km apart sub clusters were laid at 400 apart:	
			Details of the concentric circles plot:	
			Plot radius (m)	**Dbh of Trees measured**
			2	Identification of herbs and counting trees of less than 5 dbh
			5	Measuring and recording trees of 5-10 dbh
			10	Measuring and recording trees of 10 dbh to 20 dbh
			15	Measuring and recording trees of Dbh of greater than 20
Data availability:		Data are available at SUA, Faculty of Forest and Nature Conservation. Department of Forest Mensuration and Management.		

Source: Malimbwi and Mwansasu (1994)

Annex 3: Continued

Location	**Area** in ha	**Year**	**Method**
Nawenge Forest Reserve, Morogoro, Tanzania	623	2002	Stratified, systematic, 21 sampling concentric circular plots of 0.07 ha, covering 0.24 % of the forest area Concentric circular plots:
Data availability:		Data are available at SUA, Faculty of Forest and Nature Conservation (FORCONSULT)	

Source: Malimbwi and Mugasha (2002a)

Location	**Area** in ha	**Year**	**Method**
Mkindo Forest Reserve, Morogoro, Tanzania	7,541	2002	Stratified, systematic, 93 sampling concentric circular plots of 0.07 ha, covering 0.087 % of the forest area Concentric circular plots:
Data availability:		Data are available at the Sokoine University of Agriculture, Faculty of Forest and Nature Conservation. (FORCONSULT)	

Source: Malimbwi and Mugasha (2002a)

Location	**Area** in ha	**Year**	**Method**
Asamatwa village natural Forest Kiteto District, Arusha, Tanzania	18,000	2000	Stratified, systematic, 68 sampling concentric circular plots of 0.07 ha, covering 0.087 % of the forest area Concentric circular plots:
Data availability:		Data are available at SUA, Faculty of Forest and Nature Conservation. Department of Forest Mensuration and Management	

Source: Malimbwi (2000)

Location	**Area** in ha	**Year**	**Method**
Palaulanga Forest reserve, Morogora, Tanzania	10,541	2002	Stratified, systematic, 105 sampling concentric circular plots of 0.07 ha, covering 0.07 % of the total forest area Concentric circular plots at an interval of 250 m along the transact.
Data availability:		Data are available at SUA, Faculty of Forest and Nature Conservation. (FORCONSULT)	

Source: Malimbwi and Mugasha (2002b**)**

Annex 3: Continued

Location	**Area** in ha	**Year**	**Method**
Sunya Natural forest Kiteto District, Arusha, Tanzania	9,000	1999	Systematic cluster, 124 sampling concentric circular plots of 0.07 ha, covering 0.1 % of the total forest area Concentric circular cluster plots were laid at a distance of 862 m apart along the transact and 200m by 200 m between the clusters.
Data availability:		Data are available at the Sokoine University of Agriculture, Faculty of Forest and Nature Conservation. Department of Forest Mensuration and Management	

Source: Malimbwi (1999**)**

Location	**Area** in ha	**Year**	**Method**
Rufiji District Council Forest Natural Forest Rufiji Coast, Tanzania	100,000	2000	Systematic sampling, 251 concentric circular plots of 0.07 ha were laid systematically in the forest.
Data availability:		Data are available at the Sokoine University of Agriculture, Faculty of Forest and Nature Conservation. Department of Forest Mensuration and Management	

Malimbwi (2000a)

Location	**Area** in ha	**Year**	**Method**
Loltepes Village Natural Forest Kiteto District, Arusha, Tanzania	25,012.5	2000	Stratified, Systematic cluster, 51 plots concentric circular plots of 0.07 ha, covering 0.1 % of the total forest area at an interval of 862 m along the transact and 200 m by 200 m between the clusters.
Data availability:		Data are available at SUA, Faculty of Forest and Nature Conservation. Department of Forest Mensuration and Management	

Source: Malimbwi (2000b**)**

Annex 3: Continued

Location	Area in ha	Year	Method
Lengatei Village Natural Forest Kiteto District, Arusha, Tanzania	4,400	1999	Stratified, Systematic cluster, 84 sampling, concentric circular plots of 0.07 ha, covering 0.1 % of the total forest area at an interval of 150 m apart and 200 m by 200 m between the clusters.
Data availability:		Data are available at SUA, Faculty of Forest and Nature Conservation. Department of Forest Mensuration and Management	

Source: Malimbwi (1999)

Location	**Area** in ha	Year	Method
Olkitikiti Village Natural Forest Kiteto District, Arusha, Tanzania	27,837.5	2000	Stratified, Systematic cluster, 72 concentric circular plots of 0.07 ha
Data availability:		Data are available at SUA, Faculty of Forest and Nature Conservation. Department of Forest Mensuration and Management	

Source: Malimbwi (2000c**)**

Location	**Area** in ha	Year	Method
Olgira Village Natural Forest, Kiteto District, Arusha, Tanzania	18375	1999	Stratified, Systematic clusters, 121 concentric circular plots of 0.07 ha at an interval of 132 covering 0.05% of the total forest area.
Data availability:		Data are available at the Sokoine University of Agriculture, Faculty of Forest and Nature Conservation. Department of Forest Mensuration and Management	

Source: Malimbwi (2000d)

Annex 3: Continued

Location	**Area** in ha	Year	Method
Kimboza Forest Reserve, Morogoro, Tanzania.	404	2002	Stratified, random sampling with clusters plots. A total of 26 sampling concentric circular plots of 0.07 ha at an interval of 200 m covering 0.44% of the total forest area
Data availability:		Data are available at SUA, Faculty of Forest and Nature Conservation (FORCONSULT). Department of Forest Mensuration and Management	

Source: Malimbwi and Luoga (2002)

Location	**Area** in ha	Year	Method
Nanganje Forest Reserve Ifakara District, Morogoro, Tanzania	18,988	2002	Stratified, systematic random sampling with clusters plots. A total of 120 concentric circular plots of 0.07 ha at an interval of 200 m covering 0.1% of the total forest area
Data availability:		Data are available at SUA, Faculty of Forest and Nature Conservation (FORCONSULT). Department of Forest Mensuration and Management	

Source: Malimbwi and Luoga (2002)

Location	**Area** in ha	Year	Method
Tongwe Forest Reserve, Muheza Distrct, Tanga, Tanzania	544	2001	Systematic sampling. A total of 19 concentric circular plots of 0.07 ha at an interval of 250 m covering 0.1% of the total forest area.
Data availability:		Data are available at SUA, Faculty of Forest and Nature Conservation (FORCONSULT). Department of Forest Mensuration and Management	

Source: Malimbwi (2001a)

Location	**Area** in ha	Year	Method
Kwani Forest Reserve Muheza District, Tanga region, Tanzania	2,541.1	2001	Random sampling. A total of 39 concentric circular plots of 0.07 ha covering 0.1% of the total forest area.
Data availability:		Data are available at SUA, Faculty of Forest and Nature Conservation (FORCONSULT). Department of Forest Mensuration and Management	

Source: Malimbwi (2001b)